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Assessment of seed cotton yield and fiber properties portrayal of some candidate cotton varieties in national coordinated varietal trials at changing environment of Sindh and Balochistan

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ABSTRACT	**Digital Object Identifier (DOI): https:/doi.org/10.33865/IJCRT.001.01.0245**

Thirty six candidate cotton varieties developed by different breeders in Pakistan were tested consecutively for two years (2017 and 2018) and at seven locations of Sindh and Balochistan Provinces in national coordinated varietal trials (NCVT). The trials were conducted to explore seed cotton yield potential and fiber properties against two check varieties (CIM-602 and FH-142/IUB-13). As per claim of the breeders, the samples of all varieties for both the years were sent to four designated biotechnological laboratories for conducting biochemical tests also. The results revealed highly significant differences among the varieties for both the years. During the year 2017, on an average of six locations, top ten high yielding varieties recorded were GH-Haadi, Weal-AG-6, VH-189, GH-Mubarak, Weal-AG-5, MNH-1026, Badar-1(DG), FH-444, CIM-343 and TJ-Max(DG) which yielded 3434, 3407, 3342, 3255, 3251, 3248, 3185, 3154, 3134 and 3131 kg/ha seed cotton yield respectively. When the results of the 2018 trial were looked at, averagely top ten high yielding varieties were GH-Haadi, ICI-2121, CRIS-613, VH-383, VH-189, NIAB-898, FH-490, Cyto-225, Tahafuz-10(DG) and GS-Ali-7 with 3526, 3356, 3306, 3139, 3101, 3091, 3084, 3074, 3060 and 3026 kg/ha of seed cotton yield respectively. However, on an average of both the years (2017 and 2018), top ten high yielding varieties were GH-Haadi, VH-189, CRIS-613, Weal-AG-6, GH-Mubarak, Badar-1(DG), ICI-2121, Weal-AG-5, FH-940 and MNH-1026 producing 3480, 3221, 3186, 3155, 3113, 3083, 3057, 3054, 3042 and 3042 kg/ha of seed cotton respectively. As regards fiber properties, (04 candidate varieties) could qualify all fiber standards set by government. The biochemical test results received from all four laboratories revealed that on an average of four laboratories and two years, the trait purity range recorded was from 42 to 96 percent, whereas, quantification of Bt toxin ranged from 0.74 to 2.62. From the present study, it was concluded that almost 15-20 candidate varieties have the potential to be included among already approved varieties for commercial cultivation in the province of the Sindh and Balochistan.

Key word: Seed cotton yield, fiber traits, environment.

INTRODUCTION: Cotton (*G. hirsutum* L.) is an important cash crop and plays a key role as compared to all other crops (Screenivasan, 2004). Pakistan is 4th largest cotton producer in the world after China, USA and India (GOP, 2018). Cotton is a major crop of Pakistan after wheat; it occupies the largest area in Pakistan compared to other crops. It earns the country's largest export revenues. In addition to the lint, the seed of cotton for oil and meal accounts for 80 percent of the national production of oilseed. Cotton and cotton related products contribute 10 percent to gross domestic product (GDP) and 55 percent to the foreign exchange earnings of the country. In Pakistan, cotton was cultivated in an area of 2700 thousand hectares (approx. 6672 thousand acres) during the year 2017-18 with the production of 11.95 million bales, whereas, the lint yield in Pakistan for the same year was 752 kg/ha (approx. 305 kg acre). In Punjab, almost 100% Bt cotton with Mon53 event and Cry1Ac gene was sown on an area of 2053 thousand hectares (approx. 5073 thousand acres) which produced 8.78 million bales with lint yield of 669 kg/ha during the year 2017-18 (GOP, Cotistics, 2018). Five year's (2013-14 to 2017-18) data regarding cotton area, production and lint yield in Pakistan, Punjab and Sindh are depicted in table 2. The cotton crop is judged by the genotype and its interaction with the varied environments for yield potential and quality performance (Koutu and Shastry, 2004). Most of components of economic characters are indicative of the yield potential or the integrated cotton quality and are under the control of genes of various magnitudes and influences of the environments (Narayanan *et al*., 2004). Stable cotton varieties with high yield potential are of paramount importance among the large number of varieties recommended for cultivation for a particular zone (Kairon *et al*., 2000; Koutu and Shastry, 2004). In the recent years, the release of high yielding, heat and leaf curl virus disease resistant Bt cotton varieties with pre-fixed fiber quality standards by the government of Punjab have accelerated momentum to fulfil the requirements of growers, textile industry and other stakeholders. In this context, the Pakistan Central Cotton Committee (PCCC) is playing pivotal role by conducting the National Coordinated Varietal Trials (NCVT) on the candidate cotton varieties bred by public and private sector breeders. The two years NCVT is mandatory for variety approval process. Every year, NCVT is conducted at almost 17 locations of the Pakistan to test their adaptability and yield potential. If a variety excels the standard varieties in yield for consecutive two years in NCVT, that variety is forwarded in the Expert Sub Committee of the headed by Director General Agriculture Research Sindh (in case of Sindh province) for further process. The variety which qualifies the pre-fixed fiber properties standards is then recommended to Sindh Seed Council for approval and commercial cultivation in the Sindh. Distinctiveness, Uniformity and Stability (DUS) studies are also conducted by the Federal Seed Certification and Registration Department (FSC&RD) for two years of the candidate varieties simultaneously which are included in NCVT. These trials/studies (NCVT, Spot examination and DUS) are mandatory for a variety to complete the variety approval process. Considering the above approval process for cotton varieties, the two years (2017 and 2018) data were extracted from the NCVT results distributed by Director Research, PCCC for evaluation of yield and fiber properties of candidate varieties and to see which varieties could qualify and fit in the variety approval process done by the Sindh Seed Council.

OBJECTIVES: The objective of this study to evaluate advance cotton genotypes for seed cotton yield and adoptability during two consecutive years at the environmental conditions of Sindh and Baluchistan. The suitable genotypes could be preferred for general cultivation in both provinces to boost up cotton production.

MATERIAL AND METHODS: The studies were carried out to screen out the most outstanding high yielding varieties in different agro-ecological zones of Sindh and Balochistan provinces. 36 candidate Bt cotton varieties from public and private sectors duly coded by the Director Research PCCC were sown and tested at four public sector research centers in Sindh (CCRI, Sakrand; CRS Ghotki, CRS Mirpurkhas, and ARI Tandojam) and three public sectors in Balochistan (CRS Sibi, CRS Lasbela@Uthal and ARI-Khuzdar) against two standard/check varieties (CIM-602 and IUB-13) during the years 2017 and 2018 in the month of May. The coded variety seed provided by the Director, Research, PCCC was sown on the bed and furrow at all the seven locations. The plot size, however, varied location-wise with the choice of the scientist or availability of land at the station who was deputed for conducting NCVT by the station in-charge. The trials were arranged in a randomized complete block design (RBCD) replicated three times at each location. The trials were agronomically and entomologically supervised and protected by the agronomist and entomologist of each location. The required yield data were recorded at all the stations when the crop was fully matured and was ready to harvest. The data were statistically analyzed after Gomez and Gomez (1984) calculating C.V. % and CD values at 5 % and 1% probability levels to differentiate the varieties included in the trials. Each year after compilation of data, the yield results are sent back to Director, Research PCCC with same variety codes. On the basis of yield and fiber properties results, the better performing varieties could then be released as a commercial variety for the general cultivation in the province of Sindh and Balochistan.

RESULTS AND DISCUSSION: Thirty six candidate cotton varieties were yield tested consecutively for two years (2017 and 2018) and at seven locations of Sindh and Balochistan Province in national coordinated varietal trials (NCVT). The trials were conducted to explore seed cotton yield potential and fiber properties of these candidate varieties against two standard/check varieties (CIM-602 and FH-142/IUB-13). The samples of all varieties for both the years were sent to four designated biotechnological laboratories for biochemical tests also. Table 1 shows the sources of the 36+2 standards cotton candidate varieties sown for two years in the Sindh and Balochistan during 2017 and 2018, cotton seasons at public sector research institutions. Table 2 depicts the cotton area, production and yield of Pakistan, Punjab and Sindh for the last five years (2013-14 to 2017-18) which serves as ready reference for the readers to judge the ups and downs in the cotton crop in the last half decade. Table 3 demonstrates the yield performance and also results of statistical analysis (CD in 1 and 5% level oprobability, includingng CV%) of the candidate varieties during 2017, whereas, table 4 revealed the yield and statistical analysis results for 2018 cotton season against the two check varieties. The two years average yield performance of candidate varieties was calculated and is presented in table 5.

Table 1: Candidate cotton varieties tested in National Coordinated Varietal Trials (NCVT) during 2017 and 2018

Sr. No.	Name of Candidate Variety	Source of variety
1	MNH-1026	Cotton Research Institute, Multan
2	BH-221	Cotton Research Station, Bahawalpur
3	BS-18	Bandesha Seed Corporation, Jahanian
4	CEMB-100 (DG)	Center of Excellence in Molecular Biology, Lahore
5	MNH-1020	Cotton Research Institute, Multan
6	FH-444	Cotton Research Institute, AARI, Faisalabad
7	CEMB-101(DG)	Center of Excellence in Molecular Biology, Lahore
8	ICI-2121	ICI Pakistan Limited, Multan/Lahore
9	Bahar-07	Bahar Seed Corporation, Rahimyar Khan
10	IUB-69	Islamia University, Bahawalpur
11	CIM-343	Central Cotton Research Institute, Multan
12	FH-490	Cotton Research Institute, AARI, Faisalabad
13	CIM-663	Central Cotton Research Institute, Multan
14	Cyto-515	Central Cotton Research Institute, Multan
15	CRIS-613	Central Cotton Research Institute, Sakrand
16	NIAB-898	Nuclear Institute of Agriculture & Biology, Faisalabad
17	GH-Haadi	Cotton Research Station, Ghotki
18	Badar-1 (DG)	4 Brothers Seed Corporation, Multan/Lahore
19	GH-Mubarak	Cotton Research Station, Ghotki
20	Tahafuz-10 (DG)	Suncrop group, Multan
21	Weal-AG-6	Allahdin Group, Multan
22	RH-Afnan	Cotton Research Station, Khanpur
23	CIM-602 Std-1	Central Cotton Research Institute, Multan
24	TJ-MAX (DG)	Robert Cotton Associates, Khanewal
25	Bahar-2017	Bahar Seed Corporation, Rahimyar Khan
26	RH-Manthar	Cotton Research Station, Khanpur
27	VH-189	Cotton Research Station, Vehari
28	Weal-AG-5	Allahdin Group of Companies, Multan
29	GS-Ali-7	Gohar Seed Corporation, Makhdum Rashid
30	NS-191	Neelum Seeds Private Limited, Jahanian
31	CIM-717	Central Cotton Research Institute, Multan
32	IUB-13 Std-2	Islamia University, Bahawalpur
33	SLH-6	Cotton Research Station, Sahiwal
34	AA-933	Ali Akbar Group, Multan
35	VH-383	Cotton Research Station, Vehari
36	Sitara-16	Agri Farms Private Limited, Multan
37	SLH-19	Cotton Research Station, Sahiwal
38	Cyto-225	Central Cotton Research Institute, Multan

Table 1 demonstrated that out of 36 candidate varieties, 13 were introduced by the private sector which shows the breeding ability of their research centers and strength of their R & D system. The data presented in table 3 and 4 revealed highly significant yield differences among the varieties during both years of trialing. In the year 2017, on an average of seven locations (table 3), top ten high yielding varieties recorded were GH-Haadi, Weal-AG-6, VH-189, GH-Mubarak, Weal-AG-5, MNH-1026, Badar-1 (DG), FH-444,

Table 2: Pakistan, Punjab and Sindh Cotton Area, Production and Yield for last five years (2013-14 to 2017-18).

Year-Wise	2013-14	2014-15	2015-16	2016-17	2017-18
			PAKISTAN		
Area (000 hectares)	2805.65	2958.30	2901.98	2488.97	2700.27
Production (000 million bales)	12768.88	13959.58	9917.41	10671.00	11945.60
Yield (kg/ha)	774	802	581	729	752
			PUNJAB		
Area (000 hectares)	2199.02	2322.85	2242.72	1815.34	2052.93
Production (000 million bales)	9145.00	10277.00	6343.00	6978.00	8077.00
Yield (kg/ha)	707	752	481	653	669
			SINDH		
Area (000 hectares)	567.98	596.21	621.25	636.65	611.68
Production (000 million bales)	3523.42	3572.54	3475.60	3596.88	3775.76
Yield (kg/ha)	1055	1019	951	960	1049

Source: Cotistics August 2018 Bulletin published by Pakistan Central Cotton Committee, Multan.

Table 3: Seed Cotton Yield (kg/ha) of Thirty Six Cotton Candidate Varieties tested in NCVT at Seven Locations of Sindh and Balochistan during 2017.

S. No.	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	MNH-1026	3145	3603	3340	2751	3264	3851	2784	3248
2	BH-221	2416	2865	2384	2571	3624	3588	2904	2907
3	BS-18	2260	2590	2444	2272	2964	3588	2964	2726
4	CEMB-100 (DG)	2081	2989	2763	2272	2916	3612	2868	2786
5	MNH-1020	2428	2185	1992	2452	3804	3456	2520	2691
6	FH-444	3385	3123	2935	2691	2904	4006	3036	3154
7	CEMB-101(DG)	2846	3043	2350	2810	2832	3253	2940	2868
8	ICI-2121	2870	2511	2173	2195	3288	3516	2748	2757
9	Bahar-07	1842	2691	2908	3339	3120	3361	3012	2896
10	IUB-69	2775	2571	2387	3295	2484	3648	2868	2861
11	CIM-343	3408	2571	2783	3613	2832	3827	2904	3134
12	FH-490	2942	2691	2344	3365	2832	4210	2616	3000
13	CIM-663	2081	2810	3105	2092	2964	3229	2688	2710
14	Cyto-515	2583	2751	2619	2501	2736	3492	2568	2750
15	CRIS-613	3241	2930	1630	3622	3312	3971	2760	3067
16	NIAB-898	2870	2751	2072	2743	3216	3851	2652	2879
17	GH-Haadi	3672	2810	3374	3722	3168	4147	3144	3434
18	Badar-1 (DG)	2942	2631	2802	3293	2940	4844	2844	3185
19	CIM-602 Std-1	2882	2810	2558	2840	3492	4030	2784	3057
20	GH-Mubarak	3576	2810	3075	2895	3096	4126	3204	3255
21	Tahafuz-10 (DG)	2655	3947	1826	2551	2772	3827	2940	2931
22	IUB-13 Std-2	2464	2272	2830	2827	3180	3827	2892	2899
23	Weal-AG-6	3600	3050	3018	3277	3480	3947	3480	3407
24	RH-Afnan	3169	3707	2089	2937	3072	4066	2868	3130
25	TJ-MAX (DG)	3181	3767	2242	3046	2616	3708	3360	3131
26	Bahar-2017	2129	2212	2572	2929	2856	3086	2712	2642
27	RH-Manthar	3289	2272	2028	3055	2916	3995	2820	2911
28	VH-189	3636	3707	2868	2820	2820	4305	3240	3342
29	Weal-AG-5	3265	3707	2140	3220	3840	3468	3120	3251
30	GS-Ali-7	2990	2870	2914	3239	3384	3002	2940	3048
31	NS-191	2117	2392	2038	2856	3264	3887	3012	2795
32	CIM-717	2189	2810	2764	1927	3840	3480	3480	2927
33	SLH-6	2201	3408	2099	1789	2916	2870	3060	2620
34	AA-933	1938	2452	1800	2560	3036	3564	2808	2594
35	VH-383	2715	3648	1826	2139	3240	3229	2880	2811
36	Sitara-16	3038	3408	2708	3095	2832	3349	2520	2993
37	SLH-19	3301	3648	1908	2295	3396	4186	2964	3100
38	Cyto-225	2810	2691	2873	2261	3120	3755	2640	2879
	CD 5%	828.26**	629.54**	865.27**	954.4**	756.8**	435.39**	835.62**	---
	CD 1%	1092.9**	830.66**	1141.7**	1259.3**	998.58**	574.49**	710.7**	---
	CV%	19.67	13.64	23.17	21.58	15.36	7.35	11.31	---

Table 4: Seed Cotton Yield (kg/ha) of Thirty Six Cotton Candidate Varieties tested in NCVT at Seven Locations of Sindh and Balochistan during 2018.

S. No.	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	MNH-1026	2932	1943	2583	3104	3829	2513	2941	2835
2	BH-221	1735	2235	2440	3236	3470	3470	2933	2788
3	BS-18	2190	2016	2296	2519	3949	4188	3080	2891
4	CEMB-100 (DG)	1855	2085	2009	2108	3947	3292	2684	2569
5	MNH-1020	2501	1912	3157	2434	3231	2992	2876	2729
6	FH-444	2704	2084	2009	2651	3949	3111	2996	2786
7	CEMB-101(DG)	1819	1814	2296	2081	3947	3947	2371	2611
8	ICI-2121	3279	4189	3731	3638	2992	2872	2792	3356
9	Bahar-07	2597	2404	2009	3435	4069	3231	2777	2932
10	IUB-69	1627	1202	2009	2059	4069	3949	2992	2558
11	CIM-343	2262	1866	1866	3355	3470	4069	2986	2839
12	FH-490	2369	3483	3301	2784	3351	3470	2831	3084
13	CIM-663	2118	1789	1866	2879	4069	3949	3143	2830
14	Cyto-515	2118	4043	2009	2634	3470	3231	3007	2930
15	CRIS-613	3267	4386	2296	3405	3231	3323	3231	3306
16	NIAB-898	3087	3023	2296	3222	4069	2992	2947	3091
17	GH-Haadi	3135	3811	3301	2834	4308	4308	2987	3526
18	Badar-1 (DG)	2728	3082	3157	1749	4066	3588	2492	2980
19	CIM-602 Std-1	2615	3111	2368	2110	3615	3141	2753	2816
20	GH-Mubarak	3016	2737	2296	3064	3590	3231	2864	2971
21	Tahafuz-10 (DG)	2968	3108	2870	2036	3947	3947	2542	3060
22	IUB-13 Std-2	1906	2920	2691	1661	3799	3230	2663	2696
23	Weal-AG-6	3913	2612	2440	1989	3468	2631	3265	2903
24	RH-Afnan	2262	2686	1866	2382	4045	3351	2869	2780
25	TJ-MAX (DG)	1675	1518	2870	1372	3947	2272	2468	2303
26	Bahar-2017	2094	2507	1579	2576	4069	2872	3006	2672
27	RH-Manthar	2465	1002	3731	1674	4186	3229	2868	2736
28	VH-189	3135	3668	2727	1792	4066	3349	2967	3101
29	Weal-AG-5	1927	3037	2440	1615	3947	3827	3208	2857
30	GS-Ali-7	2657	4010	2296	2490	3829	2872	3030	3026
31	NS-191	2393	1812	2009	3410	3231	2872	2980	2672
32	CIM-717	1771	4255	1866	2007	4069	4188	2910	3009
33	SLH-6	1221	1629	2440	762	3349	2751	2989	2163
34	AA-933	2549	2924	2440	3071	3590	2872	3305	2964
35	VH-383	3434	3999	2296	1632	3947	3707	2956	3139
36	Sitara-16	2645	2295	2870	1964	3588	2870	3103	2762
37	SLH-19	2003	1179	2440	1345	4425	3947	2833	2596
38	Cyto-225	2010	4459	1866	2077	3949	4069	3087	3074
	CD 5%	170**	349**	632**	427**	433**	698**	485**	--
	CD 1%	227**	464**	842**	569**	577**	931**	646**	--
	CV%	4	9	16	9	7	13	10	--

Table 5: Two Year's Average Performance (Seed Cotton Yield kg/ha) of Thirty Six Cotton Candidate Varieties tested in NCVT at Seven Locations of Sindh and Balochistan during 2017 and 2018 Cotton Seasons.

Sr. No	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	MNH-1026	3039	2773	2962	2928	3547	3182	2863	3042
2	BH-221	2076	2550	2412	2904	3547	3529	2919	2848
3	BS-18	2225	2303	2370	2396	3457	3888	3022	2809
4	CEMB-100 (DG)	1968	2537	2386	2190	3432	3452	2776	2677
5	MNH-1020	2465	2049	2575	2443	3518	3224	2698	2710
6	FH-444	3045	2604	2472	2671	3427	3559	3016	2970
7	CEMB-101(DG)	2333	2429	2323	2446	3390	3600	2656	2739
8	ICI-2121	3075	3350	2952	2917	3140	3194	2770	3057
9	Bahar-07	2220	2548	2459	3387	3595	3296	2895	2914
10	IUB-69	2201	1887	2198	2677	3277	3799	2930	2710

11	CIM-343	2835	2219	2325	3484	3151	3948	2945	2987
12	FH-490	2656	3087	2823	3075	3092	3840	2724	3042
13	CIM-663	2100	2300	2486	2486	3517	3589	2916	2770
14	Cyto-515	2351	3397	2314	2568	3103	3362	2788	2840
15	CRIS-613	3254	3658	1963	3514	3272	3647	2996	3186
16	NIAB-898	2979	2887	2184	2983	3643	3422	2800	2985
17	GH-Haadi	3404	3311	3338	3278	3738	4228	3066	3480
18	Badar-1 (DG)	2835	2857	2980	2521	3503	4216	2668	3083
19	CIM-602 Std-1	2749	2961	2463	2475	3554	3586	2769	2936
20	GH-Mubarak	3296	2774	2686	2980	3343	3679	3034	3113
21	Tahafuz-10 (DG)	2812	3528	2348	2294	3360	3887	2741	2995
22	IUB-13 Std-2	2185	2596	2761	2244	3490	3529	2778	2797
23	Weal-AG-6	3757	2831	2729	2633	3474	3289	3373	3155
24	RH-Afnan	2716	3197	1978	2660	3559	3709	2869	2955
25	TJ-MAX (DG)	2428	2643	2556	2209	3282	2990	2914	2717
26	Bahar-2017	2112	2360	2076	2753	3463	2979	2859	2657
27	RH-Manthar	2877	1637	2880	2365	3551	3612	2844	2824
28	VH-189	3386	3688	2798	2306	3443	3827	3104	3221
29	Weal-AG-5	2596	3372	2290	2418	3894	3648	3164	3054
30	GS-Ali-7	2824	3440	2605	2865	3607	2937	2985	3037
31	NS-191	2255	2102	2024	3133	3248	3380	2996	2734
32	CIM-717	1980	3533	2315	1967	3955	3834	3195	2968
33	SLH-6	1711	2519	2270	1276	3133	2811	3025	2392
34	AA-933	2244	2688	2120	2816	3313	3218	3057	2779
35	VH-383	3075	3824	2061	1886	3594	3468	2918	2975
36	Sitara-16	2842	2852	2789	2530	3210	3110	2812	2878
37	SLH-19	2652	2414	2174	1820	3911	4067	2899	2848
38	Cyto-225	2410	3575	2370	2169	3535	3912	2864	2976

MNH-1026, Badar-1 (DG), FH-444, CIM-343 and TJ-Max(DG), which yielded 3434, 3407, 3342, 3255, 3251, 3248, 3185, 3154, 3134 and 3131 kg/ha seed cotton yield respectively.

Regarding 2018 trial results (Table-4), on an average of seven locations of the Sindh and Balochistan, top ten high yielding varieties were GH-Haadi, ICI-2121, CRIS-613, VH-383, VH-189, CIM-343 and TJ-Max(DG), which yielded 3434, 3407, 3342, 3255, 3251, 3248, 3185, 3154, 3134 and 3131 kg/ha seed cotton yield respectively. Regarding 2018 trial results (table 4), on an average of seven locations of the Sindh and Balochistan, top ten high yielding varieties were GH-Haadi, ICI-2121, CRIS-613, VH-383, VH-189, NIAB-898, FH-490, Cyto-225, Tahafuz-10 (DG) and GS-Ali-7 with 3526, 3356, 3306, 3139, 3101, 3091, 3084, 3074, 3060 and 3026 kg/ha of seed cotton yield respectively. However, when the results of 2017 and 2018 (both seasons) were summed up, top ten high yielding varieties were GH-Haadi, VH-189, CRIS-613, Weal-AG-6, GH-Mubarak, Badar-1(DG), ICI-2121, Weal-AG-5, FH-940 and MNH-1026 producing 3480, 3221, 3186, 3155, 3113, 3083, 3057, 3054, 3042 and 3042 kg/ha of seed cotton respectively (Table-5). It is interesting to note that among top 10 high yielding varieties, only two varieties (GH-Haadi and VH-189) were with stable yield performance due to the fact that these varieties keep their superiority in individual year (2017 and 2018) and also when the average performance was looked at. Other varieties showed their stability in a particular single year but were included in top 10 varieties when the yield results were averaged. Seeing the yield results, it is suggested that the top two high yielding varieties (GH-Haadi and VH-189) with stability in performance must be approved by the provincial seed council of Sindh and Balochistan to revive the cotton production of the provinces and not to waste/garbage this high yielding stuff. The fiber results of VH-189 are almost meeting prefixed fiber standards, whereas, GH-Haadi have low fiber length as per set standard, it might be due to environmental conditions and could be improved. Regarding fiber properties (table 6), 04 candidate varieties could qualified all fiber standards prefixed by the government. The biochemical test results (table 7) revealed that on an average of four laboratories and two years, the trait purity range recorded was from 42 to 96 percent, whereas, quantification of Bt toxin ranged from 0.74 to 2.62. From the present study, it was concluded that almost 15-20 candidate varieties have the potential to be included among already approved varieties for commercial cultivation in the province of the Punjab.

Table 6: Summary Report of Fiber Quality.

Sr. No	Genotypes	GOT (%)	Mic.	Staple Length (mm)	Fiber strength (g/tex)	Fiber uniformity (%)	Fiber maturity (%)
	Standards	**>37.5**	**<5.0**	**28.00**	**>25.5**	**>80**	**>80**
1	MNH-1026	40.0	4.0	25.5	27.4	82.2	97.00
2	BH-221	38.3	4.0	26.0	27.3	81.7	91.00
3	BS-18	41.1	4.0	27.6	27.8	82.6	96.00
4	CEMB-100 (DG)	40.8	4.2	26.6	27.1	80.2	98.00

5	MNH-1020	37.7	4.2	27.8	27.6	81.9	97.00
6	FH-444	33.8	4.2	27.4	27.5	82.1	97.00
7	CEMB-101(DG)	40.0	4.1	27.0	29.7	81.9	91.00
8	ICI-2121	42.7	4.2	25.6	26.1	81.8	93.00
9	Bahar-07	41.7	4.2	24.9	26.0	79.8	94.00
10	IUB-69	32.7	4.5	24.9	26.2	81.9	90.00
11	CIM-343	39.1	3.7	27.0	28.0	82.0	89.00
12	FH-490	40.0	4.0	25.8	27.5	82.5	99.00
13	CIM-663	38.0	3.9	25.9	28.5	83.6	87.00
14	Cyto-515	39.0	3.9	26.4	27.5	82.0	89.00
15	CRIS-613	37.8	4.2	27.8	28.2	81.6	99.00
16	NIAB-898	39.2	3.3	28.2	28.0	80.1	93.00
17	GH-Haadi	37.0	4.5	25.9	27.1	83.1	99.00
18	Badar-1 (DG)	40.8	3.8	26.0	26.6	81.1	98.00
19	GH-Mubarak	41.1	4.3	25.3	26.1	81.0	88.00
20	Tahafuz-10 (DG)	36.7	4.0	28.0	29.4	83.7	96.00
21	Weal-AG-6	40.8	3.7	28.5	28.2	83.3	98.00
22	RH-Afnan	39.0	3.7	26.2	30.1	81.2	91.00
24	TJ-MAX (DG)	35.0	3.2	28.1	29.8	84.8	87.00
25	Bahar-2017	37.8	3.9	25.7	26.9	82.0	96.00
26	RH-Manthar	37.5	3.9	27.6	29.2	83.1	88.00
27	VH-189	38.3	4.4	28.7	27.8	84.5	89.00
28	Weal-AG-5	38.3	3.9	25.3	28.1	81.0	94.00
29	GS-Ali-7	36.0	3.9	26.9	27.8	83.4	97.00
30	NS-191	34.7	3.0	28.1	31.0	81.4	93.00
31	CIM-717	40.0	5.1	26.2	26.3	82.7	89.00
33	SLH-6	38.3	3.6	25.2	26.0	79.9	93.00
34	AA-933	40.0	4.4	27.7	29.4	83.3	94.00
35	VH-383	38.3	4.4	27.4	27.0	83.7	90.00
36	Sitara-16	35.8	4.2	25.7	26.3	80.3	93.00
37	SLH-19	40.0	3.9	25.5	25.9	79.9	93.00
38	Cyto-225	39.5	3.9	30.3	31.7	80.7	98.00

Source: Spot Examination of Cotton Candidate Varieties Held during 2018 at CCRI-Sakrand and fiber traits results were tested from CCRI-Multan.

Table 7: Biochemical Test Results (Average of Four Laboratories).

Genotypes	2017		2018		Average of 2 years	
	Trait Purity	Quantification	Trait Purity	Quantification	Trait Purity	Quantification
MNH-1026	92	2.24	89	1.36	90.50	1.80
BH-221	65	2.30	76	2.37	70.50	2.34
BS-18	100	1.63	80	1.46	90.00	1.55
CEMB-100 (DG)	93	1.50	82	1.44	87.50	1.47
MNH-1020	77	2.63	55	0.87	66.00	1.75
FH-444	78	1.48	100	1.08	89.00	1.28
CEMB-101(DG)	92	1.45	100	2.66	96.00	2.06
ICI-2121	82	2.81	100	0.94	91.00	1.88
Bahar-07	85	1.05	64	1.47	74.50	1.26
IUB-69	85	2.04	64	1.00	74.50	1.52
CIM-343	75	2.45	100	1.23	87.50	1.84
FH-490	77	2.64	89	1.10	83.00	1.87
CIM-663	65	2.02	100	2.70	82.50	2.36
Cyto-515	77	2.00	80	1.59	78.50	1.80
CRIS-613	48	0.85	33	0.63	40.5	0.74
NIAB-898	78	1.53	64	1.00	71.00	1.27
GH-Haadi	85	1.57	100	2.01	92.5	1.79
Badar-1 (DG)	93	2.12	73	2.00	83.00	2.06
GH-Mubarak	82	1.11	80	1.45	81	1.28
Tahafuz-10 (DG)	82	4.14	72	1.09	77.00	2.62
Weal-AG-6	85	1.85	89	1.23	87.00	1.54
RH-Afnan	65	2.66	100	1.38	82.50	2.02

CIM-602 Std-1	85	1.41	100	1.54	92.50	1.48
TJ-MAX (DG)	85	2.01	100	1.62	92.50	1.82
Bahar-2017	85	1.05	89	1.04	87.00	1.05
RH-Manthar	77	2.00	89	1.33	83.00	1.67
VH-189	92	1.22	89	1.48	90.50	1.35
Weal-AG-5	93	1.35	62	1.26	77.50	1.31
GS-Ali-7	52	0.77	33	1.08	42.50	0.93
IUB-13 Std-2	82	1.80	64	1.18	73.00	1.49
NS-191	52	0.93	93	1.47	72.50	1.20
CIM-717	90	1.12	40	0.90	65.00	1.01
SLH-6	85	1.85	67	0.98	76.00	1.42
AA-933	82	2.17	75	2.43	78.50	2.30
VH-383	93	1.67	87	1.18	90.00	1.43
Sitara-16	85	3.07	89	1.41	87.00	2.24
SLH-19	52	1.62	67	0.91	59.50	1.27
Cyto-225	58	0.70	33	0.93	45.50	0.82

CONCLUSION: Thirty six candidate cotton varieties were evaluated at six locations of Sindh and Balochistan. On the basis of results during the two consecutive years (2017 and 2018), top ten high yielding varieties were GH-Haadi, VH-189, CRIS-613, Weal-AG-6, GH-Mubarak, Badar-1(DG), ICI-2121, Weal-AG-5, FH-940 and MNH-1026. It is note that among top 10 high yielding varieties, only two varieties (GH-Haadi and VH-189) were stable with yield performance due to the fact that these varieties maintained their superiority in individual year 2017 and 2018, also when the average performance was combined. Whereas, other varieties showed their stability in a particular single year but included in top 10 varieties, when the yield results were averaged. On the basis of yield performance, it is concluded that the top two high yielding varieties GH-Haadi and VH-189 are stable in yield performance and must be approved by the provincial seed council of Sindh and Balochistan to revive the cotton production of the provinces and not to waste/garbage this high yielding stuff

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An Overview of factors affecting on cotton production

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ABSTRACT

Cotton is well prominent as "white gold" important cash and precious crop in overall cotton growing development counties. The yield of this crop is depending upon the environment in which it is grown and management practices of the cropping system. It is noted after review of various publications of scientists that several factors are responsible which affecting cotton production, selection of cultivar should be according to environment in which it is grown, soil preparation, seed rate, plant spacing, sowing/planting dates and timely irrigation are the important factors which effect on yield. Whereas, nutrients management and crop protections are the key factors which directly affecting the plant growth and development ultimately directly responsible for decreasing yield. Along with these factors modern technology and farmer's education play a vital role for producing quality cotton production and management of farms. Therefore, suggested that farmers should apply better management practices and follow proper time management as per practices and apply timely appropriate inputs for crop growth and development and crop protection measures for sustainable cotton production.

Key word: Cotton, production factors, cultivar selection, sowing time, nutrients, crop protection.

INTRODUCTION: Cotton that is well prominent as "white gold" is an important cash and precious crop in overall cotton growing development counties. The yield of this crop is depending upon the environment in which it is grown and management practices of the cropping system. Cotton yield is stagnant for the last several years. Factor responsible for the stagnant cotton yield production include: unnecessary raining during the sowing time, high temperature fluctuation from beginning up to the flowering stage, delay in harvesting wheat which is also resulting in decline of area under the crop, incidence of cotton leaf curl virus disease, system of soil, adversaries of water application, outbreak of insect pests and the major cause for low production is inappropriate adapting of production technology in overall major cotton growing areas. Along with that; there are many other social as well as economic problems facing cotton production including: uneducated farmers who producing cotton, improper tillage operations, delay in sowing and plant density, outbreak of insect pest and diseases, climate change, inappropriate use of irrigation water, lack of supply plant nutrients at the right time, high input cost, small landholdings, no innovation adaptable by farmers through small experiments, lack of interaction between extension departments and farmers, uncertainty in the market rates and the cost of production is the most significant factor among them.

Cotton can exactly be considered as an internationally trade crop that plays a crucial role for elevating country's economy. A better cotton growth guarantees with the appropriate coordination of different agronomic practices and judicious use of various inputs and among these, appropriate sowing date is an important phase which effects on fiber characters and yield. Because cotton is an important fiber crop and occupies a key position in the world's trade and economy of Pakistan (Soomro *et. al.* 2014). According to (Khan *et al.* 1986, Hassan 1991 and Nabi 1991) observed that financial resource, inputs cost, lack of experienced with modern technology and lack of linkages with market are the major cause of low yield in cotton. They also found that sowing and cultivation cost, fertilizer, seed, irrigation, pesticide are also major factors which affecting on production of cotton. Iqbal *et al.* (2001) found that proper and timely use of seed, weedicide, fertilizer and pesticide have greatly influence on cotton production. It these can be available timely then ultimately yield will be increased. Bakhsh *et al.* (2005) reported that several factors positively affecting towards cotton production viz. land preparation, fertilizer, plant protection, irrigation and seed rate as well. Anwer *et al.* (2009) suggested that many factors affecting on cotton production viz. quality seed, fertilizers (DAP and Urea) and irrigation water has significantly affect towards produce higher cotton yield. Nadeem *et al.* (2014) conducted research and explored the factors (education, fertilizer, land preparation, plant protection measures, irrigation and seed) which affecting on cotton production. The various factors might be responsible for stumpy crop yield in the country which is discussed as below.

Cultivar selection: Selection of an appropriate cultivar according to the environment for particular zone is primary factor for the cotton production; because only suitable cultivars can be produce required yield, as it is suggested by the scientist; who evolved it as per climatic adoptability such as temperature, wind, light and humidity etc. Certified seed from public and private sector is passed through field inspection, tested at laboratory from seed certification department which meet the varietal purity standards and free from the certain weed seed and other crop mixture and diseases as well. A large number of farmers sowing cultivar which is not recommended and uncertified, their germination percent is very low, if germination percent is good then after maturation very low quantity of bud, flower & boll setting. Some of the variety after sowing emergence different types of plants in field some of them have dwarfed while others tall with different characteristics. Low categories of seed which have heavy insect pests and diseases outbreak. Pesticide and fertilizers expenses more and final maximum yield at per hectare, that income giving loss to farmers, because the inputs cost is higher than the income of per hectare. Similar theories presented by Kalhoro *et al.* (2001) screened out the best genotypes and recommended superior variety according to the central climatic conditions. Jatt *et al.* (2007) reported best cultivars CIM-446 and TH-3/83, as compared with others and suggested in the agro-climatic condition of Jamshoro for commercial cultivation. Khan *et al.* (2007) presented findings that cultivar Karishma and CIM-1100 have the best performance for parameters which were studied and hence recommended as the most suitable commercial cotton cultivars for agro-climatic conditions of D.I. Khan. Sial *et al.* (2014) conducted experiment to evaluate the best cultivars according to central climatic zone of Sindh and suggested CRIS-342 and MNH-786 has a best genetic potential to perform better and hence it is recommended that these cultivars are best suited to cultivation in given climatic condition.

Soil preparation: Cotton crop required a soil which has excellent water holding capacity and aeration with good drainage as it cannot survive excessive moisture and water logging. Consequently, healthy plant growth and development require soil conditions that have sufficient moisture and temperature in soil, and least root penetration resistance through deep ploughing. Sufficient tillage system can make perfect seedbed conditions i.e. temperature, moisture and penetration resistance for germination of seed, growth and development of plant and without hindrance of root growth. Whereas proper land leveling helps in saving irrigation and other inputs because of uniform leveling in the field. Similar findings proposed by Khan *et al.* (1986) and Hobbs *et al.* (1992) who also suggested deep tillage to decrease compaction below the plough layer and for conserving moisture. Ali *et al.* (2010) suggested that bed planting method proved to be superior to ridge and flat plantings. Gursoy *et al.* (2011) found results that for improvement in yield and plant growth ridge tillage is considered as a good agronomic practices for the reason that it provide good physical conditions in soil. Ali (2013) observed that cotton yield was significantly influence through different practices of tillage, whereas higher yield can be produced through deep ploughing as compared with minimum tillage. For plant growth and development, seed germination, unimpeded root development and ideal soil conditions i.e. temperature, moisture and penetration resistance can be created with effective tillage system (Tisdall and Hodgson 1990; Taylor and Brar 1991; Materechera and Mloza-Banda 1997; Theodore and Gemtos 2002; Atkinson *et. al.* 2007 and Krause *et. al.* 2009).

Seed rate and plant spacing: The appropriate recommended seed rate is very essential for optimum plant growth and yield. It depends upon the variety, soil type, method of sowing and cultivation practices. A recommended seed rate is 15-25 kg per hectare for genetically pure and high germination cultivars by various scientists through research and practical experiments. The most favorable seeding rate for cotton products can be easily adjusted during various cropping system without yield penalty or causing great complications in growth management. However, farmers using stumpy seed rate due to which plant population remain low in the field and ultimately cause of low yield. Whereas plant spacing is very crucial for cotton production, because excess and low plant population ultimately decreased in the per hectare yield. The recommended plant spacing is mandatory for better cotton production which is plant to plant 30 cm depends upon the selection of variety either bushy or compact type and row to row distance should be maintained 75 cm. Same findings presented by Ali *et al.* (2009) recommended that maximum seed cotton yield can be produced through maintaining proper plant spacing. Ali *et al.* (2010) suggested that cotton growers are advised to adopt bed planting method with 22.5 cm plant spacing to maintain 59260 plants for maximum yield.

Sowing/planting date: Proper sowing time is an importance factor because delayed sowing time is one of the major reasons for low yield. Planting crop too early emerging with poor crop standing the results of lower yield potential and alternately, planting too late commonly becomes very vegetative and difficult to manage and also resulting in lower yield as well. For optimal cotton production proper time of sowing need to be followed which minimizes the external factors which affecting on crop. At farmers level it was also observed late sowing of cotton crop because of unavailability of pure seed at sowing time, irrigation and fertilizer are additional reasons and ultimately getting poor growth and decrease in yield. Therefore, it is recommended that proper time of sowing/plating should be followed to avoid external factors, proper growth and development for getting high yield. Similar studies have been done by various scientists, Brown *et al.* (1992) and (1993), Silvertooth *et al.* (1993) and Unruh *et al.* (1994) several phase of cotton production system i.e. growth and development patterns, yield and insect pest management can rightly be influence with planting dates. Soomro *et al.* (2000) recommended that May 15 sown crop result increased bolls plant^{-1}, boll weight and seed cotton yield and further observed that cotton sown earlier or later than its optimum time showed a steadily decreased in its yield. Arain *et al.* (2001) reported that maximum seed cotton yield was produced when cotton was sown on May 1st at Nawab Shah Sindh Pakistan. Arshad *et al.* (2001) studied the effect of planting dates on fiber characters and suggested that when sowing time was late, staple length, fiber maturity and fiber strength were drastically decreased. Mahmood-ul-Hassan *et al.* (2003) presented findings the yield of cotton is mostly associated with sowing dates as boll weight and formation of bolls which are interred linked with the yield. Wrather *et al.* (2008), Ali *et al.* (2009), Baloch *et al.* (2010), Awan *et al.* (2011) and Deho (2012) presented research findings that optimal time of sowing/plating increase the cotton yield with attributing traits and fiber quality parameters, while it decrease when delayed. Soomro *et al.* (2014) reported that sowing to cotton crop at appropriate time produced maximum yield and yield contributing characters, whereas early or late sowing effect on decreasing yield gradually after 30 days interval.

Irrigation: Irrigation water is production tool as fertilizer and tillage which provide supplement to crop plant. Deficient water and uninterrupted drought cause remarkable losses to farmers. For sustainable crop productivity there is essential to supply of irrigation water frequently as per crop need. In case one or two critical growth stages go without irrigation during lifecycle of the crop, it results in significant reduction in crop production. According to Hake *et al.* (1992) irrigation use enhance the yield, quality and profit stability. Shafiq (2002), Maqsood *et al.*

(2006), Saleem *et al.* (2010) and Mubeen *et al.* (2012) reported that various growth and yield parameters are associated with irrigation and usually six irrigations are most important for producing maximum seed cotton yield. Ertek and Kanber (2003) reported that seed cotton yield and boll number increased linearly with irrigation water amount. Karam *et al.* (2006) found that cotton lint yield was inversely associated with irrigation amount. Onder *et al.* (2009) recommended that the highest seed cotton yield can be produced through full irrigation intervals at all growth stages of cotton crop. Hassan *et al.* (2011) found that the highest seed cotton yield was obtained with full irrigation, if deficiencies occur which effects on yield. Similar results reported by various scientists Yazar *et al.* (2002); Pettigrew (2004); Aujla *et al.* (2005); Bakhsh *et al.* (2005); Mert (2005); Jalota *et al.* (2006); Chun-yan *et al.* (2007) and Anwar *et al.* (2009).

Nutrients: Mostly agricultural soils contain very low organic matter. Moreover, nutrients deficiencies is widely reported because of harvesting of exhaustive crops year after year, high temperature, low rainfall, high cost and imbalanced use of fertilizers. Application of fertilizer in a balance amount with standard methods and at appropriate time keeping in mind the soil nutrient status, soil moisture, crop type and crop growth stage can increase yield up to 25-75 percent. According to Wahab (1985) on the basis of soil testing in Pakistan that generally deficiencies of nitrogen, phosphorus and occasionally of potassium occur in soils, which are cause of low yield. Marschner (1986) suggested that for internal part of chlorophyll molecule, nucleic acid, and protein and growth regulators nitrogen acting leading role. Power and Schepers (1989) presented that the requirement of nitrogen fertilizer effect on many factors which are yield, nitrogen mineralization and nitrogen concentration. Elayan (1993) found that the yield and its components can be increased by applying increasing nitrogen levels. Bauer (1994) reported that nitrogen management is a key aspect of cotton production, both limited and excess can reduce cotton yield. Furthermore presented that phosphorus and potassium deficiencies can also reduce yield by limiting plant growth. Whereas, excesses of these nutrients in soil interfere with the uptake and utilization of micronutrients and can reduce yield through micronutrient deficiencies. Malik *et al.* (1996) found that phosphatic fertilizer results were variable in most areas, whereas cotton crop shown marvelous response at the application of nitrogen fertilizer in all type of soils. Gill *et al.* (2000) reported that positive and economical response of cotton crop with phosphorus fertilizer application. Bukhsh *et al.* (2005) suggested that more use of fertilizer contributes towards maximum seed cotton yield and enhance their crop production by applying appropriate combination of N:P:K. Makhdum *et al.* (2001) presented that due to application of phosphorus fertilizer seed cotton yield significantly increased. Saleem *et al.* (2010) recommended through practically that earliness and seed cotton yield can be achieved by using higher dose of phosphorus fertilizer. Ali *et al.* (2011) presented that zinc and boron foliar application proved as the best balanced fertilizer dose for higher seed cotton yield. Similar results presented by various scientists Marcus-Wyner and Rains (1982); Hussein *et al.* (1985); Constable and Rochester (1988); McConnell *et al.* (1995); Jin *et al.* (1997); Sawan *et al.* (1997); Vieira *et al.* (1998); Ahmad (2000); Bronson *et al*. (2001); Katkar *et al*. (2002); Shah *et al.* (2003); Dar and Khan (2004); Singh *et al*. (2006); Abid *et al*. (2007); Kumbhar *et al*. (2008) and Ahmed and Irshad (2011).

Crop protection: The most important concern for cotton crop throughout season is weeds, insects and diseases which cause severe economic losses each year in the form of reduced yield and fiber quality. In addition, pest control through the purchase of pesticide and the use of other weed control practices is a major expense for cotton producer. Lack of quality control, high cost, adulteration, timely unavailability and lack of education and the use of faulty equipment's by untrained labour are the major constraints responsible for the ineffectiveness of pesticides, fungicides or weedicide (Bauer 1994).

Weeds: The most noticeable way weeds reduce cotton yield is through competition with cotton plant for light, nutrients and water. Weed competition is very severe when plants are young. Studies have shown that weeds must be controlled at initial stage after cotton emergence or significant yield reduction can occur. Some weeds also serve as alternate hosts for insects, diseases and nematodes (Bauer 1994). According to Schwerzel and Thomas (1971) weeds consume excessive potassium, nitrogen and magnesium 3-4 times as compared with crop. Anderson (1983) observed that weeds are severe threats for crop production by reducing yield and quality of crop as competing for water, nutrients, light and carbon dioxide. Askew *et al.* (2002) found through field trial that seed cotton yield can be increased if weeds controlled by the application of effective herbicides. Gianessi and Sankula (2003) presented that weeds are quite different as compared other pests that create problems for crop production, because weeds are relatively stable, as outbreak of insects and disease are sporadic. Ali *et al.* (2005) stated that maximum seed cotton yield can be obtained by controlling weeds with suitable application of weedicide and inter-culturing. Cheema *et al.* (2008) reported that the application of weedicide as pre-emergence were given maximum seed cotton yield with minimum weed density. Whereas, the lowest seed cotton yield was recorded with high weed density. Henderson and Anderson (1966); Rajeswari and Charyulu (1996); Van Chin (2001); Johnson *et al*. (2004); Ware and Whitacre (2004); Vasilakoglou *et al*. (2005); Shah and Khan (2006) and Chinnusamy *et al*. (2013) reported similar findings that due to weeds, seed cotton yield will be reduced.

Insects: Yield reduction by insects can be caused by attacks on vegetative plant parts that lead to delayed or reduced growth. Insect attacks on reproductive structure reduced yield by decreasing the number of bolls harvested. Defoliation by some insects can reduce boll size and may cause plant death and also reduce fiber quality (Bauer 1994). According to several researcher; (Ali 1992) reported that 18.78% cotton yield decline by attacking Jassid. Khan and Khan (1995) and Malik *et al.* (1995) reported that up to 38.7% yield losses was noted due to sucking pests. Aslam *et al*. (2004) noted that seed cotton yield is being decreased by attacking thrip, whitefly and jassid. Xingyuan *et. al.* (2004) presented that if insecticide is not applied for sucking insect pests; it ultimately cause as yield losses. Amjad and Aheer (2007) observed that sucking insect pests plays important role for yield reduction. Jothi (2007) presented that the pest pressure, particularly of bollworms, due to which crop losses in cotton becomes very high. Dhawan *et al.* (2008) observed that yield losses are due to sucking insect pests in cotton. Shahid *et al.* (2015) found that due to insect pest there were significant decline in seed cotton yield and staple length.

Diseases: Disease agents (fungi, bacteria and viruses) reduce cotton yield by decreasing stands, retarding crop growth, and causing boll rot, root rot and CLCuV etc. Quality of harvested cotton is reduced when diseased bolls or plant are harvested with the rest of crop. Development of cultivar that is resistant to or escapes these pest organisms is a major focus of disease control in cotton (Bauer 1994). Numerous species of fungi can cause seedling diseases, but the primary agents are *Rhizoctonia solani*, *R. bataticola* (*Macrophomina phaseolina*) *Pythium spp., Phoma exigua* (Ascochyta) and *Fusarium spp.* Further suggested for prevention against these disease are exclusion of the pathogen from area quarantine, use of resistant varieties/cultivars, cultural practices, time of sowing is also important, irrigation management, excessive application certain organic manure like poultry manure will induce high vegetative growth, field sanitation is another essential part of disease management, incorporation of composts in to the soil is a fundamental cultural practice in organic cotton production. i.e. (a). successful competition for nutrients by beneficial micro organisms. (b). antibiotic production by beneficial micro organisms. (c). successful predation against pathogens by beneficial micro organisms. (d). activation of disease resistant genes in plant by composts. Chemical control with an effective fungicide and biological control (Chidambaram, 2007). According to the report of Ranney *et al.* (1971) yield losses in the order of 1.5% caused by cotton bolls rot, in a particularly dry year, while in the next year these losses increased to 14% due to higher humidity and temperature. Jiskani (1992) reported that the cotton crop record revealed that root and boll rot diseases of cotton were considered as most severe and destructive, but since last decade, cotton leaf curl virus (CLCV) found to be most important disease. Mahmood *et al.* (1996) found that ClCuD caused average reduction in plant height (40.6%), number of bolls per plant (72.5%) and boll weight (33.8%) in cotton crop. Khan and Ahmed (2005) found that CLCuD is a crucial disease causing massive losses to cotton production. Allen (2006) presented that fusarium wilt is mainly common disease on farm level and averagely 6.7 percent infected plants are found during 75 percent crop survey. Iamamoto (2007) reported that bolls rot causing 20-30 percent losses in cotton productivity, whereas it losses first boll position in affected plants which produced best quality of cotton fiber. Iqbal *et al.* (2014) reviewed status of CLCuV disease and presented that for cotton production it is very crucial threat of this disease, it belongs Begomovirus genus and family Geminiviridae, transmitted through whitefly. Due to CLCuV disease extremely yield reduction was observed.

Modern technology: Management practices with modern technology at farm level increase productivity which is important to allow farmers to move farm subsistence to market-driven farming that requires changes in crop selection, cultivation, harvesting, marketing, transportation and adaptation of new technologies. Modern techniques for plant protection measures are required for effective control of diseases, insects and pests to avoid crop losses. Bukhsh *et al.* (2005) for adaptation of improved technology education acts an important role and builds maximum productivity level. At the farm educated or skill farmer apply various practices regarding production technology; furthermore, they will be in better position and to be familiar about existing marketing situation locally and nationally about farm inputs and outputs. According to earlier worker Wu (1977); Dhakal *et al.* (1989); Raza and Ramachandran (1990) and Lin (1991) reported that education improves the management skills of farmers, who tackle such issues on efficient and effective way and through modern technology implementation yield will be increased.

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Phenotypic response of cotton genotypes for yield and fiber quality traits

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ABSTRACT

Twenty five cotton genotypes were tested with two standard check varieties in National Coordinated Varietal Trial (NCVT). The significant difference was observed among all the genotypes of yield, its contributing traits and fiber quality traits, which indicated sufficient genetic diversity, were present in the material. Among the genotypes, ICI-2121, GH-Hadi and NIAB-898 are high yielding cotton genotypes; these are suggested for commercial cultivation at the environmental condition of central zone of Sindh to boost up cotton production and at the same time utilization in hybridization and breeding program to evolve high yielding variety. For the fiber quality traits NIBA-898 and NS-191 are suitable genotypes to meet the criteria of textile sector.

Key word: Cotton genotypes, phenotypic performance, seed cotton yield and fiber traits.

INTRODUCTION: Cotton is an important cash and fiber crop of Pakistan, whereas the yield of this crop is reliant upon the environment in which it is grown and management practices of the cropping system. Cotton contribute raw material to textile sector, that's why countries economy depend on this crop. It provides seeds with potential of various products viz. lint, oil, hulls and food for animals (Ozyigit 2008). Globally Pakistan is 5th largest cotton producing country, 3rd major consumer as compared with other cotton growing countries. The area under cotton cultivation in Pakistan during year 2019-20 was 2.895 million hectares and production was 12.72 million bales, as regards the provincial status, Punjab contributed 2.145 million hectares with production 7.90 million bales and Sindh was on 0.640 million hectares and 4.60 million bales production (Cotton Review, 2020). The cotton has been challenging crop for Pakistani growers due to various factors, ultimately causes decline in seed cotton yield (Choudhary *et al.* 2017 and Nachimuthu *et al.* 2017). Significant difference of various characters in cotton is due to sowing of different cotton genotypes/varieties (Afzal *et al.* 2002). Major difference of cotton traits is due to performance of varieties (Hanif *et al.* 2001). Sezener *et al.* (2006) also reported that significant variation in seed cotton yield is due to varieties. Therefore, keeping in view the cotton crop importance and different response of cotton varieties, the present research was carried out to evaluated 27 cotton genotypes and identify most promising variety for commercial cultivation to boost-up cotton production and utilization in hybridization and breeding program to transfer the traits and improve the characters.

OBJECTIVES: The main objective of this study was to assess the cotton genotypes at the environmental condition of Sakrand, Sindh and best genotypes which produce high yield with better fiber traits that could be used commercial to boost up cotton production and good stuff also utilized for breeding program to evolve high yield variety with desirable fiber traits. The significant variation was recorded in mean performance of genotypes for all the characters which suggested that varieties are statistically differ from each other.

MATERIALS AND METHODS: The trial was conducted at experimental farm of Central Cotton Research Institute Sakrand, 27 advance cotton genotypes were tested in National Coordinated Varietal Trial (NCVT) during the 2018-19 for yield and fiber traits at the environmental condition of Sakrand. The experiment was conducted with randomized complete block design with three replications. The plot size was maintained 30'x10. The seed was planted on ridges with plant to plant and row to row distance was maintained at 30 cm and 75 cm respectively. The agronomic practices viz. weedicide, irrigation, thinning and inter-culturing were done uniform accordingly in all the replications. The fertilizer and plant protection measures were applied as per need whenever required. The 5 plants were tagged from each replication to record the data. The traits were studied viz. plant height, sympodial branches plant^{-1}, bolls plant^{-1}, boll weight, seed cotton yield (kg ha^{-1}), ginning outturn, staple length, micronaire value and fiber strength. The significance difference of genotypes were tested through using method suggested by Steel and Torrie (1980) and the comparison of means were tested by Duncan Multiple Range Test (DRMT) at 5% and 1% probability by using statistical computer software application Statistix.8.1.

RESULTS AND DISCUSSION

The significant difference was observed among all the genotypes of yield, its contributing traits and fiber quality traits at 1% and 5% probability, which indicated sufficient genetic diversity, were present in the material (table 1). The significant variation was recorded in mean performance of genotypes for all the characters. Regarding the plant height (figure 1), the tallest varieties was observed NS-191 given (107.2 cm), while lowest was given by NIAB-898 (85.2 cm). The variation in plant height among various cotton genotypes were due to significant difference in genetic makeup of strains. Similar findings were reported by Anwar *et al.* (2002), Corpur (2006) and Ashokkumar and Ravikesavan (2011). Cotton breeders and farmers prefer medium height varieties due to lodging. Therefore, selection of varieties should be based on medium plant height. The *per se* performance of sympodial

Table 1: Analysis of variance means performance and statistical analysis of yield and fiber traits of cotton.

Traits	Replication DF-2	Genotypes DF-26	Error DF-52	CD 5%	CD 1%	CV %
Plant Height	51.308	99.664**	42.591	10.53	14.03	6.75
Sympodial Branches	13.823	14.531**	6.753	4.20	5.59	9.86
Bolls Plant^{-1}	66.952	112.107**	44.066	10.87	14.49	8.51
Boll Weight	0.0267	0.4587**	0.082	0.47	0.62	7.84
Seed cotton Yield	38971	657178**	10775	170.07	218.5	4.36
Ginning Outturn	0.011	21.515**	0.327	1.39	1.85	4.50
Staple Length	0.583	3.332**	0.245	0.81	1.08	2.87
Micronaire Value	0.007	0.3418**	0.0103	0.17	0.23	2.58
Fiber Strength	0.0414	6.205**	0.709	1.37	1.83	3.05

Figure 1: Plant height.

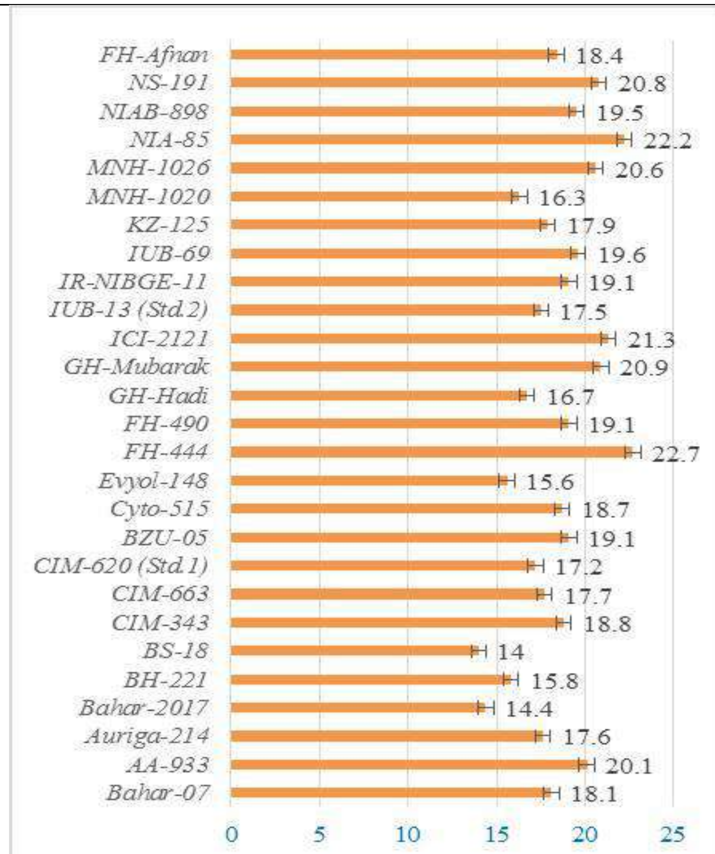

Figure 2: Sympodial Branches

branches (figure 2) revealed significant variation among cultivars, FH-444 given maximum sympodial branches (22.7). It was statistically at par with variety NIA-85 (22.2). While, minimum was noted in strain BS-18 (14.0). The results are in accordance with Corpur (2006), Ehsan *et al.* (2008) and Ashokkumar and Ravikesavan (2011).

Bolls plant^{-1} considered as important character that has direct effect on seed cotton yield. Among the varietal performance GH-Mubarak formed maximum (46.0) number of bolls plant^{-1}, followed 45.4 and 43.2 given by varieties AA-993 and NIAB-898 (figure 3) as compared with standard check varieties, CIM-602 and IUB-13. While, minimum number of bolls plant^{-1} produced by BS-18 (22.8), which indicated that variety could not perform well in Sakrand environment that could be due to stability and changing environmental condition. Boll weight is also an important trait which contributed in seed cotton yield. Out of 27 genotypes FH-444 given bigger boll and stood top as compared with other advance cotton genotypes and standard check varieties. The smaller boll weight was weighted in variety NIA-85 (figure 4). The character seed cotton yield place a unique position as compared to other traits. It is a joint contribution of other traits and their direct effect on increasing and decreasing yield. All the cotton genotypes were statistically differ from each other. The utmost seed cotton yield was produced by genotypes ICI-2121 (3279 kg ha^{-1}), followed by GH-Hadi (3135 kg ha^{-1}) and NIAB-898 (3087 kg ha^{-1})which were highest among all other genotypes as well as comparison with standard check varieties CIM-602 and IUB-13 (figure 5). Whereas, the lowest seed cotton yield was given by BZU-05 and IUB-69 which were below from standard check varieties. The results indicated that every genotype performed in different way at the environmental condition of Sakrand on the basis of varietal genetic makeup, characters, stability, environmental condition and might be soil factors. Therefore, it is suggested that varieties which possess higher boll plant-1, boll weight and seed cotton yield could be preferred for commercial cultivation

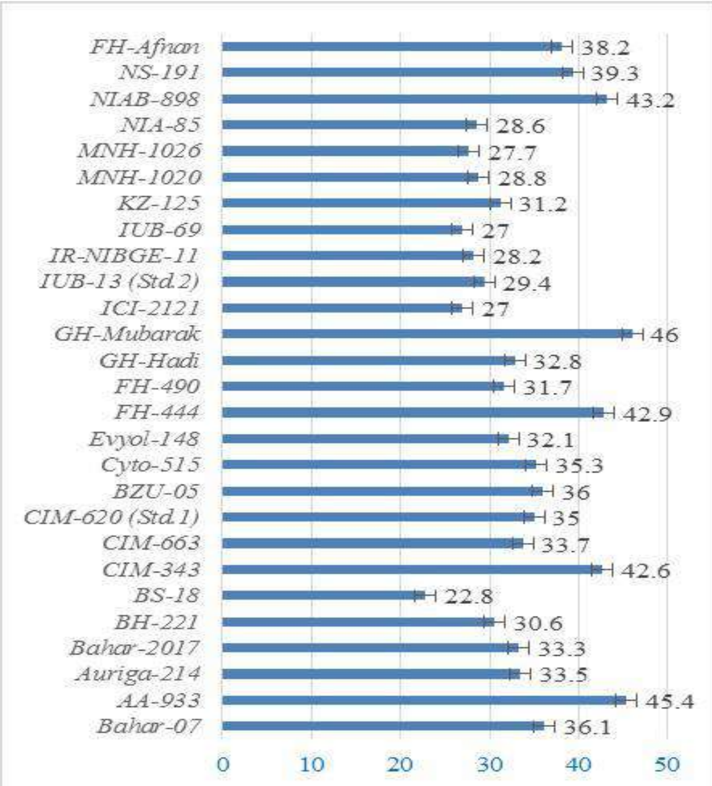

Figure 3: Bolls Plant^{-1}

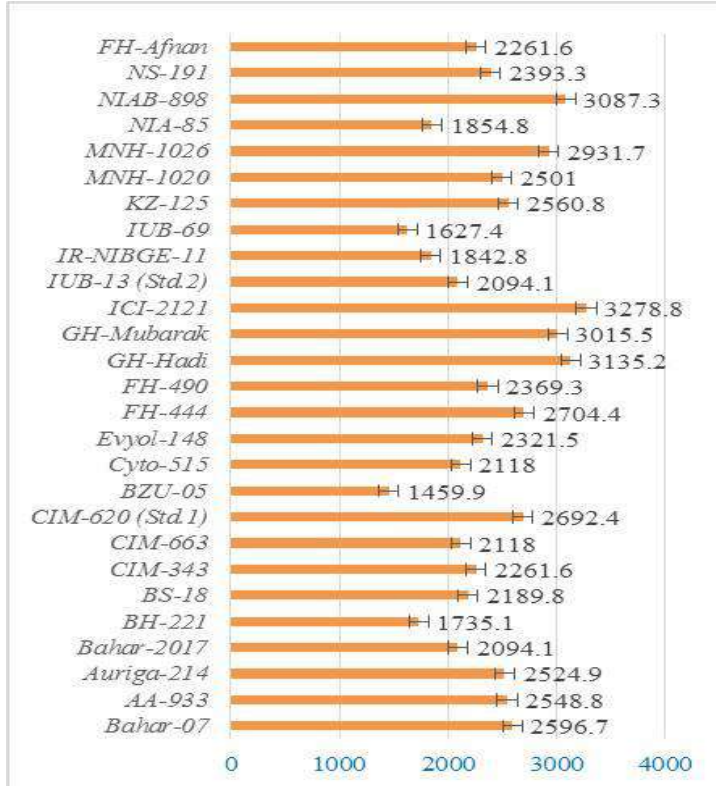

Figure 5: Seed cotton yield.

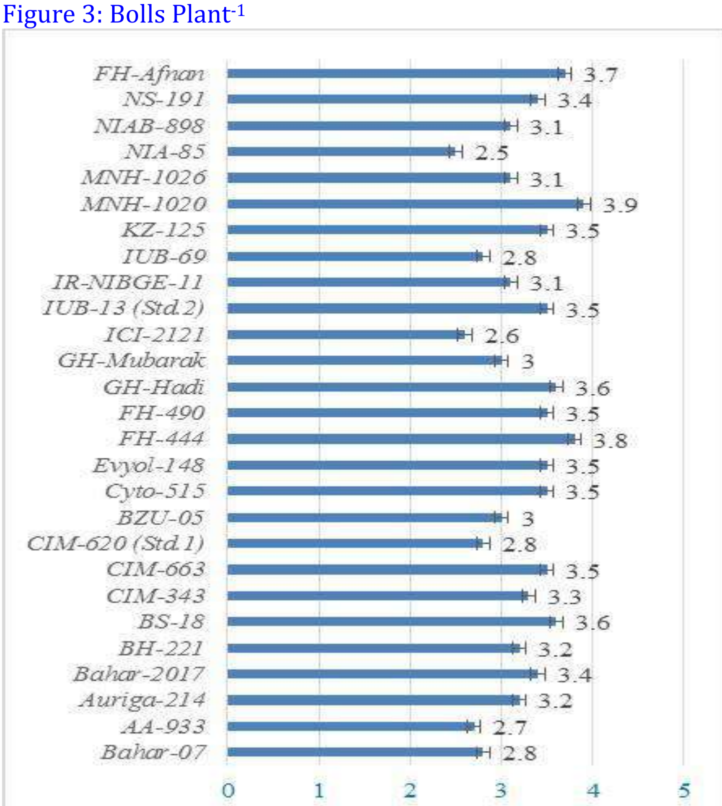

Figure 4: Boll Weight

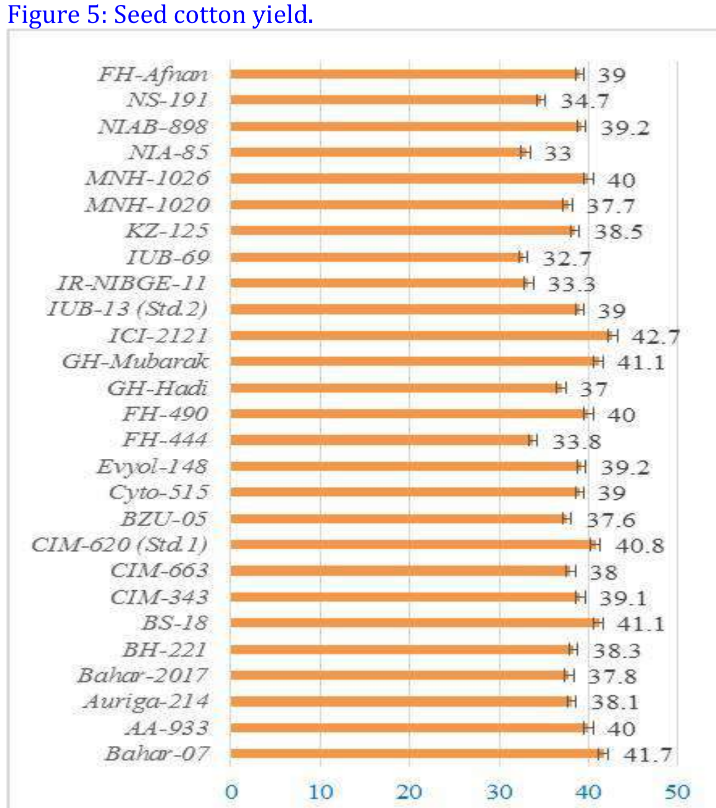

Figure 6: Ginning outturn

as well as utilization in breeding program to improve the characters. Corpur (2006), Ehsan *et al.* (2008) and Ashokkumar and Ravikesavan (2011) also reported significant difference among varieties for bolls plant^{-1}, boll weight and seed cotton yield. Hofs *et al.* (2006) documented variation in boll weight due to varieties. Khalid and Mueen-u-Din (2018) found variation in mean performance of genotypes for bolls plant^{-1}, boll weight and seed cotton yield. Kairon *et al.* (2000), Koutu and Shastry (2004), Khan *et al.* (2008), Shah *et al.* (2015) and Sekloka *et al.* (2018) described stable cotton genotypes with high potential for seed cotton yield in particular zone.

Data pertaining to ginning outrun per se performance (figure 6) indicated that ICI-2121 ginned higher ginning outturn (42.7%) followed by Bahar-07, BS-18 and GH-Mubarak compared with standard check varieties CIM-602 and IUB-13. While, nine advance strains lowest ginning outturn which was below than standard. The results of varieties for ginning outturn was found statistically differ from each other. The results are supported with Wang *et al.* (2004), Ehsan *et al.* (2008) and Ashokkumar and Ravikesavan (2011). The comparison of treatment means indicated that varieties had significant effect on staple length. The longest staple length was measured in genotype NIAB-898 (28.2 mm) and NS-191 (28.1 mm) as compared with standard check varieties CIM-602 and IUB-13. However, out of twenty five advance genotype only two genotypes given staple length more than set standard (figure 7). As regards the trait fiber strength (figure 8), the strongest fiber strength was noted in genotype NS-191 and FH-Afnan as compared with other genotypes and standard check variety.

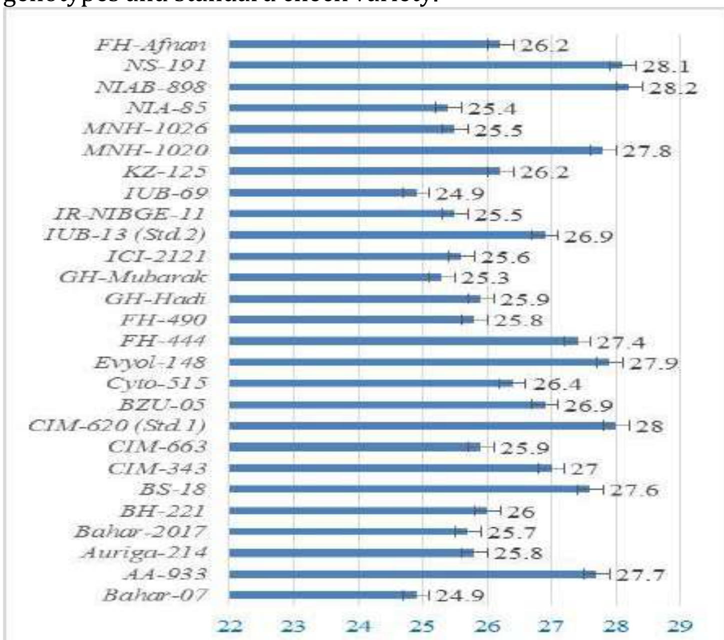

Figure 7: Staple length

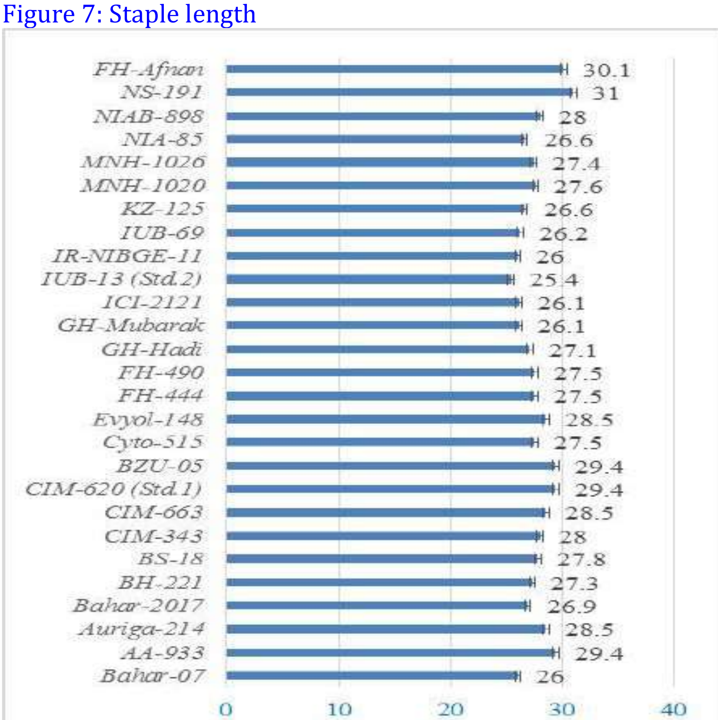

Figure 8: Fiber strength

Fiber fineness/micronaire value is an important trait in fiber quality parameters and is very valuable for textile industry. The significant difference in mean performance was observed for micronaire value (figure 9).

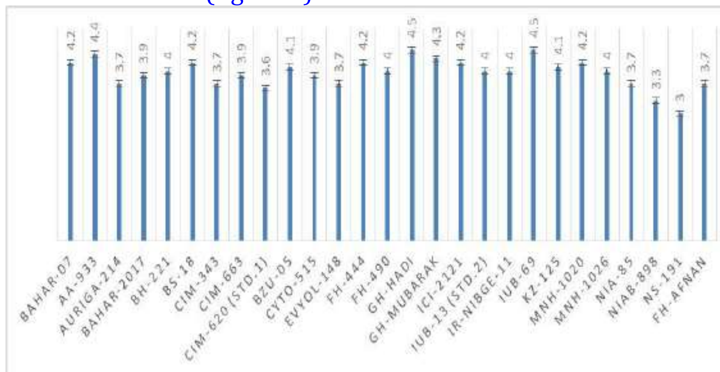

Figure 9: Micronaire value

The genotypes NIAB-898 and NS-191 declared as best which produced fineness fiber 3.0 and 3.3 respectively, as compared with other genotypes and standard check varieties CIM-602 and IUB-13. The findings are agreement with those of Copur (2006), Ehsan *et al.* (2008) and Ashokkumar and Ravikesavan (2011), Khokhar *et al.* (2017).

CONCLUSION: It was concluded that ICI-2121, GH-Hadi and NIAB-898 are high yielding cotton genotypes, these are suggested for commercial cultivation at the environmental condition of central zone of Sindh to boost up cotton production and at the same time utilization in hybridization and breeding program to evolve high yielding variety. For the fiber quality traits NIBA-898 and NS-191 are suitable genotypes to meet the criteria of textile sector.

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A comprehensive report of the National Coordinated Varietal Trial (NCVT) of Cotton conducted during 2019-20 in National Cotton Varietal Testing Program

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Author's Contribution	**Ahsan, Z. A** performed the experiments and wrote the report.
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ABSTRACT

One hundred and two cotton cultivars, developed by the different scientists were grouped in four sets and tested at six locations in Punjab, four locations in Sindh, three locations in Balochistan and one location in KPK to test the adaptability of seed cotton yield. The quantitative and qualitative analysis of Bt toxin of these cultivars was conducted at four designated labs. The results revealed highly significant differences among the cultivars for seed cotton yield per hectare. In Set-A top performance cultivar is Saim-102 (2519kgha^{-1}) followed by the Tahafuz 12 (2350kgha^{-1}), in set-B Rustram-11 (2655kgha^{-1}) and BF-1 (2288kgha^{-1}) perform best as compared to the other cultivars. In Set–C cultivar, NIAB-1011 (2604kgha^{-1}) and GH-Uhad (2531kgha^{-1}) out yield the all other cultivars and in Set-D cultivar, Bt-CIM-775 (2588kgha^{-1}) and Sahara-Klean-5 (2508kgha^{-1}) surpass the yield from other candidate cultivars. Overall top varieties in Punjab, Sindh, Balochistan and National level were Rustam-11 (2484kgha^{-1}), Sahara-Klean-5 (2714kgha^{-1}), Diamon-2 (3742kgha^{-1}), GH-Hamaliya (2594kgha^{-1}), Rustam-11 (2655kgha^{-1}),The average trait purity for BG-I (Cry1Ac) was 25 to 100%, for BG-II (Cry1Ac and Cry2Ab) none of the variety observed positive and for BG-III (Cry1Ac, Cry2Ab and RR) trait purity was 57 to 100%.

Key word: National coordinated varietal trial, NCVT, biochemical tests, Bt toxin protein.

INTRODUCTION: Cotton is Pakistan's most valuable cash crop and exports of cotton goods account for 55% of the country's overall foreign exchange earnings. Nearly 26% of farmers cultivate cotton, and more than 15% of the overall cultivated area is dedicated to this crop, with two provinces producing primarily. In Punjab, which has dry conditions, about 65% of Pakistan's cotton is grown, and the rest is grown in Sindh, which has a wetter climate, with cotton areas in Khyber Pakhtunkhwa and Balochistan being marginal. Cotton output accounts for 4.5% of the Ag GDP value added and 0.8% of GDP, respectively. It serves as the raw material for the textile industry, hiring 17% of the country's largest agro-industrial market, receiving 60% of foreign exchange and contributing 8.5% to GDP (GOP, 2019, Niamatullah *et al.,* 2019).

Cotton production in Pakistan has been underwhelming, considering its significance. In terms of area under cotton production, the country now ranks 4th, but ranks 39th in cotton output per hectare. In 2019/20, cotton yield in Pakistan is projected to be about 513 kgs per hectare, against 1660 kgs per hectare in Brazil, which ranks fifth in cotton cultivation area (Wajid *et al.,* 2020).

Among the vast number of varieties recommended for cultivation in a specific region, stable cotton varieties with a high yield potential are of paramount importance. In the recent years, the release of high yielding Bt cotton varieties with pre-fixed fiber consistency criteria resistant to heat and leaf curl virus disease has increased momentum to meet the requirements of the farmers, the textile industry and the other stakeholders. In this context, by conducting National Coordinated Varietal Trials (NCVT) on the candidate cotton varieties bred by public and the private sector breeders, the Pakistan Central Cotton Committee (PCCC) plays a pivotal role.

OBJECTIVES: The objective of this experiment was to evaluate the adaptability and stability of seed cotton yield of different cotton cultivars throughout the cotton belt of Pakistan and to recommend the best performed cultivars to higher authority for proper approval and inclusion in seed system of the country.

MATERIALS AND METHODS: In the National Coordinated Varietal Trial NCVT (table 1), a total of 102 candidate strains produced by the various cotton research institutes and private seed sector breeders were grown at fifteen locations throughout Pakistan's cotton belt during 2019-2020. The experiment was carried out during the regular growing season. In a randomized complete block design of three replications, each genotype was planted in a plot of four rows of 5 meters in length and spacing was held 75 cm between rows and 30 cm between plants. Gap filling and thinning was done accordingly to sustain the plant population. All agronomic maintenance was conducted as needed, i.e. weeding, irrigation, inter-cultivation, application of fertilizers, application of pesticides. Picking of the plot was carried out at maturity and yield was determined as kg per hectare by multiplying the yield to the hectare area.

Bt toxin profiling: Quantitative and qualitative profiling of all genotypes were tested for gene expression at following four designated labs.

- National Institutes for Genomics and Biotechnology (NIGAB) NARC Islamabad.
- National Institute for Biotechnology and Genetic Engineering (NIBGE) Faisalabad.
- Center of Excellence and Molecular Biology (CEMB) Lahore.
- Agriculture Biotechnology Research Institute (ABRI) AARI Faisalabad.

Approximately, after eighty days of sowing validation and gene trait purity, PCR and Cry protein (Bt toxin) quantification were performed by sandwich-ELISA in all of the entries. Sample was taken from the fully expended third leaf tissue of each entry.

Table 1: Genotypes tested under Set-A

Code	Strain	Institute	Code	Strain	Institute
PC-1901	Weal-AG-201	Weal-Ag Seeds Corporation, Multan	PC-1913	Diamond-2	Suncrop Seeds Corporation, Multan
PC-1902	Weal-AG-301	Weal-Ag Seeds Corporation, Multan	PC-1914	Suncrop-3	Suncrop Seeds Corporation, Multan
PC-1903	Weal-AG-8	Weal-Ag Seeds Corporation, Multan	PC-1915	CIM-602 (Bt-Std)	Central Cotton Research Institute Sakrand
PC-1904	Weal-AG-7	Weal-Ag Seeds Corporation, Multan	PC-1916	Tahafuz-12(C-II)	Suncrop Seeds Corporation, Multan
PC-1905	Weal-AG-10	Weal-Ag Seeds Corporation, Multan	PC-1917	Suncrop (C-II)	Suncrop Seeds Corporation, Multan
PC-1906	Weal-AG-9	Weal-Ag Seeds Corporation, Multan	PC-1918	Sayban-209	Auriga Seed Corporation Lahore
PC-1907	PC-1907		PC-1919	Saim-102	
PC-1908	PC-1908		PC-1920	Rohi-2	Rohi Seeds Corporation, Rajanpur
PC-1909	PC-1909		PC-1921	Rohi-1	Rohi Seeds Corporation, Rajanpur
PC-1910	Tassco-115	Tassco Seeds Corporation TandoAllahyar	PC-1922	TJ-King (C-II)	RCA Seeds Corporation Khanewal
PC-1911	Tassco-112	Tassco Seeds Corporation TandoAllahyar	PC-1923	PC-1923	
PC-1912	Tahafuz-15	Suncrop Seeds Corporation, Multan	PC-1924	NS-211	Neelum Seeds Corporation, Jahanian

RESULTS AND DISCUSSION: Seed cotton yield: During 2019-20, total 102 cotton cultivars were divided into four sets and tested on fourteen locations all over the country. These cultivars were tested on six locations in Punjab, four locations in Sindh, 3 locations in Baluchistan and 1 in KPK.

Set-A had twenty-four cultivars from PC-1901 to PC-1924 (table 1). In Punjab Set-A was conducted at seven locations (Cotton Research Station Faisalabad, Cotton Research Station Sahiwal, Central Cotton Research Institute Multan, ICI Seeds Multan, Cotton Research Station Vehari, Cotton Research Station Bahawalpur and Cotton Research Station Khanpur) (table 5). Saim-102 (2364 kgha^{-1}) followed by the Tahafuz-12 (C-II) 2283 kgha^{-1} produced highest seed cotton yield and lowest seed cotton yield was obtained from the cultivars PC-1909 (1525 kgha^{-1}) and Tassco-115 (1343 kgha^{-1}) (table 6). In Sindh province set-A was experimented at four locations (Cotton Research Station Ghotki, Central Cotton Research Institute Sakrand, Agriculture Research Institute Tandojam and Cotton Research Station Mirpur Khas) (table 5). Highest average seed cotton yield was obtained from the Tahafuz-12 (2475 kgha^{-1}) followed by the Tahafuz-15 (2383 kgha^{-1}) in contrast lowest yield was harvested from Weal-AG-9 (1640 kgha^{-1}) and Rohi-2 (1569 kgha^{-1}) (table 6). In Balochistan the trial was conducted on three locations (Cotton Research Station Lasbela, Cotton Research Station Sibbi and Agriculture Research Institute Khuzdar) (table 5) and maximum yield was harvested from Diamon-2 (3742 kgha^{-1}) and Saim-102 (3431 kgha^{-1}) and Weal-AG-8 and Sayban-209 produced lowest yield i.e. 2260 kgha^{-1} and 231 kgha^{-1} respectively (table 6). In KPK the trial was conducted at Cotton Research Institute D.I. Khan (table 5) and in KPK Tahafuz-15 and TJ-King are highest yield producing cultivars with average yield 2014 kgha^{-1} and 1982 kgha^{-1} respectively and poor yield was obtained from PC-1907 (978 kgha^{-1}) and Tassco-115 (833 kgha^{-1}) (table 6). Over all in Pakistan, the trial was conducted at 14 locations, and in average seed cotton yield the cultivars Saim-102 and Tahafuz-12 surpassed the other cultivars with average yield 2519kgha^{-1} and 2350 kgha^{-1} respectively and in contrast TJ-King (1843 kgha^{-1}) and PC-1909 (1794 kgha^{-1}) and lowest yield producing cultivars (table 6).

Set-B had twenty-six cultivars starting from PC-1925 to PC-1950 (table 1). In Punjab Set-B was experimented at seven locations, in Sindh on four locations and in Balochistan on three locations and in KPK on single location. In Punjab, the trial was conducted at Cotton Research Station Faisalabad, Cotton Research Station Sahiwal, Central Cotton Research Institute Multan, ICI Seeds Multan, Cotton Research Station Vehari, Cotton Research Station Bahawalpur and Cotton Research Station Khanpur (table 5). Out of twenty-six cultivars, highest yield was taken from Rustam-11 (2484 kgha^{-1}) and followed by the NIAB-SANAB-M (2337 kgha^{-1}) and lowest yield was obtained from the Rustam-Beej-111 and Rustam-Beej-11 (1704kgha^{-1}) (table 7). In Sindh Province, the Set-B (table 2) trial was conducted at four locations i.e. Cotton Research Station Ghotki, Central Cotton Research Institute Sakrand, Agriculture Research Institute Tandojam and Cotton Research Station Mirpur Khas (table 5). The highest yield was marked by the Rustam-11 (2424 kgha^{-1}) and Bahar-136 (2359 kgha^{-1}) and poor seed cotton yield was obtained from Badar-3 (1527kgha^{-1}) and Badar-4 (1493 kgha^{-1}) (table 7). In Balochistan Province Set-B, trial was conducted at Cotton Research Station Lasbela, Cotton Research Station Sibbi and Agriculture Research Institute Khuzdar (table 5). In Balochistan cultivars Rustam-11 and Eye-20 was marked as highest yielding cultivars with the average production 3553 kgha^{-1} and 3310 kgha^{-1} respectively. The lowest producing cultivars were identified as Eagle-4 2321 kgha^{-1} and NIAB-SANAB-M (2320 kgha^{-1}). In KPK province, the trial was experimented at Cotton Research Station D.I. Khan (table 5). Overall yield in KPK was low as compared to the locations. Anyway highest yield was harvested from the cultivar Rustam-11 (2086 kgha^{-1}) followed by the ICI-2424 (1989 kgha^{-1}) and lowest was obtained from the cultivar Rustam-Beej-111 (594 kgha^{-1}) and Badar-3 (558 kgha^{-1}) (table 7). All over the country, the trial was planted at fifteen locations. Highest national average yield was exhibited by the Rustam-11 (2655 kgha^{-1}) followed by the BF-1 (2288 kgha^{-1}) and lowest seed cotton yield was contributed by the Badar-4 (1815 kgha^{-1}) and Rustam-Beej-111 (1760 kgha^{-1}) (table 7).

Set-C (table 3) had twenty-five cultivars from PC-1951 to PC-1975 (table 1). In Punjab Set-C was conducted at seven locations Nuclear Institute for Agriculture and Biology Faisalabad, Cotton Research Station Sahiwal, Central Cotton Research Institute Multan, Four Brother Seeds Multan, Cotton Research Station Vehari, Cotton Research Station Bahawalpur and Cotton Research Station Khanpur) (table 5). NIAB-1011 (2321 kgha^{-1}) followed by the NIAB-135 (2209 kgha^{-1}) produced highest seed cotton yield and lowest seed cotton yield was obtained from the cultivars RH-Kashish (1386 kgha^{-1}) and

NIA-89 (1117 kgha^{-1}) (table 8). In Sindh Province Set-C was experimented at four locations (Cotton Research Station Ghotki, Central Cotton Research Institute Sakrand, Nuclear Institute for Agriculture Tandojam and Cotton Research Station Mirpur Khas) (table 5). Highest average seed cotton yield was obtained from the NIAB-1011 (2564 kgha^{-1}) followed by the GH-Sultan (2536 kgha^{-1}) in contrast lowest yield was harvested from RH-Kashish (1733 kgha^{-1}) and IUB-73 (1676 kgha^{-1}) (table 8). In Balochistan the trial was conducted on three locations (Cotton Research Station Lasbela, Cotton Research Station Sibbi and Agriculture Research Institute Khuzdar) (table 5) and maximum yield was harvested from NIAB-1011 (3453 kgha^{-1}) and GH-Uhad (3399 kgha^{-1}) and FH-492 and FH-155 produced lowest yield i.e. 2224 kgha^{-1} and 2235 kgha^{-1} respectively (table 8). In KPK the trial was conducted at Cotton Research Institute D.I. Khan (table 5) and in KPK GH-Hamaliya and GH-Sultan are highest yield producing cultivars with average yield 2594 kgha^{-1} and 2548 kgha^{-1} respectively and poor yield was obtained from NIAB-135 (1745 kgha^{-1}) and RH-Kashish (1591 kgha^{-1}) (table 8). Over all in Pakistan, the trial was conducted at 14 locations, and in average seed cotton yield the cultivars NIAB-1011 and GH-Uhad surpassed the other cultivars with average yield 2604 kgha^{-1} and 2531 kgha^{-1} respectively and in contrast RH-Kashish (1691 kgha^{-1}) and IUB-73 (1673 kgha^{-1}) and lowest yield producing cultivars (table 8).

Set-D had twenty-seven cultivars starting from PC-1976 to PC-2002 (table 1). In Punjab Set-D (table 4) was experimented at seven locations, in Sindh on four locations and in Balochistan on three locations and in KPK on single location. In Punjab, the trial was conducted at National Institute for Biotechnology and Genetic Engineering Faisalabad (NIBGE), Cotton Research Station Sahiwal, Central Cotton Research Institute Multan, Neelum Seeds Multan, Cotton Research Station Vehari, Cotton Research Station Bahawalpur and Cotton Research Station Khanpur (table 5). Out of twenty-seven cultivars, highest yield was taken from Bt-CIM-775 (2423 kgha^{-1}) and followed by the Sahara-Klean-5 (2165 kgha^{-1}) and lowest yield was obtained from the CIM-602 (1661 kgha^{-1}) and Cyto-124 (1394 kgha^{-1}) (table 9). In Sindh Province, the Set-B trial was conducted at four locations i.e. Cotton Research Station Ghotki, Central Cotton Research Institute Sakrand, Sindh Agriculture University Tandojam and Tassco Seeds Tandojam (table 5). The highest yield was obtained from the Sahara-Klean-5 (2714 kgha^{-1}) and CEMB-Klean-Cotton-4 (2547 kgha^{-1}) and lowest seed cotton yield was obtained from Bt-CIM-303 (1527 kgha^{-1}) and PC-1997 (1100 kgha^{-1}) (table 9). In Balochistan Province Set-B, trial was conducted at three locations *viz.* Cotton Research Station Lasbela, Cotton Research Station Sibbi and Agriculture Research Institute Khuzdar (table 5). In Balochistan cultivars Bt-CIM-775 and Bt-CIM-785 was marked as highest yielding cultivars with the average production 3328 kgha^{-1} and 3291 kgha^{-1} respectively. The lowest producing cultivars was identified as Cyto-226 (2203 kgha^{-1}) and CYTO-124 (2009 kgha^{-1}) (table 9). In KPK province, the trial was experimented at Cotton Research Station D.I. Khan (table 5). Highest yield was harvested from the cultivar Bt-Cyto-533 (2731 kgha^{-1}) followed by the Bt-Cyto 535 (2583 kgha^{-1}) and lowest was obtained from the cultivar CRIS-644 (1851 kgha^{-1}) and CIM-602 (1647 kgha^{-1}) (table 9). All over the country, the trial was planted at fifteen locations. Highest national average yield was exhibited by the Bt-CIM-775 (2655 kgha^{-1}) followed by the Sahara-Klean-5 (2508 kgha^{-1}) and lowest seed cotton yield was contributed by the PC-1997 (1677 kgha^{-1}) and Cyto-124 (1583 kgha^{-1}) (table 9).

Biochemical testing: Biochemical Testing of Bt toxin was performed in designated four biotechnology labs. For BG-I (Cry1Ac) almost all cultivars that was claimed this technology was tested positive through PCR, but their trait purity was different and ranged from 35% to 100%. Most of the cultivars showed above 50% trait purity only Tahafuz 12 (35%), the cultivars those did not claimed any gene technology also showed positive for BG-I tested but their trait purity is less and gene expression is also very low. The Bt toxin protein quantification was carried out through ELISA test. It was observed as high as 4.32 µg/g in RH-Afnan-2 and 4.2 µg/g in Rohi-2 and as low as 0.74µg/g (VH-402), 0.88 µg/g in SLH-33 and 0.96 µg/g in MNH-1035 this might be due to the mixing of germplasm or outcrossing with unknown source in the field. No cultivar was confirmed positive for BG-II (Cry1Ac +Cry2Ab) so the ELISA test was not performed for BG-II. For BG-III technology nine cultivars was reported positive and they had 70% to 100% trait purity. The Centre of Excellence of Molecular Biology (CEMB) also developed their own BG-II and BG-III technology. Nine cultivars claimed CEMB BG-II technology and were reported positive for this technology through PCR, the trait purity was also 100%. Five cultivars i.e. Eagle-3, Bahar-136, ASL-709, NIAB-SANAB-M and VH-383 did not claimed BG-II technology but were also reported positive with high trait purity. Fourteen cultivars claimed CEMB BG-III technology and all were reported positive with high trait purity. The Bt protein toxin level for BG-III technology in these cultivar was in the range of 2.6 to 3.8 µg/g i.e. higher than the commercial standard of toxin recommended by the USDA (table 10, table 11, table 12 and table 13).

Table 2: Genotypes tested under Set-B

Code	Strain	Institute	Code	Strain	Institute
PC-1925	Eye-22	Kanzo Seed Corporation Multan	PC-1938	Ghauri-2(CKC)	Four Brothers Seed Corporation Multan
PC-1926	Eye-111	Kanzo Seed Corporation Multan	PC-1939	Badar-3(C-II)	Four Brothers Seed Corporation Multan
PC-1927	Eye-20	Kanzo Seed Corporation Multan	PC-1940	Badar-4(C-II)	Four Brothers Seed Corporation Multan
PC-1928	Rustam-Beej-111(CKC)	Jullundur Seeds Corporation, Rahim Yar Khan	PC-1941	BF-1	Baba-Fareed Seed Corporation, Vehari
PC-1929	Rustam-Beej-11(C-II)	Jullundur Seeds Corporation, Rahim Yar Khan	PC-1942	PC-1942	
PC-1930	Rustam-11	Jullundur Seeds Corporation, Rahim Yar Khan	PC-1943	PC-1943	
PC-1931	ICI-2424	ICI, Pakistan, Multan	PC-1944	Bahar-136	Bahar Seed Corporation

					Sadiqabad
PC-1932	YBG-2323(CKC)		PC-1945	ASPL-710	
PC-1933	YBG-2222(C-II)		PC-1946	ASPL-709	
PC-1934	Eagle-4	Four Brothers Seed Corporation Multan	PC-1947	IR-NIBGE-15	NIBGE, Faisalabad
PC-1935	CIM-602 (Bt-Std)	Central Cotton Research Institute Sakrand	PC-1948	IR-NIBGE-14	NIBGE, Faisalabad
PC-1936	Eagle-3	Four Brothers Seed Corporation Multan	PC-1949	IR-NIBGE-13	NIBGE, Faisalabad
PC-1937	Hatf-3(CKC)	Four Brothers Seed Corporation Multan	PC-1950	NIAB-SANAB-M	NIAB, Faisalabad

Table 3: Genotypes tested under set-C

Code	Strain	Institute	Code	Strain	Institute
PC-1951	NIAB-512	NIAB, Faisalabad	PC-1964	RH-Afnan-2	Cotton Research Institute, Khanpur
PC-1952	NIAB-973	NIAB, Faisalabad	PC-1965	RH-670	Cotton Research Institute, Khanpur
PC-1953	NIAB-819	NIAB, Faisalabad	PC-1966	GH-Hamaliya	Cotton Research Station Ghotki
PC-1954	NIAB-135	NIAB, Faisalabad	PC-1967	GH-Sultan	Cotton Research Station Ghotki
PC-1955	NIAB-1011	NIAB, Faisalabad	PC-1968	GH-Uhad	Cotton Research Station Ghotki
PC-1956	NIA-89	NIA, Tandojam	PC-1969	FH-Anmol	Cotton Research Station Faisalabad
PC-1957	IUB-73	Islamia University Bahawalpur	PC-1970	FH-492	Cotton Research Station Faisalabad
PC-1958	VH-383	Cotton Research Station Vehari	PC-1971	FH-155	Cotton Research Station Faisalabad
PC-1959	VH-189	Cotton Research Station Vehari	PC-1972	FH-Super-Cotton-2017	Cotton Research Station Faisalabad
PC-1960	CIM-602 (Bt-Std)	Central Cotton Research Institute Multan	PC-1973	FH-AM-Cotton-2017	Cotton Research Station Faisalabad
PC-1961	VH-402	Cotton Research Station Vehari	PC-1974	BH-224	Cotton Research Station Bahawalpur
PC-1962	SLH-33	Cotton Research Station Sahiwal	PC-1975	BH-223	Cotton Research Station Bahawalpur
PC-1963	RH-Kashish	Cotton Research Institute, Khanpur			

Table 4: Genotypes tested under set-D

Code	Strain	Institute	Code	Strain	Institute
PC-1976	MNH-1050	Cotton Research Institute, Multan	PC-1990	Bt-CIM-789	Central Cotton Research Institute Multan
PC-1977	MNH-1035	Cotton Research Institute, Multan	PC-1991	Bt-CIM-678	Central Cotton Research Institute Multan
PC-1978	CEMB-Klean-Cotton-6	CEMB, Lahore	PC-1992	Bt-CIM-303	Central Cotton Research Institute Multan
PC-1979	CEMB-Klean-Cotton-5	CEMB, Lahore	PC-1993	CIM-602 (Bt-Standard)	Central Cotton Research Institute Multan
PC-1980	CEMB-Klean-Cotton-4	CEMB, Lahore	PC-1994	Cyto-124 (Non-Bt Standard)	Central Cotton Research Institute Multan
PC-1981	CEMB-Klean-Cotton-3	CEMB, Lahore	PC-1995	NIAB-929	NIAB, Faisalabad
PC-1982	CRIS-638	Central Cotton Research Institute Sakrand	PC-1996	NIA-88	NIA, Tandojam
PC-1983	CRIS-673	Central Cotton Research Institute Sakrand	PC-1997	PC-1997	
PC-1984	CRIS-671	Central Cotton Research Institute Sakrand	PC-1998	CRIS-644	Central Cotton Research Institute Sakrand
PC-1985	Bt-Cyto-535	Central Cotton Research Institute Multan	PC-1999	Cyto-226	Central Cotton Research Institute Multan
PC-1986	Bt-Cyto-533	Central Cotton Research Institute Multan	PC-2000	Sahara-Klean-5	Patron Seeds Corporation Multan
PC-1987	Bt-CIM-785	Central Cotton Research Institute Multan	PC-2001	Sahara-300	Patron Seeds Corporation Multan
PC-1988	Bt-CIM-775	Central Cotton Research Institute Multan	PC-2002	MZM-7	Agri-Farms Services, Multan
PC-1989	Bt-Cyto-511	Central Cotton Research Institute Multan			

Table 5: Location of NCVT sowing across the different areas of Pakistan

Sr.	Province	Zone	Station	Sets
1	Khyber Pakhtunkhawa	D.I. Khan	Cotton Research Station D.I. Khan	A,B,C,D
2	Punjab	Faisalabad	Cotton Research Station Faisalabad	A,B
			Nuclear Institute for Agriculture and Biology	C
			National Institute for Biotechnology and Genetic Engineering	D
		Sahiwal	Cotton Research Station Sahiwal	A,B,C,D
		Multan	Central Cotton Research Institute Multan	A,B,C,D
			ICI, Multan	A,B
			Four Brothers Seed Corporation Multan	C
			Neelum Seeds	D
		Vehari	Cotton Research Station Vehari	A,B,C,D

		Bahawalpur	Cotton Research Station Bahawalpur	A,B,C,D
		Khanpur	Cotton Research Station Khanpur	A,B,C,D
		Ghotki	Cotton Research Station Ghotki	A,B,C,D
		Sakrand	Central Cotton Research Institute Sakrand	A,B,C,D
3	Sindh	Tandojam	Agriculture Research Institute Tandojam	A,B
			Nuclear Institute for Agriculture Tandojam	C
			Sindh Agriculture University Tandojam	D
			Tassco Seeds Tandojam	D
		Mirpur Khas	Cotton Research Station Mirpur Khas	A,B,C
		Lasbela	Cotton Research Station Lasbela	A,B,C,D
4	Balochistan	Sibbi	Cotton Research Station Sibbi	A,B,C,D
		Khuzdar	Agriculture Research Institute Khuzdar	A,B,C,D

Table 6: Seed cotton yield (kg/ha) of twenty four candidate varieties tested in NCVT Set-A during 2019-20

Code	Strain	Punjab	Sindh	Balochistan	KPK	Average
PC-1901	Weal-AG-201	1914	1688	2896	1172	2001
PC-1902	Weal-AG-301	2197	2186	2894	1630	2296
PC-1903	Weal-AG-8	1821	1726	2260	1553	1866
PC-1904	Weal-AG-7	1959	2005	2274	1275	1989
PC-1905	Weal-AG-10	1876	2045	2856	1411	2086
PC-1906	Weal-AG-9	2013	1640	2542	1537	1988
PC-1907	PC-1907	1838	2028	2596	978	1983
PC-1908	PC-1908	2119	2044	2613	1401	2150
PC-1909	PC-1909	1525	1677	2783	1181	1794
PC-1910	Tassco-115	1344	2140	3132	833	1880
PC-1911	Tassco-112	1996	2188	2937	1498	2202
PC-1912	Tahafuz-15	2148	2383	2559	2014	2284
PC-1913	Diamond-2	2024	1912	3742	1343	2292
PC-1914	Suncrop-3	1696	1936	2528	1701	1927
PC-1915	CIM-602 (Bt-Std)	1706	1954	2707	1582	1964
PC-1916	Tahafuz-12(C-II)	2283	2475	2535	1766	2350
PC-1917	Suncrop (C-II)	1911	1827	2438	1956	1997
PC-1918	Sayban-209	2010	2128	2231	1530	2054
PC-1919	Saim-102	2364	2260	3431	1905	2519
PC-1920	Rohi-2	1721	1569	2760	1808	1894
PC-1921	Rohi-1	1655	1921	2797	2127	1986
PC-1922	TJ-King (C-II)	1553	1687	2683	1982	1843
PC-1923	PC-1923	2124	1866	2502	1934	2118
PC-1924	NS-211	2061	2153	2695	1708	2189
	Average	**1911**	**1977**	**2725**	**1576**	**2069**
	CV	**10.3**	**13.2**	**11.3**	**7**	**-**

Table 7: Seed cotton yield (kg/ha) of twenty four candidate varieties tested in NCVT Set-B during 2019-20

Code	Strain	Punjab	Sindh	Balochistan	KPK	Average
PC-1925	Eye-22	1924	2103	2765	1960	2142
PC-1926	Eye-111	2081	2094	3003	1262	2215
PC-1927	Eye-20	2116	2071	3310	1023	2270
PC-1928	Rustam-Beej-111(CKC)	1704	1537	2575	594	1760
PC-1929	Rustam-Beej-11(C-II)	1704	1686	2600	1343	1854
PC-1930	Rustam-11	2484	2424	3553	2086	2655
PC-1931	ICI-2424	2151	2011	2610	1989	2195
PC-1932	YBG-2323(CKC)	1841	1524	2932	1013	1920
PC-1933	YBG-2222(C-II)	2037	2089	2888	1417	2179
PC-1934	Eagle-4	2059	2147	2321	1340	2087
PC-1935	CIM-602 (Bt-Std)	1826	2228	3105	1046	2137
PC-1936	Eagle-3	1784	1854	2636	1201	1934
PC-1937	Hatf-3(CKC)	1845	1862	2405	1068	1910
PC-1938	Ghauri-2(CKC)	1866	1891	2672	1114	1984
PC-1939	Badar-3(C-II)	1758	1527	2827	558	1830
PC-1940	Badar-4(C-II)	1715	1493	2867	645	1815
PC-1941	BF-1	2030	2241	3197	1556	2288
PC-1942	PC-1942	2083	2039	3228	904	2222
PC-1943	PC-1943	1717	1765	2960	1210	1944
PC-1944	Bahar-136	2031	2359	2398	1081	2129
PC-1945	ASPL-710	2188	2150	2907	649	2219
PC-1946	ASPL-709	2093	1844	2686	781	2058
PC-1947	IR-NIBGE-15	2035	1935	3186	600	2143
PC-1948	IR-NIBGE-14	2156	1954	2547	1181	2116

PC-1949	IR-NIBGE-13	2206	1923	2578	1201	2138
PC-1950	NIAB-SANAB-M	2337	2229	2320	1766	2267
	Average	**1991**	**1961**	**2811**	**1176**	**2093**
	CV	**10.0**	**11.9**	**11.1**	**10.2**	**-**

Table 8: Seed cotton yield (kg/ha) of twenty four candidate varieties tested in NCVT Set-C during 2019-20

Code	Strain	Punjab	Sindh	Balochistan	KPK	Average
PC-1951	NIAB-512	2079	2223	2435	1908	2184
PC-1952	NIAB-973	1496	1864	2481	2102	1856
PC-1953	NIAB-819	1519	2110	2318	2061	1898
PC-1954	NIAB-135	2209	2426	2804	1745	2365
PC-1955	NIAB-1011	2321	2564	3453	1914	2604
PC-1956	NIA-89	1117	2173	2965	2060	1882
PC-1957	IUB-73	1499	1676	1926	1939	1673
PC-1958	VH-383	1777	1972	2794	1934	2062
PC-1959	VH-189	1800	2139	2239	2227	2022
PC-1960	CIM-602 (Bt-Std)	1536	2119	2527	2084	1954
PC-1961	VH-402	1576	1825	2262	2259	1843
PC-1962	SLH-33	1647	1899	2482	1961	1920
PC-1963	RH-Kashish	1386	1733	2281	1591	1691
PC-1964	RH-Afnan-2	1856	2123	2526	1972	2084
PC-1965	RH-670	1701	2441	2912	2103	2201
PC-1966	GH-Hamaliya	2061	2471	3077	2594	2434
PC-1967	GH-Sultan	1964	2536	3081	2548	2408
PC-1968	GH-Uhad	2193	2452	3399	2270	2531
PC-1969	FH-Anmol	1796	2104	2580	2064	2071
PC-1970	FH-492	1831	2057	2224	2043	1995
PC-1971	FH-155	1834	2442	2235	2031	2108
PC-1972	FH-Super-Cotton-2017	1957	2418	3034	2066	2327
PC-1973	FH-AM-Cotton-2017	1771	2071	3152	2078	2175
PC-1974	BH-224	1857	2016	3003	2090	2165
PC-1975	BH-223	1807	2178	2589	2043	2098
	Average	**1784**	**2161**	**2671**	**2067**	**2102**
	CV	**7.3**	**9.5**	**10.1**	**5**	**-**

Table 9: Seed cotton yield (kg/ha) of twenty four candidate varieties tested in NCVT Set-D during 2019-20

Code	Strain	Punjab	Sindh	Balochistan	KPK	Average
PC-1976	MNH-1050	1808	2032	2631	1930	2041
PC-1977	MNH-1035	2034	1660	2867	2115	2106
PC-1978	CEMB-Klean-Cotton-6	2109	2378	2796	2102	2318
PC-1979	CEMB-Klean-Cotton-5	2094	2355	3011	2188	2353
PC-1980	CEMB-Klean-Cotton-4	2078	2547	3001	2268	2400
PC-1981	CEMB-Klean-Cotton-3	2161	2476	2730	2144	2358
PC-1982	CRIS-638	1920	1645	2876	2151	2053
PC-1983	CRIS-673	2091	2136	2571	2148	2203
PC-1984	CRIS-671	1946	2211	2548	2331	2163
PC-1985	Bt-Cyto-535	1961	2072	2952	2583	2230
PC-1986	Bt-Cyto-533	2015	2009	2835	2731	2225
PC-1987	Bt-CIM-785	1830	1748	3291	2573	2150
PC-1988	Bt-CIM-775	2423	2331	3328	2552	2588
PC-1989	Bt-Cyto-511	2070	1840	2843	2335	2181
PC-1990	Bt-CIM-789	1986	2027	3275	2441	2285
PC-1991	Bt-CIM-678	1768	1945	3148	2378	2132
PC-1992	Bt-CIM-303	1791	1513	2789	2419	1958
PC-1993	CIM-602 (Bt-Standard)	1661	1949	2419	1647	1889
PC-1994	Cyto-124 (Non-Bt Std)	1394	1519	2009	1890	1583
PC-1995	NIAB-929	2116	1616	2600	2082	2077
PC-1996	NIA-88	1977	2257	3248	1908	2301
PC-1997	PC-1997	1700	1100	2256	2090	1677
PC-1998	CRIS-644	1746	2198	2802	1851	2085
PC-1999	Cyto-226	1786	1679	2203	2425	1883
PC-2000	Sahara-Klean-5	2165	2714	3170	2102	2508
PC-2001	Sahara-300	2068	2370	2874	2008	2306
PC-2002	MZM-7	1952	1734	2767	1971	2058
	Average	**1950**	**2002**	**2809**	**2199**	**2152**
	CV	**7.5**	**7.1**	**9**	**5**	**-**

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Evaluation of high yielding candidate cotton genotypes tested in National Coordinated Varietal Trial at different locations of Sindh and Balochistan

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ABSTRACT

The research was conducted during the two consecutive years 2018 and 2019; twenty eight (28) advance cotton strains were tested in national coordinated varietal trials (NCVT) at seven locations of Sindh and Balochistan. The results revealed highly significant difference among the varieties during both the years. On the basis of two years average performance only two candidate strains GH-Uhad and NIAB-135 showed their stability in yield performance during both the years. Therefore, it is recommended that top two high yielding varieties (*GH-Uhad and NIAB-135*) with stability in performance must be approved by the provincial seed council of Sindh and Balochistan to revive the cotton production of the provinces as well as national economy and not to waste/garbage this high yielding stuff and also suggested to cotton breeders utilization in hybridization/breeding program to evolve high yield variety.

Key word: Seed cotton yield, advance strains, locations, environmental.

INTRODUCTION Cotton (*Gossypium hirsutum* L.) is an important cash crop and plays a key role as compared to all other crops (Ahmad *et al.*, 2007). Pakistan is 4th largest cotton producer in the world after China, USA and India (GOP, 2018). Cotton is a major crop of Pakistan after wheat; it occupies the largest area in Pakistan compared to other crops. It earns the country's largest export revenues. In addition to the lint, the seed of cotton for oil and meal accounts for 80 percent of the national production of oilseed. Cotton and cotton related products contribute 10% to gross domestic product (GDP) and 55% to the foreign exchange earnings of the country. Koutu and Shastry (2004) reported that cotton is judged by genotypes to its interaction with environment for yield and quality performance. Singh *et al.* (2002) reported that evaluation and development of high yielding crop varieties are major aim of agricultural scientists to fulfil crop requirements to become self-sufficient.

In Pakistan, cotton was cultivated on an area of 2700 thousand hectares (approx. 6672 thousand acres) during the year 2017-18 with the production of 11.95 million bales, whereas, the lint yield in Pakistan for the same year was 752 kg/ha (approx. 305 kg acre). In Punjab, almost 100% Bt cotton with Mon53 event and Cry1Ac gene was sown on an area of 2053 thousand hectares (approx. 5073 thousand acres) which produced 8.78 million bales with lint yield of 669 kg/ha during the year 2017-18 (GOP, 2018). Five year's (2013-14 to 2017-18) data regarding cotton area, production and lint yield for Pakistan, Punjab and Sindh are depicted in Table-1. Most of components of economic characters are indicative of the yield potential or the integrated cotton quality and are under the control of genes of various magnitudes and influences of the environments. Stable cotton varieties with high yield potential are of paramount importance among the large number of varieties recommended for cultivation for a particular zone (Kairon *et al.*, 2000; Koutu and Shastry, 2004).

In the recent years, the release of high yielding, heat and leaf curl virus disease resistant Bt cotton varieties with pre-fixed fiber quality standards by the government of Punjab has accelerated momentum to fulfil the requirements of growers, textile industry and other stake holders. In this context, Pakistan Central Cotton Committee (PCCC) is playing pivotal role by conducting the National Coordinated Varietal Trials (NCVT) on the candidate cotton varieties bred by public and private sector breeders. The two years NCVT is mandatory for variety approval process. Every year, NCVT is conducted at almost 17 locations of the Pakistan to test their adaptability and yield potential. If a variety excels the standard varieties in yield for consecutive two years in NCVT, that variety is forwarded in the Expert Sub Committee of the headed by Director General Agriculture Research Sindh (in case of Sindh province) for further process. The variety which qualifies the pre-fixed fiber properties standards is then recommended to Sindh Seed Council for approval and commercial cultivation in the Sindh. Distinctiveness, Uniformity and Stability (DUS) studies are also conducted by the Federal Seed Certification and Registration Department (FSC&RD) for two years of the candidate varieties simultaneously which are included in NCVT. These trials/studies (NCVT, Spot examination and DUS) are mandatory for a variety to complete the variety approval process. Considering the above approval process for cotton varieties, the two years (2017 and 2018) data were extracted from the NCVT results distributed by Director Research, PCCC for evaluation of yield and fiber properties of candidate varieties and to see which varieties could qualify and fit in the variety approval process done by the Sindh Seed Council.

OBJECTIVES: The objective of this research to select best suitable high yielding genotypes according to stability in both the provinces. The idea of study to identify an outstanding candidate strain to hold a place for commercial variety in future to boost up cotton production and national economy.

MATERIALS AND METHODS: The study was carried out to screen out the most appropriate high yielding varieties at seven locations of Sindh and Balochistan provinces.

Every year Pakistan Central Cotton Committee (PCCC) conducts National Coordinated Varietal Trials throughout Pakistan with the objectives to test the yield performance and adaptability of cotton candidate varieties developed by public and private sector cotton breeders. The 28 candidates Bt cotton strains from public and private sectors duly coded by the Director Research PCCC were tested at research centers in Sindh (CCRI, Sakrand; CRS Ghotki, CRS Mirpurkhas, and ARI Tandojam) and three centers at Balochistan (CRS Sibi, CRS Lasbela@Uthal and ARI-Khuzdar) against one standard/check variety CIM-602 during the years 2018-19 and 2019-20. The coded varieties seed provided by the Director Research, PCCC was sown on bed and furrow at all the seven locations. The plot size however, varied location-wise with the choice of the scientists or availability of land at the station who was deputed for conducting NCVT by the station in-charge. The trials were arranged in randomized complete block design with three replications at each location.

The experiment was conducted with randomized complete block design with three replications. The plot size was maintained 30'x10. The seed was planted on ridges with plant to plant and row to row distance was maintained at 30 cm and 75 cm respectively. The agronomic practices viz. weedicide, irrigation, thinning and inter-culturing were done uniform accordingly in all the replications. The fertilizer and plant protection measures were applied as per need whenever required. The 5 plants were tagged from each replication to record the data. The data were statistically analyzed after Gomez and Gomez (1984) calculating C.V. % and CD values at 5 % and 1% probability levels to differentiate the varieties included in the trials. Each year after compilation of data, the yield results were sent back to Director Research PCCC with same variety codes. On the basis of yield and fiber properties results, the better performing varieties could then be released as commercial variety for the general cultivation in the province of Sindh and Balochistan.

RESULTS AND DISCUSSION: Twenty eight candidate cotton varieties were tested during two consecutively years 2018 and 2019 at seven locations of Sindh and Balochistan Provinces in national coordinated varietal trials (NCVT). The research was conducted to evaluate cotton candidate varieties against commercial standard/check variety CIM-602 for seed cotton yield and environmental adaptability. The samples of these varieties were sent to four biotechnological laboratories for biochemical tests also. Table 1 shows the sources of the 28 + 1 standards cotton candidate varieties sown for two years in the Sindh and Balochistan during 2018 and 2019, cotton seasons at public sector research institutions. Table-1 indicated the cotton area, production and yield of Pakistan, Punjab and Sindh for last five years (2013-14 to 2017-18) which serves as ready reference for the readers to judge the ups and downs in cotton crop in last half decade. Table 2 demonstrates the yield performance and also results of statistical analysis (CD at 1 and 5% level of probability including CV%) of the candidate varieties during 2017, whereas, table 3 revealed the yield and statistical analysis results for 2018 cotton season against the two check varieties. The two years average yield performance of candidate varieties was calculated and is presented in table 4.

Table 1: Cotton area of Pakistan, Punjab and Sindh with Production and Yield for last five years (2013-14 to 2017-18).

Year-Wise	2013-14	2014-15	2015-16	2016-17	2017-18
PAKISTAN					
Area (000 hectares)	2805.65	2958.30	2901.98	2488.97	2700.27
Production (000 million bales)	12768.88	13959.58	9917.41	10671.00	11945.60
Yield (kg/ha)	774	802	581	729	752
PUNJAB					
Area (000 hectares)	2199.02	2322.85	2242.72	1815.34	2052.93
Production (000 million bales)	9145.00	10277.00	6343.00	6978.00	8077.00
Yield (kg/ha)	707	752	481	653	669
SINDH					
Area (000 hectares)	567.98	596.21	621.25	636.65	611.68
Production (000 million bales)	3523.42	3572.54	3475.60	3596.88	3775.76
Yield (kg/ha)	1055	1019	951	960	1049

Source: Cotistics August 2018 Bulletin published by Pakistan Central Cotton Committee, Multan.

The mean performance of varieties during first year 2018 (table-2) revealed highly significant seed cotton yield differences among the genotypes, on an average of all locations, top ten varieties were found CIM-878, Rohi-1, VH-383, VH-189, FH-AM cotton 2017, CRIS-671, NIAB-135, VH-402, GH-Uhad and Cyto-511 which produced maximum seed cotton yield (kg ha^{-1}) with 3213, 3149, 3139, 3078, 3075, 3042, 3007, 2912, and 2908 respectively, as compared with remaining cotton candidate varieties as well as standard check CIM-602. Similar findings also reported by Khan *et al.* (2007) and Khan *et al.* (2008) who evaluated advance cotton genotypes in multiple environment and reported high yielding strains comparison with standard varieties. Sial et al. (2014) check yield performance of cotton genotypes and reported high yielding cotton varieties for commercial cultivation. Regarding the second year experiment results during 2019 (table 3) was surprised that the varieties which performed better during first year, that could not show their superiority in second year, because of their adoptability or due to influence of environmental conditions. On an average of second year top ten high yield varieties were; NIAB-1011, Rustam-11, GH-Uhad, FH-Super Cotton 2017, RH-670, NIAB-135, CIM-789, FH-AM Cotton 2017, Tassco-112, Tahafuz-12 (C-II) which given higher seed cotton yield 2945, 2908, 2857, 2682, 2643, 2588, 2562, 2534, 2509 and 2501 as compared with other candidate strains and also from standard check variety CIM-602. The present findings are according with Yasin *et al.* (2019) who also documented high yield cotton variety comparison with standard check. Ehsan *et al.* (2008) evaluated advance strains and reported high yield cotton genotype on the basis of yield performance. Jatt *et al.* (2007) assessed performance of cotton genotypes and high yield varieties recommended for commercial cultivation.

Table 2: Seed cotton yield (kg/ha) of 28 cotton candidate varieties tested in NCVT at 7 Locations of Sindh and Balochistan during 2018-19.

S. No.	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	Tassco-112	1735	1148	4305	1688	3231	3231	2616	2565
2	Tahafuz-12 (C-II)	1221	3157	4091	1256	3349	2512	2768	2622
3	Rohi-1	2561	2440	4487	1841	4069	4308	2335	3149
4	TJ-King (C-II)	2764	2296	2747	2045	4305	2272	2398	2690
5	Eye-111	2393	2153	3479	1857	4428	3710	2234	2893
6	Eye-20	1651	2870	2252	1194	3829	4069	2647	2645
7	Rustam-11	1998	1435	4984	1674	3710	3590	2762	2879
8	ICI-2424	1364	2009	3612	1930	3590	2872	2920	2614
9	IR-NIBGE-13	2142	2009	4684	2191	3590	2513	3069	2885
10	NIAB-135	2668	3157	3090	1978	3949	3710	2494	3007
11	NIAB-1011	2489	2296	3253	2547	3351	3111	2485	2790
12	VH-383	3434	2296	3999	1632	3947	3707	2956	3139
13	VH-189	3135	2727	3668	1632	4066	3349	2967	3078
14	VH-402	2513	2153	4319	1936	3949	3231	2286	2912
15	SLH-33	1149	2440	2601	984	3829	2633	2241	2268
16	RH-670	2202	2296	3935	1698	3710	2872	2496	2744
17	GH-Uhad	2513	2153	4319	1936	3949	3231	2286	2912
18	FH-155	1424	1579	3287	3181	3710	3710	2992	2840
19	FH-Super Cotton 2017	1675	2440	3749	1478	3590	3590	2756	2754
20	FH-AM Cotton 2017	1448	1866	4823	1940	4188	4308	2949	3075
21	BH-223	2226	2440	3577	1588	4069	3351	2817	2867
22	MNH-1035	1675	2009	2275	1633	4069	4069	2694	2632
23	CRIS-671	2645	3588	3346	1534	3949	3590	2641	3042
24	CRIS-673	2860	3014	1817	1659	3231	3231	2758	2653
25	Cyto-511	2262	2440	3482	1731	3949	3829	2664	2908
26	CIM-789	1603	1435	3986	1507	2633	3949	2671	2541
27	CIM-878	2142	4449	3763	1426	3949	3949	2812	3213
28	CIM-303	694	2009	3845	1211	3949	4069	2917	2671
29	CIM-602 (Std.)	2615	2368	3111	2110	3619	3141	2753	2817
	CD 5%	163.4**	197.8**	235.4**	186.3**	276.8**	410.2**	180.7**	---
	CD 1%	218.1**	295.3**	364.8**	278.8**	405.3**	513.6**	214.5**	---
	CV%	6.2	11.8	13.5	10.9	16.5	12.2	9.5	---

Table 3: Seed cotton yield (kg/ha) of 28 cotton candidate varieties tested in NCVT at 7 Locations of Sindh and Balochistan during 2019-20.

S. No.	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	Tassco-112	2114	2690	1630	2316	3395	3306	2110	2509
2	Tahafuz-12 (C-II)	2560	2942	2431	1965	2858	2738	2010	2501
3	Rohi-1	1925	2601	1467	1691	2961	2896	2535	2297
4	TJ-King (C-II)	1925	2601	1467	1691	2961	2896	2535	2297
5	Eye-111	1947	2661	1938	1831	2832	2792	3386	2484
6	Eye-20	1828	2661	1938	1831	2832	2792	3386	2467
7	Rustam-11	2847	2690	2301	1857	3745	3708	3206	2908
8	ICI-2424	2119	2691	1698	1536	2808	2732	2289	2268
9	IR-NIBGE-13	1960	2571	1485	1674	2571	2523	2641	2204
10	NIAB-135	2561	2930	1568	2646	2791	2565	3057	2588
11	NIAB-1011	3158	2810	2153	2134	3772	3713	2874	2945
12	VH-383	1851	2332	1677	2027	2675	2590	3117	2324
13	VH-189	1735	2571	1776	2475	1963	1901	2854	2182
14	VH-402	1572	2452	1113	2161	2353	2314	2119	2012
15	SLH-33	1850	2391	1155	2200	2478	2397	2572	2149
16	RH-670	2113	2212	1746	3693	3185	3115	2435	2643
17	GH-Uhad	2726	2690	2078	2312	4070	4037	2089	2857
18	FH-155	2607	2870	2139	2153	3220	2284	2102	2482
19	FH-Super Cotton 2017	2835	2451	1952	2432	3541	3522	2039	2682
20	FH-AM cotton 2017	1527	2332	1888	2536	3336	3306	2813	2534
21	BH-223	1915	2810	1458	2529	2433	2368	2967	2354
22	MNH-1035	2433	1401	1631	1176	2822	2816	2962	2177

23	CRIS-671	1945	2052	2395	2453	2929	2768	1948	2356
24	CRIS-673	2318	2429	1847	1948	2852	2804	2057	2322
25	Cyto-511	2232	2054	1692	1380	2815	2595	3119	2270
26	CIM-789	2151	1918	1889	2149	3476	3486	2863	2562
27	CIM-878	2672	2060	1730	1319	3745	3767	1931	2461
28	CIM-303	1200	1630	1800	1420	3334	3300	1734	2060
29	CIM-602 (Std.)	2248	2581	1295	2124	2918	2839	2312	2331
	CD 5%	136.8**	271.2**	223.7**	169.5**	202.4**	184.7**	227.1**	---
	CD 1%	201.4**	353.3**	403.6**	242.8**	381.3**	318.9**	436.8**	---
	CV%	8.4	14.5	12.8	11.2	15.8	12.4	11.5	---

Table 4: Two year's average performance (seed cotton yield kg/ha) of 28 candidate varieties tested in NCVT at 7 locations of Sindh and Balochistan during 2018-19 and 2019-20 Cotton Seasons.

Sr. No.	Genotypes	Sindh				Balochistan			Average
		Sakrand	Mirpur Khas	Ghotki	Tandojam	Khuzdar	Lasbela	Sibi	
1	Tassco-112	1925	1919	2968	2002	3313	3269	2363	2537
2	Tahafuz-12 (C-II)	1891	3050	3261	1611	3104	2625	2389	2561
3	Rohi-1	2243	2521	2977	1766	3515	3602	2435	2723
4	TJ-King (C-II)	2345	2449	2107	1868	3633	2584	2467	2493
5	Eye-111	2170	2407	2709	1844	3630	3251	2810	2689
6	Eye-20	1740	2766	2095	1513	3331	3431	3017	2556
7	Rustam-11	2423	2063	3643	1766	3728	3649	2984	2893
8	ICI-2424	1742	2350	2655	1733	3199	2802	2605	2441
9	IR-NIBGE-13	2051	2290	3085	1933	3081	2518	2855	2545
10	NIAB-135	2615	3044	2329	2312	3370	3138	2776	2797
11	NIAB-1011	2824	2553	2703	2341	3562	3412	2680	2868
12	VH-383	2643	2314	2838	1830	3311	3149	3037	2731
13	VH-189	2435	2649	2722	2054	3015	2625	2911	2630
14	VH-402	2043	2303	2716	2049	3151	2773	2203	2462
15	SLH-33	1500	2416	1878	1592	3154	2515	2407	2209
16	RH-670	2158	2254	2841	2696	3448	2994	2466	2693
17	GH-Uhad	2620	2422	3199	2124	4010	3634	2188	2885
18	FH-155	2016	2225	2713	2667	3465	2997	2547	2661
19	FH-Super Cotton 2017	2255	2446	2851	1955	3566	3556	2398	2718
20	FH-AM Cotton 2017	1488	2099	3356	2238	3762	3807	2881	2804
21	BH-223	2071	2625	2518	2059	3251	2860	2892	2611
22	MNH-1035	2054	1705	1953	1405	3446	3443	2828	2405
23	CRIS-671	2295	2820	2871	1994	3439	3179	2295	2699
24	CRIS-673	2589	2722	1832	1804	3042	3018	2408	2488
25	Cyto-511	2247	2247	2587	1556	3382	3212	2892	2589
26	CIM-789	1877	1677	2938	1828	3055	3718	2767	2551
27	CIM-878	2407	3255	2747	1373	3847	3858	2372	2837
28	CIM-303	947	1820	2823	1316	3642	3685	2326	2365
29	CIM-602 (Std.)	2432	2475	2203	2117	3269	2990	2533	2574

However, when the results of 2018 and 2019 (both seasons) mean performance were summed up, then top ten high yielding varieties were found Rustam-11, GH-Uhad, NIAB-1011, CIM-878, FH-AM cotton 2017, NIAB-135, VH-383, Rohi-1, FH-Super Cotton and CRIS-671 which produced maximum seed cotton yield (kg ha^{-1}) 2893, 2885, 2868, 2837, 2804, 2797, 2731, 2723, 2718 and 2699 as compared with other candidate strains and standard check variety CIM-602 (table 4). It is interesting to recorded that among top ten high yielding varieties, only two varieties (GH-Uhad and NIAB-135) were found stable during the both years and yield performance due to the fact that these varieties keep their superiority in individual year (2018 and 2019) and also when the average performance was looked at. Other varieties shown their stability in a particular single year but were included in top 10 varieties when the yield results were averaged. Seeing the yield results, it is suggested that the top two high yielding varieties (GH-Uhad and NIAB-135) with stability in performance must be approved by the provincial seed council of Sindh and Balochistan to revive the cotton production of the provinces and not to waste/garbage this high yielding stuff. The results are in line with Shah *et al.* (2015) who evaluated candidate strains in national coordinated varietal trial in Sindh province with recommendation of high yield strains for commercial cultivation. Koutu and Shastry (2004) reported that performance of variety can be judged by the genotypes and its interaction with various environments for yield performance. Kairon *et al.* (2000) stated that stable cotton genotypes with high yielding potential are of paramount important among the large number of varieties recommended for cultivation for particular zone.

CONCLUSION: During the two consecutive years 2018 and 2019, twenty eight (28) advance cotton strains were tested in national coordinated varietal trials (NCVT) at seven locations of Sindh and Balochistan. On the basis of two years average performance only two candidate strains GH-Uhad and NIAB-135 shown their stability in yield performance during both the years. Therefore, it is recommended that top two high yielding varieties (*GH-Uhad and NIAB-135*) with stability in performance must be approved by the provincial seed council of Sindh and Balochistan to revive the cotton production of the provinces and not to waste/garbage this high yielding stuff.

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Yield and some agronomic parameters of upland cotton as affected by planting dates

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ABSTRACT

A field experiment was conducted at ICI Research Farm, Multan to evaluate the effect of different sowing dates on plant height, number of monopodia, number of sympodia, number of bolls per plant, boll weight, seed cotton yield kg/ha of two upland cotton varieties (ICI-2121 and ICI-2424) developed by ICI Pakistan Limited, Multan against a standard check variety IUB-2013 during 2019, and 2020 years. These varieties were planted on 1st April, 15th April, 1st May, 15th May, 1st June, and 15th June, at ICI Cotton Research Station, 19-Kasi Vehari Road, Multan. Results revealed that statistically highly significant differences in planting dates were observed for all the parameters studied except number of monopodial branches and boll weight which depicted non-significant differences. Regarding varieties and interaction between varieties and planting times, similar trend of statistical differences was observed. As regards to planting dates, generally, all the parameters under study showed their maximum performance when crop was planted on 1st May followed by 1st April planting date, whereas, minimum performance of the parameters was recorded when the crop was planted on 15th June followed by 1st June. Regarding varietal performance, on an average, maximum plant height (146cm) was observed in ICI-2121 followed by IUB-2013. Same trend of performance of varieties regarding number of monopodia and sympodia per plant was observed. Regarding average number of bolls per plant in different varieties, it was observed that ICI-2121 produced maximum (32 bolls) followed by ICI-2424 (31 bolls) and IUB-2013 (28 bolls) irrespective of planting dates. The same trend of varietal performance regarding boll weight was recorded. When seed cotton yield (kg/ha) was evaluated, on an average of varieties, ICI-2121 produced maximum seed cotton yield (1228 kg/ha) followed by ICI-2424 and IUB-2013 which produced 1147 and 1046 kg/ha seed cotton yield respectively irrespective of planting dates. It was concluded that under agro-climatic conditions of Multan, 1st May planting date was evaluated as optimum cotton sowing time. Before or after 1st May, this study does not recommend growing cotton in this particular zone. Among cotton varieties, ICI-2121 is recommended for sowing under this planting time being producing higher yields.

Key word: Cotton (*Gossypium hirsutum*) varieties, sowing dates, yield.

INTRODUCTION: Time of cotton planting definitely affects seed cotton yield as per studies conducted by the researchers around the globe. Among other factors which affect seed cotton yield could be the varieties, seed rate, plant geometry, maturity, temperature, water management, water logging, salinity and insect's pests etc. Sowing time plays an important role in obtaining maximum seed cotton yield in country like Pakistan where the climate conditions varied from province to province and within province. Yield of seed cotton can sufficiently be increased if cotton grower knows the optimum time for sowing in particular zone. Yield potential of any variety can only be realized if it is sown at its ideal time. Agronomic traits like plant height, number of monopodia, number of sympodia, number of bolls per plant, and boll weight may also come under effect of planting dates. Plant height primarily depends on planting date (Munk, 2001). Many researchers were of the view that early sown cotton produces taller plants. However, Nuti *et al.* (2006) concluded that plants grow faster and taller in late planting compared with early or normal planted cotton. The number of monopodia and sympodia is dependent on genotype and environmental fluctuations. Butter *et al.* (2004) observed that early sowing gave higher number of monopodial and sympodial branches per plant. Dong *et al.* (2006) also obtained higher number of sympodial branches per plant in early sown cotton crop. Number of bolls per plant or per unit area is one of the most important yield components of cotton. Previous researchers observed that higher number of bolls per plant was acquired through early sown cotton (Dong *et al.*, 2006) because plants produced fewer flower with delayed planting. On the contrary, Dong *et al.* (2006) recorded a greater number of bolls per unit area in late planting than normal planting.

When planting time of cotton was delayed, the boll weight recorded was less because seeds per boll decreased with delayed sowing while. However, Dong *et al.* (2006) found non-significant effect on boll weight by sowing date. Soomro *et al.* (2000) observed that cotton sown earlier or later than its optimum time showed a rapid yield decline. Gormus and Yucel (2002) revealed that early planting date gave 11.2% higher lint yield than late planting date. Iqbal *et al.* (2011) observed higher cotton yield with early planting in 3rd week of May compared to 2nd week of June. On the other hand, late planting results in delayed flowering that pushes boll development into cooler weather resulting in reduced yield (Akhtar *et al.*, 2002). Late planted cotton is usually associated with shorter fruiting period and delayed maturity that leads to reduced yield and impaired fiber quality. Soomro *et al.* (2000) found that even a delay of one week from optimum time resulted in marked decline in yield. Similarly, significant reduction in number of bolls per plant and boll weight was recorded in late planting.

Soomro *et al.* (2000) observed that 15th May sown crop gave increased number of bolls per plant, boll weight and seed cotton yield per hectare, they further observed a remarkable decline in the yield of late sown crop. Arain *et al.* (2001) reported that early sown cotton (15th April to 15th May) gave significantly higher plant height, number of sympodial branches, number of bolls and seed cotton yield per hectare. Akhtar *et al.* (2002) reported the results of six cotton varieties under four sowing dates from 1st May to 15th June and opined that regardless of varieties, the best results were obtained when crop was planted on 16th May under Bahawalpur conditions. Muhammad *et al.* (2002) concluded that cotton sowing in the beginning of May gave significantly higher seed cotton yield than all other sowing dates. They further stated that 1st May sown crop's yield was 15% more than 1st June. On overall bases of all varieties, yield was reduced to 24% and 45% in 15th and 30th June respectively as compared to 1st May sowing dates. Early sowing of cotton gave better yield than late sown crop. Soomro *et al.* (2004) conducted studies on three cotton strains TH-4/90, TH-199/90 and TH-204/90 under four sowing dates (10th April, 25th April, 10th May to 25th May). The optimum sowing time for these strains was 25th April. The yields were decreased 14.25%, 38.27 % and 70.82% when crop was delayed or sown earlier irrespective of varieties.

OBJECTIVES: Keeping in view the findings from different researchers regarding sowing dates, the present study was undertaken to judge the optimum sowing time of two upland cotton varieties (ICI-2121 and ICI-2424) against a standard check variety (IUB-2013) under the climatic conditions of Multan.

MATERIALS AND METHODS: The experiment was conducted at ICI Research Station near 19-Kasi, Multan during 2019-20, and 2020-21 cotton seasons. Two cotton varieties ICI-2121 and ICI-2424 were tested in six planting dates (1st April, 15th April, 1st May, 15th May, 1st June and 15th June). The experiment was carried out in split plot design replicated three times on a plot size of 25m². The sowing dates were arranged in main plots and the varieties in sub-plots. All other cultural practices and plant protection measures were carried out as per recommendations and production technology of these varieties as mentioned by the breeders. Varieties and planting dates were evaluated for their agronomic traits like plant height, number of monopodia and sympodia, boll weight, number of bolls per plant and seed cotton yield. The observations recorded on plant height, monopodia and sympodia, boll weight and number of bolls per plant as the average of 10 indexed plants, whereas, seed cotton yield was recorded on net plot basis and then calculated on per hectare basis. Statistical analysis was performed after Gomez and Gomez (1984) to perceive the differences among varieties and planting times.

RESULTS AND DISCUSSION: Seed cotton yield and some agronomic parameters (plant height, number of monopodia and sympodia, boll weight, number of bolls per plant) of three cotton varieties under different planting dates (1st April, 15th April, 1st May, 15th May, 1st June and 15th June) in agro-climatic conditions of Multan were evaluated during 2019-2020 and 2020-2021 cotton seasons. Average performance of two years and statistical results in the form of CD 5% for each parameter are depicted in table 1. Each agronomic trait is discussed under separate heading hereunder

Plant height (cm): There existed significant differences in planting dates, varieties and their interaction. Maximum plant height (154cm) was recorded in the 1st April sowing date followed by 15th April (149cm) and 1st May (141cm). Minimum plant height of 104cm was displayed by 15th June sowing time followed by 1st June (120cm). This may be due to the fact that plants remained for longer period in the field and took maximum nutrition present in the soil. Among varieties, ICI-2121 produced 146cm tall plants followed by IUB-2013 and ICI-2424 which produced 130cm and 125cm tall plants respectively. These results are in accordance with the results reported by Arain *et al.* (2001) and Gormus and Yucel (2002) opined that early sown cotton produces taller plants. However, present findings are contradictory to the findings of Nuti *et al.* (2006) who concluded that plants grow faster and taller in late planting compared with early or normal planted cotton.

Number of monopodial branches per plant: The number of monopodia is dependent on genotype and environmental fluctuations. Non-significant differences were observed in planting dates, varieties and their interaction. Maximum monopodia (2.83) were recorded in the 1st April sowing date followed by 15th April (2.39) and 1st May (2.36). Minimum number of monopodial branches (1.71) was produced when crop was sown on 15th June followed by 1st June (2.01). Among varieties, ICI-2121 produced maximum monopodia (2.72) followed by IUB-2013 and ICI-2424 which produced 2.04 and 2.01 number of monopodial branches respectively. The present results are in conformity with the results of Arain *et al.* (2001) Munk (2001) and Butter *et al.* (2004) who observed that early sowing of cotton produced higher number of monopodial branches per plant as compared to late sown crop.

Number of sympodial branches per plant: Sympodial branches are also dependent on genotype and environmental interactions. Highly significant differences were observed in planting dates, varieties and their interaction. Maximum sympodia (27.08) were recorded in the 1st April sowing date followed by 15th April (26.14) and 1st May (24.80). Minimum number of sympodia (18.19) was produced when crop was sown on 15th June followed by 1st June (21.11). ICI-2121 produced maximum sympodia (25.53) followed by IUB-2013 and ICI-2424 producing 22.75 and 21.93 number of sympodial branches respectively. The results of present study support the results of Arain *et al.* (2001), Munk (2001) and Butter *et al.* (2004) who observed that early sowing produced higher number of sympodial branches per plant as compared to late sown crop. Gormus and Yucel (2002) and Dong *et al.* (2006) also obtained higher number of sympodial branches in early sown cotton crop.

Boll weight (gm): Non-significant differences were observed for boll weight in sowing times, varieties and their interactions. Maximum boll weight (3.4gm) was recorded in the 1st April sowing date followed by 1st and 15th May (3.2gm). Minimum boll weight was observed in 15th June sowing (3.0gm) followed by 15th April and 1st June (3.1gm). As regards to varieties, ICI-2121 produced heavier bolls of 3.32gm followed by ICI-2424 (3.15gm) and IUB-2013 with 3.03gm boll weight. The results of present study are in line with the results obtained by Pettigrew (2002) who were of the view that when planting time of cotton was delayed, the boll weight recorded was less because seeds per boll decreased with delayed sowing. However, Dong *et al.*

(2006)found non- significant effect on boll weight by sowing date.

Table 1: Performance of seed cotton yield and some agronomic parameters of three cotton varieties under different planting times in agro-climatic conditions of Multan (average of 2019 and 2020 cotton seasons).

Planting Dates	ICI-2121	ICI-2424	IUB-2013	Average of planting dates
Average Plant Height (cm)				
1st April	165	147	151	154
15th April	161	141	145	149
1st May	157	130	137	141
15th May	145	121	129	132
1st June	133	113	115	120
15th June	112	98	101	104
Average of varieties	146	125	130	-
Average Number of Monopodia per Plant				
1st April	3.57	2.55	2.37	2.83
15th April	2.91	2.12	2.13	2.39
1st May	2.82	2.05	2.22	2.36
15th May	2.77	1.97	1.97	2.24
1st June	2.33	1.85	1.85	2.01
15th June	1.91	1.54	1.67	1.71
Average of varieties	2.72	2.01	2.04	-
Average Number of Sympodia per Plant				
1st April	28.95	25.79	26.49	27.08
15th April	28.25	24.74	25.44	26.14
1st May	27.54	22.81	24.04	24.80
15th May	25.44	21.23	22.63	23.10
1st June	23.33	19.82	20.18	21.11
15th June	19.65	17.19	17.72	18.19
Average of varieties	25.53	21.93	22.75	-
Average boll weight (g)				
1st April	3.5	3.3	3.4	3.4
15th April	3.2	3.1	2.9	3.1
1st May	3.3	3.2	3.0	3.2
15th May	3.5	3.2	3.0	3.2
1st June	3.2	3.1	3.1	3.1
15th June	3.2	3.0	2.8	3.0
Average of varieties	3.32	3.15	3.03	-
Average number of bolls per plant				
1st April	33	31	29	31
15th April	32	29	28	30
1st May	45	41	35	40
15th May	34	39	31	35
1st June	27	27	25	26
15th June	23	21	21	22
Average of Varieties	32	31	28	-
Average seed cotton yield (Kg/ha)				
1st April	1387	1277	1198	1287
15th April	1371	1255	1181	1269
1st May	1497	1381	1254	1377
15th May	1222	1178	1095	1165
1st June	1115	1055	967	1046
15th June	773	735	688	732
Average of Varieties	1228	1147	1064	-

C.D @5%

	Plant height	Monopodia	Sympodia	Boll weight	Number of bolls/plant	Seed cotton yield
Planting Time (PT)	9.11	Ns	4.12	Ns	3.17	196.15
Variety (V)	6.3	Ns	5.74	Ns	3.21	113.24
PT x V	18.1	Ns	7.23	Ns	4.54	215.71

Number of bolls per plant: Number of bolls per plant on per unit area is one of the most important yield components of cotton. Highly significant differences for number of bolls per plant in sowing times, varieties and their interactions. Maximum number of bolls (40) were produced when the crop was sown on 1st May followed by 15th May and 1st April sown crop where 35 and 31 bolls respectively were achieved. As regards to varieties, ICI-2121 produced maximum number of bolls per plant (40) followed by ICI-2424 (31) and IUB-2013 (28). On the contrary, Dong *et al.* (2006) recorded a greater number of bolls per unit area in late planting than normal planting.

Seed cotton yield (Kg/ha): Highly significant differences were observed for seed cotton yield (kg/ha) in sowing times, varieties and their interactions. Maximum seed cotton yield (1377 kg/ha) was produced when the crop was sown on 1st May followed by 1st April and 15th April sown crop where 1287 and 1269 kg/ha seed cotton yield respectively was obtained. As regards to varieties, ICI-2121 produced maximum yield of 1228 kg/ha followed by ICI-2424 (1147 kg/ha) and IUB-2013 (1064 kg/ha). Soomro *et al.* (2000) and Gormus and Yucel (2002) also observed that earlier or later sown crop than optimum time, showed a rapid yield decline. Soomro *et al.* (2000) also observed that even a delay of one week from optimum time resulted in marked decline in yield. Iqbal *et al.* (2011) observed higher cotton yield with early planting in 3rd week of May compared to 2nd week of June. Akhtar *et al.* (2002) viewed that late planting results in reduced yield. Muhammad *et al.* (2002) summarized that cotton sowing in the beginning of May gave significantly higher seed cotton yield than all other sowing dates. All the above-mentioned studies are in line with the present findings.

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The Effects of drought stress on physiological properties of cotton (*G. Hirsutum* L.)

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ABSTRACT

As cotton is a product that is grown by irrigating during the summer and rainfall periods, global warming and the drought stress associated with it affect the cotton cultivation negatively. The aim of this study was to investigate the effects of different field capacity saturation degrees (FCSD) on some physiological properties of cotton cultivars. The study was carried out in Dicle University Faculty of Agriculture in the experimental area in 2014-2015 with 3 replications according to the split plot design. The experiment was arranged in a split- plots design with three replications. Main plots were different FCSD (100%, 80%, 60%, and 40%) and sub plots were cotton varieties (Stoneville-453, GW-Teks, and Deltaopal). Leaf temperature (°C), leaf stoma conductivity (mmol m^{-2} s^{-1}) (leaf photosynthesis yield (µmol m^{-2} s^{-1}), leaf SPAD value, canopy temperature (°C) and seed cotton yield (g.per $plant^{-1}$) properties were investigated in this study. Physiological adverse effects of cotton plant in limited irrigation conditions were determined. Although linear regression was determined between deficit irrigation conditions and leaf temperature, canopy temperature, leaf SPAD value, quadratic regression was detected between leaf stomatal conductivity, leaf photosynthesis yield and seed cotton yield.

Key word: Cotton, drought, physiological properties, stress.

INTRODUCTION: There has been a decrease in the amount of precipitation and irregularity along with climate change in recent years. This shows that drought will be even more problematic in agricultural production in the future. It is predicted that climate zones will shift with the effect of global climate change. In addition, Turkey's influence will remain a hotter and drier climate, cannot adapt to the climate, the flora and fauna will disappear, this change is expected to alter the pattern of agricultural products (Türkes *et al.*, 2000). The world's temperature will rise by 4 °C by 2100; this increase can be as high as 8-9°C is noted in Turkey (Tarakcioglu, 2008). Irrigation requires increasing yield in the region due to inadequate precipitation during the growing season of cotton. The global climate change and the drought have become a major problem in agricultural production. Global warming and the resulting drought stress adversely affect cotton farming both in our country and in the world. Therefore, it is of great importance to investigate how drought stress causes a change in the micro ecology, morphology and physiology of the cotton plant. It is importance to understand the occurrence of drought and the extent of the damage and to take some necessary measures to prevent the damage caused by drought and will increase in the future. In addition, understanding the change caused by drought on the cotton plant is important in future cotton breeding studies.

OBJECTIVES: This study was carried out in order to contribute to scientific and practical applications in the studies to be carried out in order to less effect the production in water stress in cotton production.

MATERIALS AND METHODS: The study was carried out in with 3 replications according to the split plot design in Dicle University Faculty of Agriculture experimental area in 2014-2015. The main parcel is arranged as different field capacity saturation degree (FCSD) (%) (100%, 80%, 60%, 40%) obtained from different irrigation water amount and the sub parcel is arranged as cotton varieties (ST-453 (Stoneville-453), GW-Teks, and Deltaopal). Diyarbakir province has a hard land climate. The summers are very hot, the winters are cold, but the cold is not as severe as in Eastern Anatolia. The hottest month average is 31ºC and the coldest month average is 1.8ºC. The highest temperature to date was 46.2ºC (21 July 1937) and the lowest temperature was -24.2ºC (11^{th} January 1933). Approximately 2% of the average annual precipitation is 496 mm^2, falls in summer. Average relative humidity occurs mostly in December and January (77%) and minimum (20%) in July and August. Delta T Profile Probe Tube was placed between the middle 2 rows of each plot in order to determine soil moisture level before the first irrigation. A profile was opened from a point representing the trial site, and distorted and undisturbed soil samples were taken in 30 cm layers up to 90 cm. Soil samples, using the analysis methods specified by Tüzüner and Rural Affairs (1990); field capacity, wilting point, volume weight, soil structure, soil reaction, total salt, organic matter, lime, available phosphorus and potassium were analysed (table1).

Depth	Structure	saturation with water	field capacity	wilting point,	Volume weight
90 cm	clay-loam	62%	41.52%	11.88%	1.35 g/cm^3
pH	**Salt**	**Lime Content**	**P_2O_5**	**K_2O**	**Organic Matter**
7.87	1.064 ds/m	30.4%	4.4%	2.5%	1.8%

Table1. Soil analyses of experimental area.

Fertilization was applied as 160 kg ha^{-1} N and 70 kg ha^{-1} P_2O_5 pure fertilizer to the experimental area. Drip irrigation method made with irrigation. The first irrigation was made to all parcels when irrigation to the level of soil field capacity was reduced to

35%. Plant water consumption was calculated by Moisture (Beyce *et al.*, 1972). Soil moisture measurements were carried out before and after irrigation by Delta T Profile Probe. Soil moisture changes are given in figure 1. In the Study were

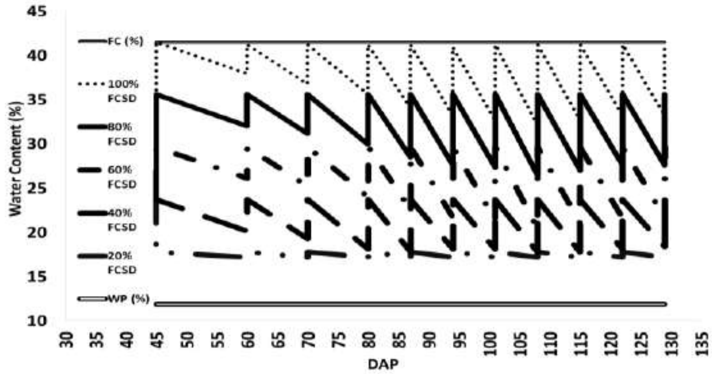

Figure 1: Soil moisture changes before and after irrigation with Delta T Profile Probe (FC: Field capacity (42%); WP: Wilting point (11%); FCDS: Field capacity saturation degrees; DAP: Day after Planting).

Reduction Method which is related to water balance equality investigated leaf temperature (◦C) (infrared thermometer), canopy temperature (FLIR E60 thermal imager) (˚C), leaf stoma conductivity (mmol m^{-2} s^{-1}) (Delta-T Model AP-4 porometer), SPAD values (Minolta SPAD-502 Chlorophyll-Meter), leaf photosynthesis yield (μmol m^{-2} s^{-1}) (EARS-PPM Plant Photosynthesis System), and cotton seed yield (g $plant^{-1}$). Physiological observations were taken from 3 plants which were marked from each parcel between 10: 00-11: 30 in the morning 90 days after of planting date. The values obtained for each trait were analysed statistically using JMP 5.0 (Copyright © 1989-2002 SAS Institute Inc.) statistical package program in the study. The results were analysed by F test, correlation and regression analysis. Means were grouped according to LSD test.

RESULTS AND DISCUSSION: Mean values of leaf temperature (˚C), canopy temperature (˚C), leaf stomatal conductivity (mmol m^{-2} s^{-1}) of the investigated traits are given in Table 1 and Mean values of leaf SPAD value, leaf photosynthesis yield (μmol m^{-2} s^{-1}), and seed cotton yield (g $plant^{-1}$) of the investigated traits are given in table 2.

Varieties	FCSD (%)	Leaf temperature (◦C) 2014	2015	Means	Canopy temperature (◦C) 2014	2015	Means	Leaf stoma conductivity (mmol m^{-2} s^{-1}) 2014	2015	Means
Deltaopal	20%	48.14	45.12	46.63	56.33	53.16	54.74	664.86	615.49	640.17fgh
	40%	44.23	41.79	43.01	50.59	48.04	49.32	673.88	708.90	691.39fg
	60%	43.94	41.70	42.82	45.58	43.25	44.41	1318.90	1642.90	1480.90de
	80%	33.22	31.47	32.34	33.35	31.54	32.44	2579.49	2316.93	2448.21b
	100%	29.03	28.28	28.66	24.78	24.02	24.40	1722.78	2101.65	1912.22c
ST-453	20%	46.65	44.30	45.47	54.90	52.44	53.67	522.46	442.47	482.47h
	40%	44.70	42.45	43.57	51.25	48.89	50.07	535.95	502.34	519.14gh
	60%	43.57	41.49	42.53	45.31	43.14	44.23	1131.31	1463.33	1297.32e
	80%	31.03	29.64	30.33	28.70	29.62	29.16	2276.03	3058.13	2667.08a
	100%	29.15	29.63	29.39	24.89	25.44	25.17	1812.38	2140.19	1976.29c
GW-Teks	20%	48.69	46.86	47.78	56.75	54.86	55.81	646.60	639.24	642.92fgh
	40%	48.81	46.17	47.49	55.36	52.60	53.98	787.65	888.05	837.85f
	60%	45.61	43.21	44.41	47.27	44.76	46.02	1518.55	1499.63	1509.09d
	80%	34.78	33.19	33.98	34.93	33.26	34.10	2454.15	2425.50	2439.82b
	100%	32.72	31.58	32.15	28.59	27.42	28.01	1771.78	2161.34	1966.56c
Deltaopal		39.71	37.67	38.69 b	42.13	40.00	41.06 b	1391.98	1477.17ab	1434.58
ST-453		42.12	40.20	38.26 b	41.01	39.90	40.45 c	1255.63	1521.29a	1388.46
GW-Teks		39.02	37.50	41.16 a	44.58	42.58	43.58 a	1435.75	1522.75a	1479.25
Means	20%	47.83	45.43	46.63 a	55.99	53.48	54.74 a	611.31g	565.73g	588.52d
	40%	45.91	43.47	44.69 b	52.40	49.85	51.12 b	665.83g	699.76g	682.79d
	60%	44.37	42.13	43.25 c	46.05	43.72	44.88 c	1322.92f	1535.29e	1429.10c
	80%	33.01	31.43	32.22 d	32.33	31.47	31.90 d	2436.56b	2600.18a	2518.37a
	100%	30.30	29.83	30.06 e	26.09	25.63	25.86 e	1768.98d	2134.39c	1951.69b
Means		40.28 a	38.46 b	39.37	42.57	40.83b	41.70	1361.12b	1507.07a	1434.10

Table 2: Mean values of leaf temperature, canopy temperature, and leaf stoma conductivity.

Leaf temperature (˚C): The leaf temperatures of cotton varieties used as materials varied between 38.26 ˚C (ST-453) and 41.16 ˚C (GW-Teks) (table 1). The leaf temperature values of all cotton varieties are highly affected by different FCSDs, and there is a linear relationship between FCSD and leaf temperature properties in all cotton varieties. A negative correlation (r=-0.89, p<0.001) between FCSD and leaf temperature. When all varieties were taken into account, y=-0.2745x+56.775 (R^2=0.79) regression/change equation was obtained (figure 2). The leaf temperature of the cotton plant is highly affected in arid and extreme irrigation conditions. It was determined that leaf temperature was very close to the varieties and amount of water used. Excessive leaf temperature

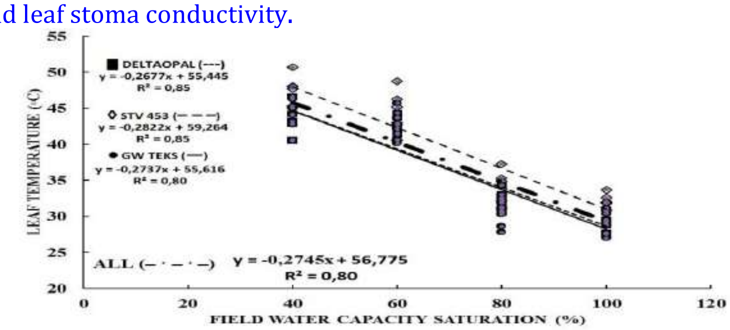

Figure 2: The relationship between leaf temperature and FCSD.

increases are of great importance in terms of leaf viability and functions. Extremely high drought stress can cause irreversible damage to the plant with prolonged persistence. The fact that the leaf temperature is a very easily and practically measurable and verifiable feature reveals that it can be used in plant stress studies. Our results coincide with Jackson (1982) and Zia-Khan *et al.* (2015).

Canopy temperature (◦C): The canopy temperatures of different cotton varieties varied between 40.45 ˚C and 43.58 ˚C (table 1). In all cultivars, it was found that canopy temperature values were highly influenced by different FCSDs, and there was a linear relationship between FCSD and canopy temperature characteristics in all cotton varieties. A negative correlation ($r=-0.89$, $p<0.001$) between FCSD and canopy temperature supports these results. When all varieties were taken into account, it was found that $y=-0.4439x + 69.516$ ($R^2=0.92$) regression equation. Drought stress on cotton plant development affects the leaf temperature of the plant. If there is not enough moisture in the soil, the canopy temperature of the plant will increase. The change in canopy temperature is not only related to drought stress but also to the level of temperature stress (figure 3). Our findings are similar to those of Mahan *et al.* (2005), Conaty *et al.* (2012) and Köken *et al.* (2016).

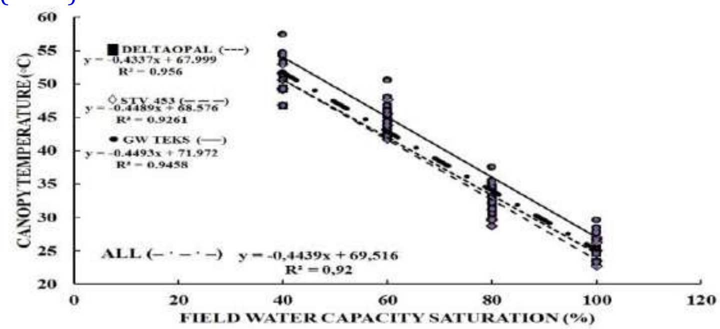

Figure 3: The relationship between canopy temperature and FCSD

Leaf stoma conductivity (mmol m⁻².s⁻¹): Cotton varieties, leaf stomatal conductivity, 442.47 mmol m^{-2} s^{-1} and 3058.13 mmol m^{-2} s^{-1} varied between table 1. It is seen that the stoma conductivity values of all varieties are highly affected by different FCSDs and there is a quadratic relationship between FCSD and stoma conductivity property in all cotton varieties. A positive correlation ($r=+0.79$, $p<0.001$) between FCSD. When all varieties were taken into account, it was found that $y=-0.772x^2+132.17x-3457.1$ ($R^2=0.84$) regression equation (figure 4). The highest stoma conductivity value is obtained, the FCSD value is 85%; the highest stoma conductivity values were found to be 2200 mmol m^{-2} s^{-1}. Stomatal conductivity is one of the most important parameters affecting the respiration and photosynthesis of cotton plant. However, there are many factors that affect this parameter. A similar result was reported by Zia-Khan *et al.* (2015) and Köken *et al.* (2016).

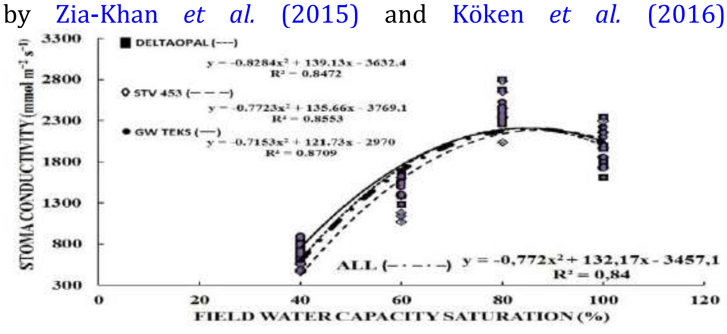

Figure 4: The relationship between stoma conductivity and FCSD.

Leaf SPAD value: The leaf SPAD values of cotton varieties ranged between 47.29 and 49.35 (table 2). It is seen that leaf SPAD values of all cultivars are highly affected by different FCSDs, and there is a linear relationship between FCSD and leaf SPAD properties in all cotton varieties. A negative correlation ($r = -0.95$, $p <0.001$) between FCSD and leaf SPAD supports this result. When all varieties were taken into account, it was found that $y=-0.6404x+88.465$ ($R^2=0.91$) regression equation the chlorophyll content of the leaves is of great importance in the development of cotton plants (figure 5). The differences in the chlorophyll content of the existing stresses in both plant nutrition and growing ecology of the plant and the fact that this feature is clearly understood under drought stress conditions, being easy to detect and demonstrating that this feature can be used in next studies. A similar result was reported by Bauerle *et al.* (2004) and Köken *et al.* (2016).

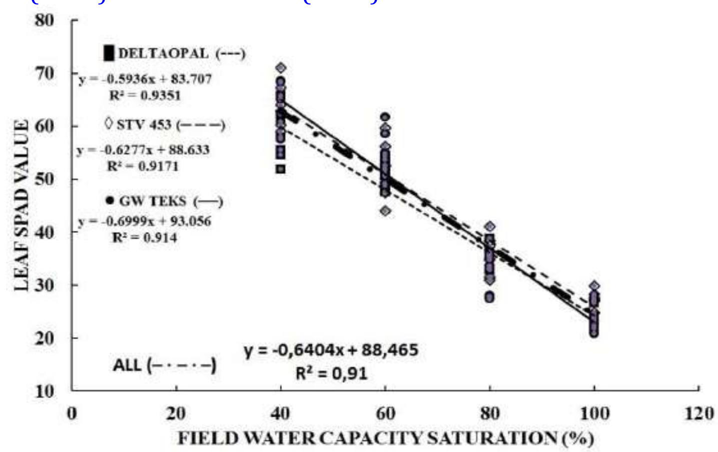

Figure 5. The relationship between leaf SPAD value and FCSD

Leaf photosynthetic efficiency (µmol m⁻²s⁻¹): Cotton varieties photosynthetic efficiency values ranged from 569.46 µmol m^{-2} s^{-1} (2014) to 630.53 µmol m^{-2} s^{-1} (2015), (figure 6). It

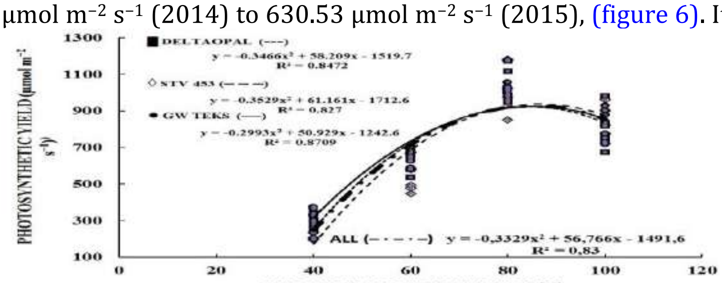

Figure 6. The relationship between photosynthetic yield and FCSD.

was determined, photosynthesis yield values of all cultivars were affected by different FCSDs and quadratic regression was found between FCSD and photosynthesis yield properties. A positive correlation ($r=+0.78$, $p<0.001$) between FCSD and photosynthesis yield was supported by this result. When all varieties were taken into consideration, was obtained that $y=-0.3329x^2+56.766x-1491.6$ ($R^2 = 0.83$) regression. The highest photosynthesis yield value was obtained 85% FCSD. The photosynthesis yield has an important role in the physiological development of cotton plant. These results are in agreement with those of Bauerle *et al.* (2004) and Köken *et al.* (2016).

Seed cotton yield (gr): Seed cotton yield of the varieties ranged from 12.24 g. to 56.99 g. (table 2). It is seen that seed cotton yields are affected by different FCSDs and quadratic regression between FCSD and seed cotton yields. In addition, a

positive correlation (r=+0.84, p <0.001) between FCSD and cotton yield values supports this result. Considering all the varieties used as material $y=-0.1472x^2+25.739x-645.11$ (R^2 = 0.91) regression equation is obtained, the highest seed cotton yields obtained FCSD value is 87%; the highest seed cotton yield was found to be 50.41 g (figure 7). Water has an important role in the development of cotton plant. Under dry conditions, the growth, development and morphological structure of cotton plant deteriorates and yield decreases significantly. These results are in agreement with those of Başal and Aydın (2006).

Varieties	FCSD (%)	Leaf SPAD Value				Yield of Leaf Photosynthesis ($\mu mol\ m^{-2}\ s^{-1}$)			Cotton Yield Yield ($g.plant^{-1}$)		
		2014	2015	Means		2014	2015	Means	2014	2015	Means
Deltaopal	20%	70.23	65.43	67.83		278.16	257.51	267.83	15.54	15.74	15.64
	40%	59.80	56.33	58.06		281.94	296.59	289.26	16.35	18.03	17.19
	60%	52.96	49.79	51.38		551.80	687.35	619.58	31.82	39.73	35.78
	80%	36.54	34.12	35.33		1079.21	969.35	1024.28	52.59	50.40	51.50
	100%	24.05	23.62	23.84		720.78	879.29	800.03	46.21	45.56	45.88
ST-453	20%	66.01	64.25	65.13		218.58	185.12	201.85	18.06	17.22	17.64
	40%	65.94	62.16	64.05		224.23	210.17	217.20	19.44	21.74	20.59
	60%	53.23	49.86	51.55		473.32	612.22	542.77	35.44	35.00	35.22
	80%	36.68	34.71	35.70		952.24	1279.46	1115.85	56.99	55.13	56.06
	100%	28.04	26.93	27.49		758.26	895.41	826.84	47.00	46.48	46.74
GW-Teks	20%	72.22	68.78	70.50		270.53	267.44	268.98	13.20	12.24	12.72
	40%	65.88	62.60	64.24		329.54	371.54	350.54	14.00	13.78	13.89
	60%	56.14	53.15	54.64		635.33	627.42	631.37	28.44	36.84	32.64
	80%	33.24	31.51	32.37		1026.76	1014.78	1020.77	53.30	50.61	51.96
	100%	23.99	26.02	25.00		741.28	904.26	822.77	48.02	46.06	47.04
Deltaopal		48.72	45.86	47.29	b	582.38	618.02	600.20	32.50	33.89	33.32 b
ST-453		49.98	47.58	48.78	a	525.33	636.48	580.90	35.39	35.11	35.25 a
GW-Teks		50.29	48.41	49.35	a	600.69	637.09	618.89	31.39	31.91	31.65 b
Means	20%	69.49	66.15	67.82	a	255.76	236.69	246.22d	15.60	15.07	15.33 d
	40%	63.87	60.36	62.12	b	278.57	292.77	285.67d	16.60	17.85	17.22 d
	60%	54.11	50.93	52.52	c	553.48	642.33	597.91c	31.90	37.19	34.55 c
	80%	35.49	33.45	34.47	d	1019.40	1087.86	1053.63a	54.29	52.05	53.17 a
	100%	25.36	25.52	25.44	e	740.11	892.99	816.55b	47.08	46.03	46.55 b
Means		**49.66a**	**47.28b**	**48.47**		**569.46b**	**630.53a**	**599.99**	33.09	33.64	**33.37**

Table 3: Leaf SPAD value, leaf photosynthesis yield and cotton mass yield average values of properties

Seed cotton yield (gr): Seed cotton yield of the varieties ranged from 12.24 g. to 56.99 g. (table 2). It is seen that seed cotton yields are affected by different FCSDs and quadratic regression between FCSD and seed cotton yields. In addition, a positive correlation (r=+0.84, p <0.001) between FCSD and cotton yield values supports this result. Considering all the varieties used as material $y=-0.1472x^2+25.739x-645.11$ (R^2 = 0.91) regression equation is obtained, the highest seed cotton yields obtained FCSD value is 87%; the highest seed cotton yield was found to be 50.41 g (figure 7). Water has an important role in the development of cotton plant. Under dry conditions, the growth, development and morphological structure of cotton plant deteriorates and yield decreases significantly. These results are in agreement with those of Başal and Aydın (2006), Sezener *et al.* (2015) and Niu *et al.* (2018).

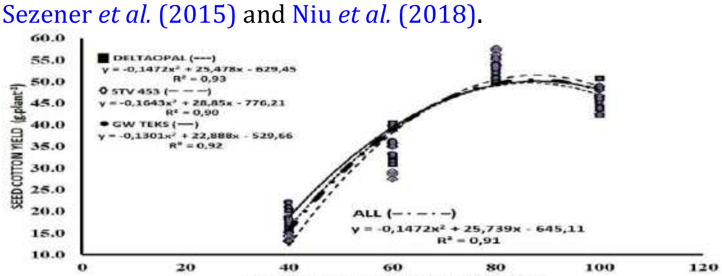

Figure 7: The relationship between seed cotton yield and FCSD.

CONCLUSIONS: Drought stress, as in many other plants, showed important results in terms of physiological properties examined in cotton. Although there was a negative correlation between drought stress and leaf temperature, canopy temperature and leaf SPAD values, there was a positive correlation between drought stress and leaf stoma conductivity, leaf photosynthesis yield and seed cotton yield. The most suitable FCSD values in terms of leaf stoma conductivity, leaf photosynthesis yield and seed cotton yield were 85%, 85%, 87%, respectively. In the study were found to be important and practical to properties such as leaf temperature, canopy temperature, leaf SPAD value, leaf stoma conductivity, leaf photosynthesis yield and cotton mass yield properties to determine the performance of genotypes under drought stress conditions.

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Evaluation of different cotton varieties against drought tolerance: A comparative analysis

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ABSTRACT

The limited water supply for irrigation is a major constraint to cotton production. Morphological and physiological traits provide useful information for drought tolerance. This research work was carried out for the identification of cotton genotypes having better drought tolerance. For this purpose, forty (40) genotypes of upland cotton were studied under two moisture regime, i.e. normal and drought environment in field conditions. The experiment was conducted using split plot design under RCBD arrangement. All the genotypes behaved differently under two moisture levels. The interaction of cotton genotypes with two moisture levels were studied for various traits, i.e. plant height, sympodial branches, seed cotton yield, boll weight, number of bolls per plant, excised leaf water loss and relative water content by using Principle Component Analysis (PCA). Results showed that the genotypes VH-144, IUB-212, MNH-886, VH-295, IR-3701, AA-802, NIAB-111, NS-121, FH-113, and FH-142 are either stable or showing positive interaction with drought conditions for most of the traits under studied. These genotypes can be used in further breeding program for developing varieties suitable for cultivation under drought conditions, whereas; IR-3, CIM-443, FH-1000, MNH-147, S-12 interacted undesirably with drought stress.

Key word: *Gossypium hirsutum* L., breeding program, stable, seed cotton yield, water deficit, principle component analysis.

INTRODUCTION: Cotton is a major fiber yielding crop and ranked second as an oilseed crop after soybean (Mammadov *et al.*, 2018). In Pakistan, it is a cash crop and major earnings of foreign exchange. Pakistan ranked at the fourth number in largest cotton production in the whole world. The share of cotton in agriculture is 5.1% and in overall GDP is 1.0% (Ashraf *et al.*, 2018). The total 99% of cotton area in Pakistan and 90% of the world's cotton area is covered with upland cotton. This crop is mostly grown in arid and semiarid regions where a water shortage is often occurring.

The economy of a predominantly agricultural country mainly depends upon the agricultural activities, consisting of many disciplines in which crop husbandry plays an important role. When a seed is planted in the soil, the plant development and productivity are subject to numerous biotic and abiotic stresses. It is evidenced that abiotic stresses are the major contributor to the reduction of crop growth and yield. The losses due to drought, high temperature, salinity, low temperature, and by other factors are 17%, 40%, 20%, 15% and 8% respectively (Ullah *et al.*, 2019; Zaidi *et al.*, 2020). Drought stress has been affecting globally to the agriculture which causes higher yield losses as compared to all other abiotic stresses. Drought along with high temperature is a major constraint to plant growth, survival and productivity on a global basis (Ahmad *et al.*, 2018). It reduces the crop growth and productivity and affects various physiological, biochemical and molecular processes in crop plants. The water deficit along with global climate change makes the condition more severe in major agricultural domains (Khan *et al.*, 2018).

The situations in which it is impossible to modify the environments to suit the crop plants, plant breeders and geneticists are trying to modify the crop plants for adverse environmental stresses. This alternative strategy is being used to tackle the problem of drought stress (Ahmed *et al.*, 2020). This approach consists of modification of the genetics of crop plants through selection and breeding, to make them suitable for drought declared areas. To develop such material, variability in the crop plant is a basic requirement for drought tolerance and this variability must have some genetic components. Information about these components is necessary for exploitation of these genetic resources through selection and breeding. The variability in a species plays important role in the identification of the target genotypes for the improvement of character under study (Ullah *et al.*, 2017).

The selection and breeding, crop plants against drought may be better if the variation is genetically controlled. Previous studies suggest that drought tolerance is polygenetically controlled. Significant genetic variation has been found in many traits which are associated with drought stress in many crops. The variability in drought stress tolerance in cotton crop is limited as reported by previous work, but a few studies reported that the variation in drought tolerance is available at crop maturity. The information about response of plants to drought stress is essential for improving the drought stress tolerance since morphological traits have been usually used to classify drought tolerant and sensitive genotypes in upland cotton (Jaleel *et al.*, 2009). The main advantages of using these morphological traits in screening include no requirement of any specialized equipment for measuring them. Significant variation has been reported in various morphological traits such as plant height, number of bolls per plant and boll weight (Mahmood *et al.*, 2006). Reduced leaf area is major symptoms of cotton under drought stressed to reduce transpiration. High leaf water content being genetically controlled and usually used as reliable measures to determine drought tolerant plants (Prasad *et al.*, 2008; Brito *et al.*, 2011).

OBJECTIVES: Therefore, the present study was planned for the assessment of genotypic variation under water deficit condition at maturity stage in the field condition in commercial and newly developed elite cotton varieties and to identify drought tolerant and drought sensitive genotypes.

MATERIALS AND METHODS: In this study, forty cotton accessions were screened at maturity stage in the research area of Department of Plant Breeding and Genetics, UAF. These genotypes were evaluated under two moisture regimes, normal (To) and drought stress (T_1) in the field conditions. For this purpose, forty genotypes of cotton were grown under normal and drought conditions in split plot design under RCBD arrangement. The main plots contained irrigations while sub-plots contained genotypes in each replication. Ten plants of each genotype were grown in a single row. The distance between rows to row was 75 cm while plant to plant was 30 cm. All the practices, including agronomic as well as cultural were the same except irrigations. The rainfall during June-August (vegetative phase) and September-November (reproductive phase) was 213.2 and 3.8 mm respectively. Drought stress treatment was given 50% reduced irrigations as compared to the normal treatment (Kirda *et al.*, 2005). Climatic conditions prevailing during present experimentation (April-November) in the year 2013 were provided in the figure 1. (Source: Agromet Bulletin, Agriculture Meteorology Cell, Department of Crop Physiology, UAF, Pakistan). At the maturity stage, when drought symptom appeared, 5 guarded plants for each of the genotypes per replication and treatment were tagged for measuring the data for plant height, number of sympodial branches, number of bolls per plant, boll weight, seed cotton yield per plant, excised leaf water loss and relative water content.

Plant height of the main stem from cotyledonary node to the apex was measured in centimeters. The sympodial branches were counted from each tagged plant on each of the genotype per treatment and replication and then average was calculated. The matured, open bolls were picked from each randomly selected plant from each genotype, per treatment and replication and then average was calculated as number of bolls per plant. For measuring boll weight, five opened bolls having a good opening were picked from each tagged plant for each genotype per treatment and replication. The seed cotton was weighed in grams in electrical balance and then the average boll weight of each entry was calculated by dividing seed cotton weight of five bolls by five. All the opened bolls having a good opening were picked by three picks at maturity and then seed cotton was weighed in grams and then the average weight of seed cotton yield per plant was calculated.

For the measurement of relative water content, three matured leaf samples were obtained from each of the tagged plants from each replication and treatment during the end of September. These leaf samples were kept in polythene bags after they were excised and their fresh weight was taken on the electronic balance. After that the samples were left in the water for one night and by using an electronic balance turgid weight were measured. After keeping these samples at room temperature for drying for about one hour, these samples were oven dried for 72 h. at 70°C and dry weight of leaf samples were measured. The relative water content was calculated by the formula as under (Barr and Weatherley, 1962).

$$\text{RWC} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

For measuring excised leaf water loss, a sample of three matured leaves was obtained from each of the tagged plants for each of the genotype per replication and treatment during the end of September. These leaf samples were kept in bags soon after they were excised from the plant and their fresh weight was measured on an electronic balance. Then the leaf samples were kept at room temperature on the laboratory bench. The wilted weight of leaves samples were measured after 24 h. and then these samples were oven dried for 72 h. at 70°C for measuring dry weight. The excised leaf water loss was calculated by the formula as under (Clarke and and Mccaig, 1982).

$$\text{ELWL} = \frac{\text{Fresh weight} - \text{Wilted weight}}{\text{Dry weight}} \times 100$$

Collected data were subjected to analysis of variance using Statistix 8.1. Principle component analysis (PCA) was performed on the mean data using XLSTAT software (Ahmed *et al.*, 2019).

RESULTS: Mean squares showed significant differences for genotypes, treatments and genotype × treatments interaction for all the traits (table 1). Traits showing significant differences for genotypes and treatments were further analysed by principle component analysis (PCA).

Plant height (cm): The biplot analysis for plant height revealed that there was significant variation in forty genotypes of cotton (figure 2). It is obvious that genotypes which are tolerant under drought stress produced taller shoots as compared to sensitive ones. Maximum plant height under normal and drought stress was shown by VH-148. The genotypes such as IUB-212, CRS-2007, NIAB-111, MNH-147 and NS-131 also showed the genetic potential for improving drought tolerance under both conditions. The other genotypes showed specific response against treatment because these genotypes formed positive, but shorter vectors along the vectors of treatment. For example, VH-144, CIM-443, IUB-222 and FH-114 were well under normal treatment whereas FH-170, CIM-707, IR-3 and MNH-886 did better under drought condition. The genotypes i.e. AA 703, FH-171, MG-6, FH-172, VH-293, AA-802. CRS-456, CIM-240, AS-01, S-12, NIAB-820 and VH-282 showed sensitivity against drought stress due to their location on negative side of treatment vectors.

Number of sympodial branches: Genotypes i.e. IUB-212, CIM-707, VH-148, NIAB-111 and IR-901 had shown more sympodial branches and these genotypes were located on the extreme right of treatment vectors (figure 3). The remaining genotypes which performed better under normal and drought conditions were included CRS-2007, FH-170 and VH-144 because these genotypes formed longer vectors which showed their tolerant response under drought stress. The shorter but positive vectors were found in the genotypes such as VH-283, IUB-222, FH-175 and FH-169 which showed a specific response to treatment. The genotypes AA-703, CRS-456, VH-295, FH-113 and IR-3701 were most sensitive to drought stress. In addition the genotypes such as FH-172, FH-941, AS-01, FH-1000, FH-171, MG-6 and IR-3 also showed sensitivity to drought stress because of their vector location on the negative side of vectors of the treatment.

SOV	D.F	PH	SB	BP	BW	SCY	RWC	ELWL
Rep.	2	9.100	11.760	3.990	0.063	98.000	0.001	0.034
Trt.	2	48986.100**	555.774**	6854.430**	54.198**	173834.000**	0.396**	1.221**
Error-I	4	0.300	0.429	0.180	0.042	36.000	0.000	0.010
Gen.	39	955.000**	25.706**	95.210**	2.341**	3265.000**	0.059**	1.577**
Trt*Gen	78	253.400**	7.365**	40.740**	0.423**	1040.000**	0.023**	0.338**
Error-II	234	0.900	0.881	1.850	0.011	27.000	0.000	0.009

Table 1: Mean squares for various traits of screening at maturity stage in the field.
significant, **= highly significant, PH= plant height, SB= number of sympodial branches, BP= number of bolls per plant, BW= boll weight, RWC= relative water content, ELWL= excised leaf water loss.

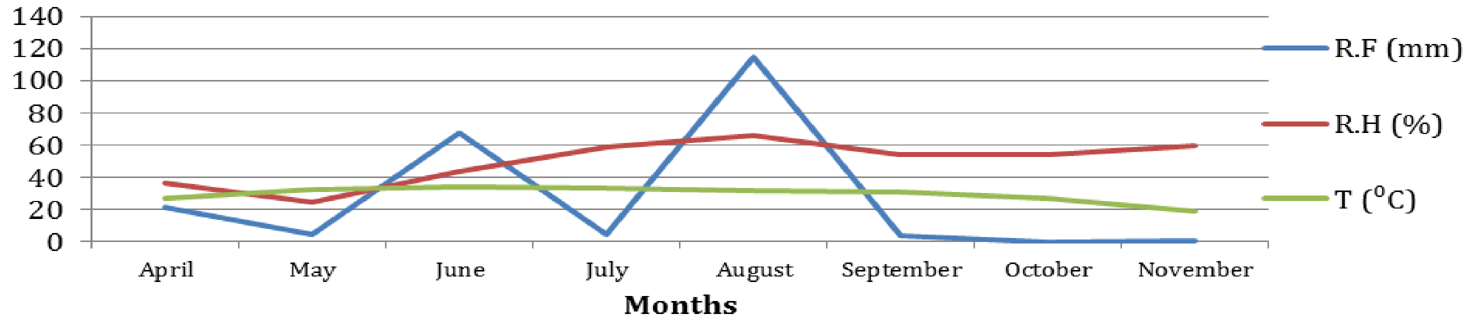

Figure 1: Rainfall, relative humidity and average temperature from April to November during 2013.

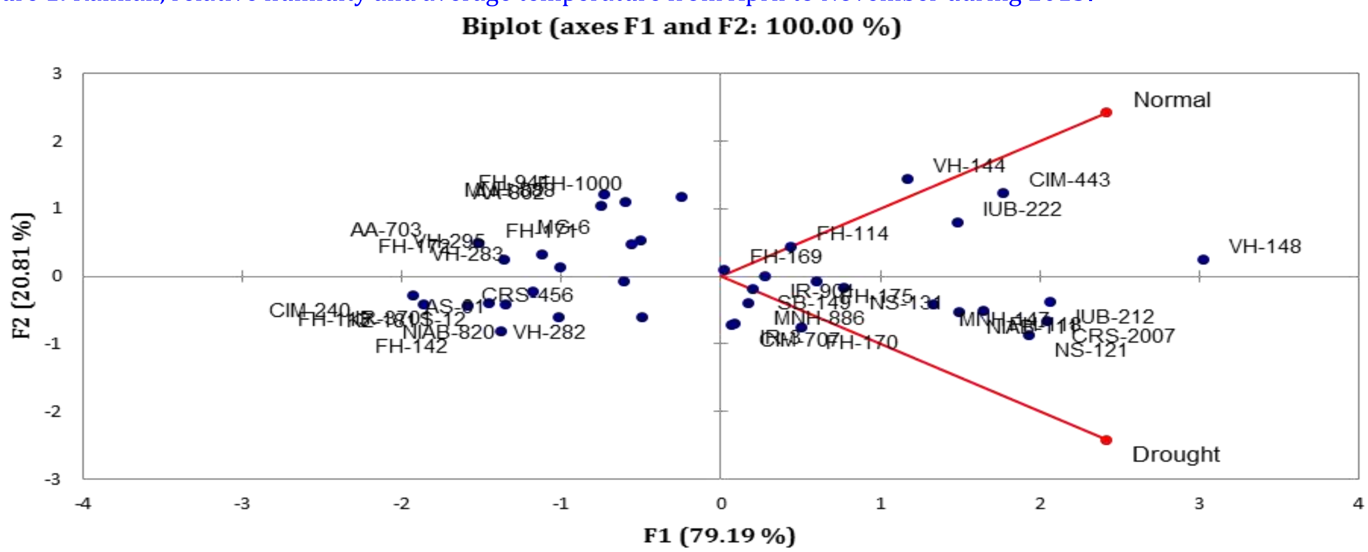

Figure 2: Biplot for plant height of forty cotton genotypes under normal and drought conditions.

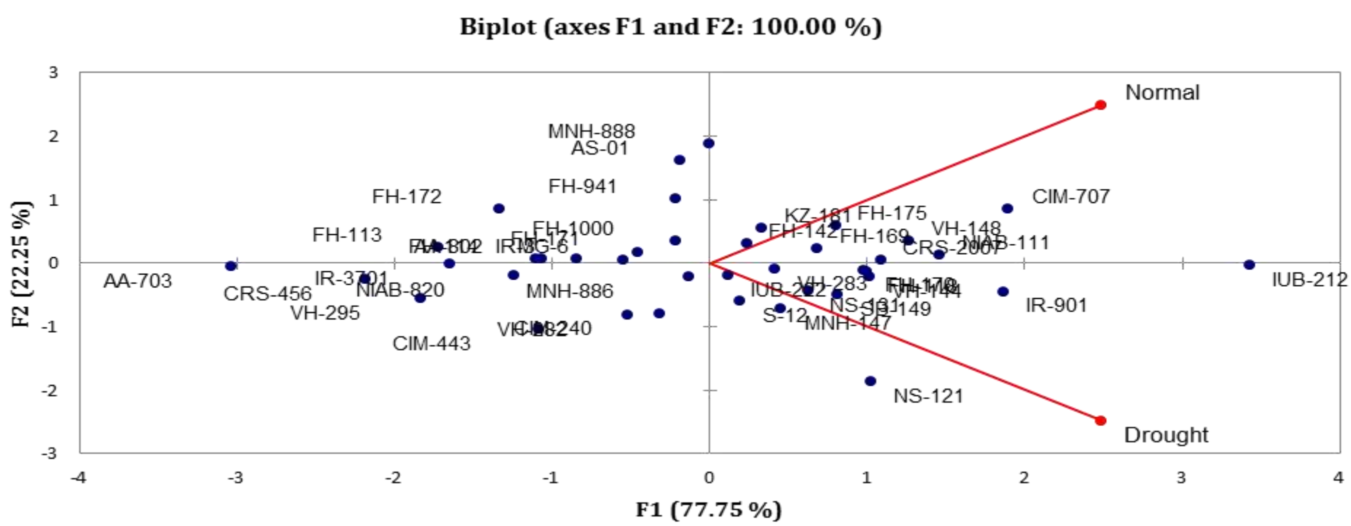

Figure 3: Biplot for sympodial branches of forty cotton genotypes under normal and drought conditions.

Number of bolls per plant: Significant variation was found in 40 genotypes for a number of bolls per plant. The longest stretches with treatment vectors were formed by NIAB-111 and MNH-147 which signified the high number of bolls per plant under normal and drought conditions. The genotypes NS-121, IUB-212, CRS-2007, VH-282 and VH-148 also revealed high genetic potential for drought stress tolerance by retaining more number of bolls per plant and in contrast, genotypes NIAB-820, CRS-456, MNH-886, FH-169 and VH-144 which were located on the opposite to the treatment vectors and ranked as highly drought sensitive genotypes. The remaining genotypes which were located on the negative side of treatment vectors such as IR-3701, AA-703, FH-941, AS-01, FH-113 and S-12 ranked as sensitive genotypes to drought stress (figure 4).

Boll weight (g): In biplot graph for boll weight, the genotypes with maximum boll weight were located right side of treatment vectors which indicated their potential to maintain high boll weight under both treatments (figure 5). This group consisted of highly tolerant genotypes, for example, CIM-707 and FH-170. Other genotypes which also showed some degree of drought tolerance were included IUB-212, NS-121, MNH-147, VH-148 and FH-118. In comparison, the genotypes which were present on left side of treatment vectors showed severe decline in boll weight, therefore the genotypes such as AS-01 and NIAB-111 were found highly sensitive under normal and drought stress. The genotypes such as CRS-456, FH-171, FH-113, FH-175, S-12 and CIM-443 could be clearly categorized as sensitive.

Seed cotton yield (g): This biplot showed significant genetic variation of forty cotton genotypes indicated by their dispersion around biplot origin for seed cotton yield (figure 6). Highest seed cotton yield was recorded in genotypes FH-170, CIM-707 and MNH-147 indicating extreme tolerance to drought stress in these cultivars. The seed cotton yield was also high in NS-121, IUB-212 and VH-148 which were present on the positive side of biplot. Minimum seed cotton yield was observed in genotypes which were located on the left side of treatment vectors such as CRS-456, VH-144, FH-142, MNH-886 and AS-01 which showed more sensitivity to drought stress. In addition, FH-171, NIAB-111, AA-703 and S-12 were also sensitive to drought condition.

Relative water content: This biplot showed that there were significant variations in the genotypes for this trait (figure 7). The genotypes which showed their longest vector length with treatment vectors were CIM-707 and VH-295 which indicated high relative water content under normal and drought conditions. The genotypes for example FH-171, SB-149, IUB-212, FH-172, FH-118, MNH-147, FH-114 and NS-121 also showed the genetic potential for drought tolerance by maintaining high leaf water content. The genotypes FH-113 and CIM-443 which were located on the reverse side of the treatment vectors were ranked as highly drought sensitive. The remaining genotypes which were present on negative sections of biplot included IR-3701, S-12, KZ-181, MNH-886, NIAB-111 and FH-142 and marked as sensitive to drought stress.

Excised leaf water loss:In this biplot (excised leaf water loss) the genotypes showing slightest water loss were located left to the treatment vectors which indicated their capacity to maintain high leaf water content under both conditions (figure 8). This group consisted of highly tolerant genotypes for example KZ-181, VH-283, VH-144 and FH-142. The other genotypes which showed some degree of drought tolerance were included CRS-456, CIM-240, MNH-886 and IR-3. Whereas, the genotypes which were located on the right side of treatment vectors indicated a maximum water loss, these included FH-1000, CRS-2007 and FH-941 which were marked as sensitive to drought stress.

Correlation study: Correlation studies under normal condition revealed that plant height and sympodial branches are significantly and positively associated with seed cotton yield and number of bolls (table 2). The number of bolls per plant was positively correlated with sympodial branches and seed cotton yield, but negatively correlated with boll weight which is obviously logical. Average boll weight presented significant and positive correlation with seed cotton yield, but negatively associated with number of bolls. Seed cotton yield was significantly and positively associated with plant height, number of sympodial branches, number of bolls and boll weight. Under drought condition, the plant height presented significant positive association with sympodial branches per plant, number of bolls, boll weight and seed cotton yield (table 3). The sympodial branches showed significant positive correlation with plant height, number of bolls, boll weight and seed cotton yield. The number of bolls showed a significant positive association with plant height, sympodial branches and seed cotton yield but negatively associated with boll weight. There were positive association of boll weight with plant height, number of sympodial branches and seed cotton yield and negatively correlated with number of bolls per plant which is logical. Seed cotton yield was significantly positively associated with plant height, sympodial branches, boll weight and bolls per plant.A negative correlation of relative water content and excised leaf water loss with the yield components was observed under both normal and drought the condition but it was statistically non-significant. The study advocated that these traits were not associated with yield related traits on the genetic basis. They did not play any significant role in enhancing seed cotton yield, but they contributed to the plants survival under water deficit condition and can be used as screening techniques in breeding drought tolerance programme.

DISCUSSIONS: The availability of two components is essential for development of drought tolerance through natural or a deliberate selection in *Gossypium hirsutum* L. Firstly, the variability in the plant trait must be present, and secondly, this variability must be controlled by a significant additive component. In the present research work, 40 cotton genotypes were screened at maturity stage in field condition under two moisture regime i.e. normal and drought condition. By comparing different traits such as plant height, number of sympodial branches, number of bolls per plant, boll weight, seed cotton yield, relative water content and excised leaf water loss drought tolerant and sensitive genotypes were selected. Data generated were compared using mean values through biplot analysis. Previous workers for example, (Kar *et al.*, 2005; Shakoor *et al.*, 2010; Iqbal *et al.*, 2011; Ademe *et al.*, 2017) had used screening of drought-tolerant and drought sensitive genotypes for morphological and physiological traits.

By comparing differences and similarities in morphological and physiological traits under two moisture stress conditions (Normal and drought condition), a significant reduction in these characters was observed.

Variables	PH	SB	BP	BW	RWC	ELWL
SB	0.3127*					
BP	0.4994	0.2599**				
BW	0.1488	0.1252	-0.454**			
RWC	-0.0849	0.1251	0.294	0.3185		
ELWL	-0.0907	-0.1263	0.0127	-0.098	-0.2124	
SCY	0.3708**	0.2291**	0.8283**	0.8685**	0.364	-0.0503

Table 2: Correlation coefficient for various traits under normal condition
*= significant, **= highly significant, PH= plant height, SB= number of sympodial branches, BP= number of bolls per plant, BW= boll weight, RWC= relative water content, ELWL= excised leaf water loss.

Variables	PH	SB	BP	BW	RWC	ELWL
SB	0.7478**					
BP	0.6304**	0.5962**				
BW	0.4292**	0.4267**	-0.3909**			
RWC	0.0794	0.2247	0.1433	0.2996		
ELWL	-0.2036	-0.2699	-0.2552	-0.1551	-0.108	
SCY	0.5934**	0.5799**	0.7762**	0.8698**	0.2941	-0.2281

Table 3: Correlation coefficient for various traits under drought condition*= significant, **= highly significant, PH= plant height, SB= number of sympodial branches, BP= number of bolls per plant, BW= boll weight, RWC= relative water content, ELWL= excised leaf water loss.
*= significant, **= highly significant, PH= plant height, SB= number of sympodial branches, BP= number of bolls per plant, BW= boll weight, RWC= relative water content, ELWL= excised leaf water loss.

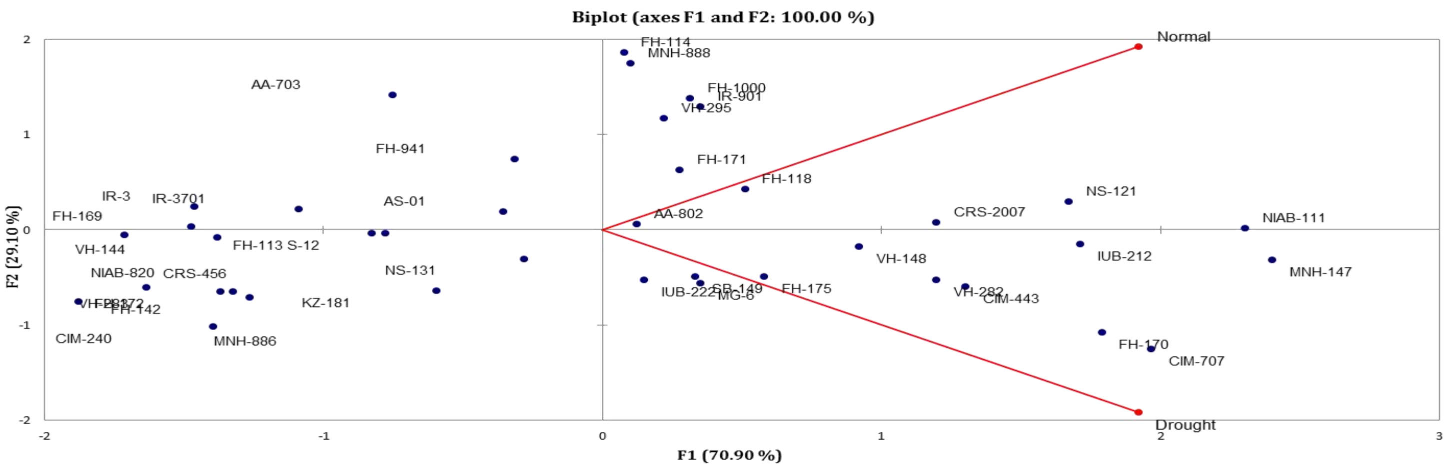

Figure 4: Biplot for number of bolls per plant of forty cotton genotypes under normal and drought conditions.

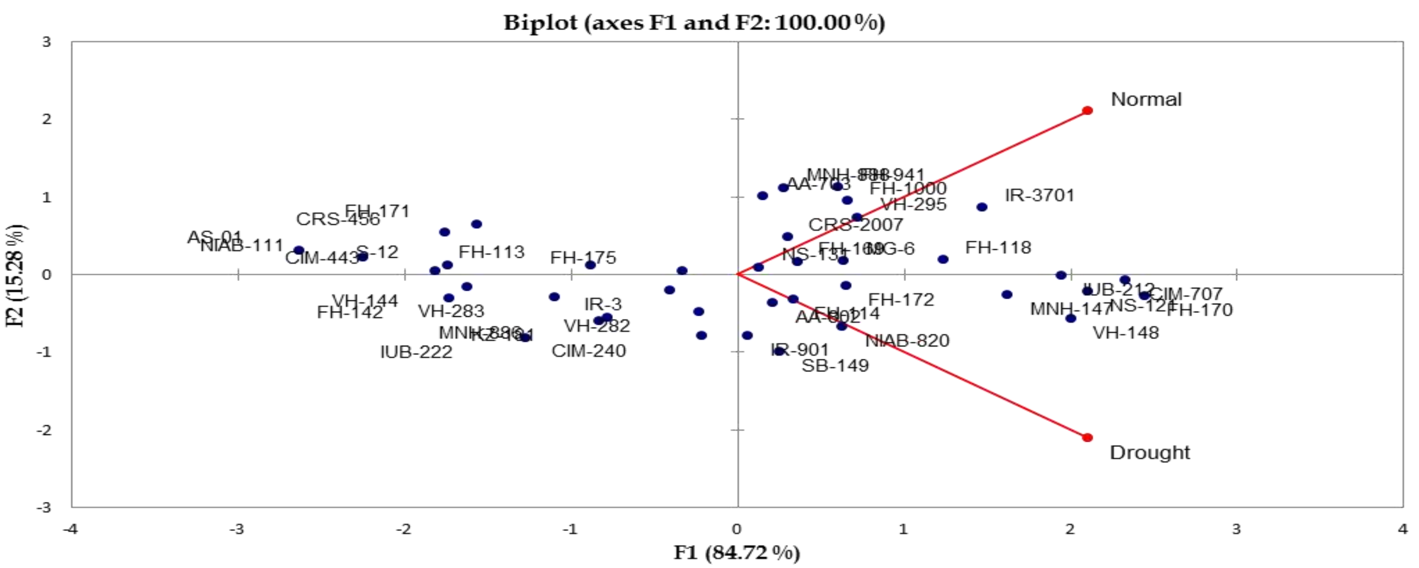

Figure 5: Biplot for boll weight of forty cotton genotypes under normal and drought conditions.

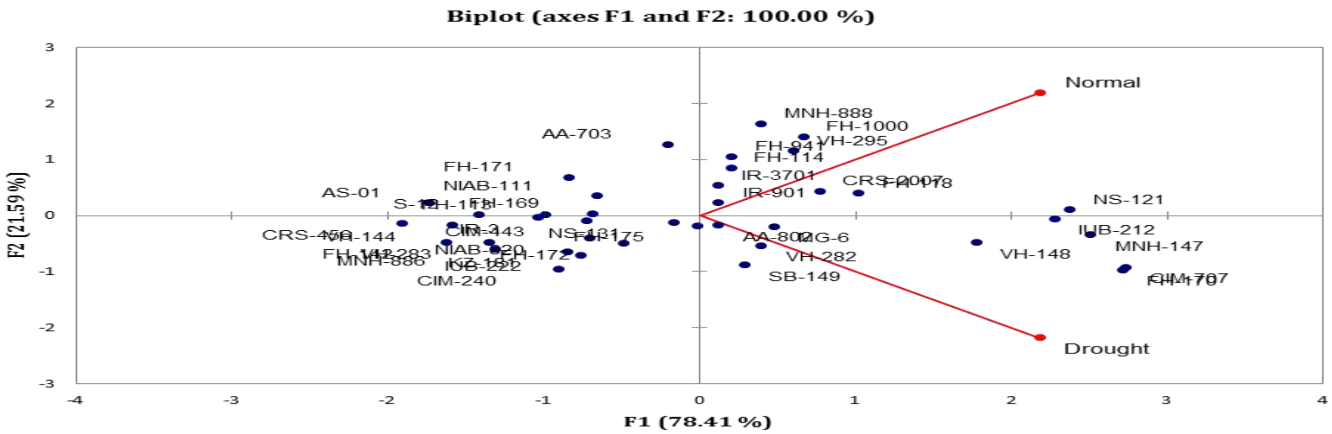

Figure 6: Biplot for seed cotton yield of forty cotton genotypes under normal and drought conditions.

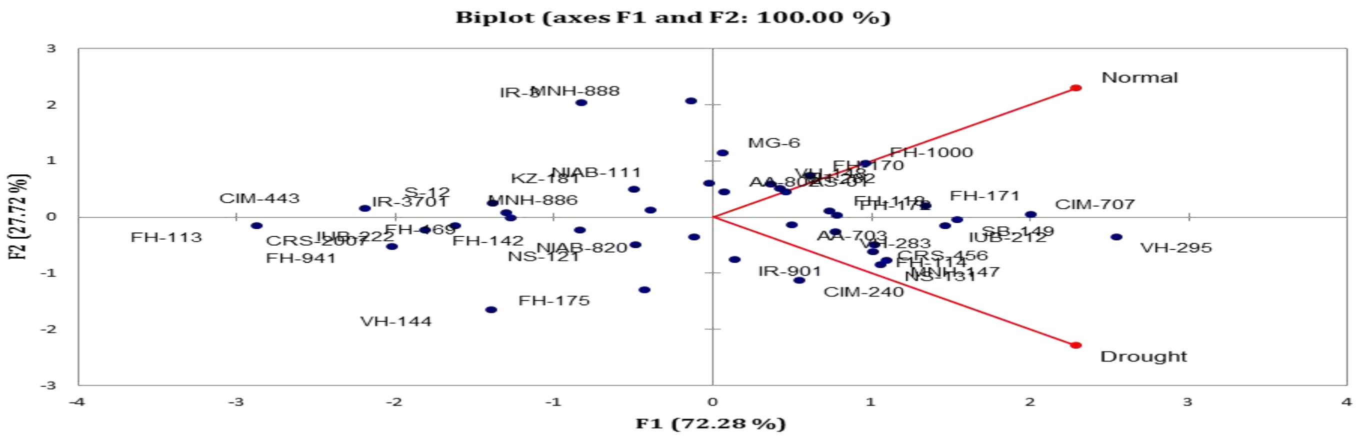

Figure 7: Biplot for relative water content of forty cotton genotypes under normal and drought conditions.

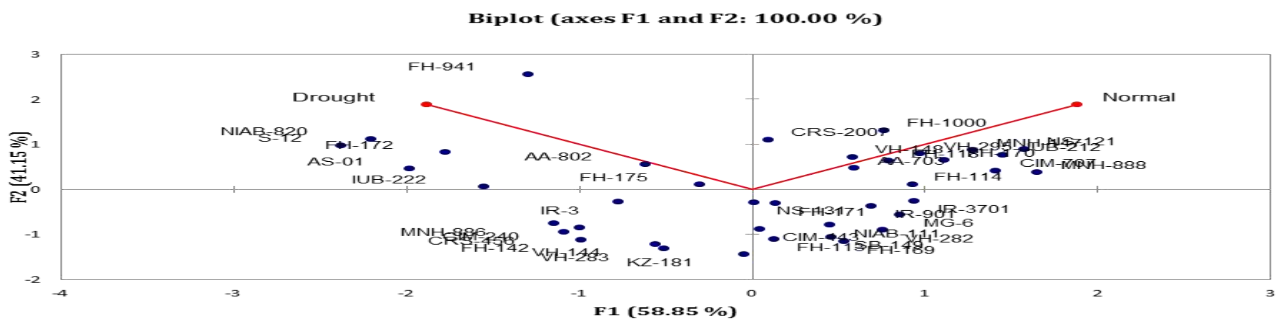

Figure 8: Biplot for excised leaf water loss of forty cotton genotypes under normal and drought conditions.

The genotypes VH-144, IUB-212, MNH-886, VH-295, IR-3701, AA-802, NIAB-111, NS-121 FH-113 and FH-142 were found as tolerant, whilst IR-3, CIM-443, FH-1000, MNH-147 and S-12 were sensitive to drought stress. It was further observed that effect of drought stress on number of bolls, boll weight and seed cotton yield was greater than that on other traits. Previously, similar responses in these traits were studied in water stressed plants of *Pennisetum glaucum* and cotton (Shakoor *et al.*, 2010; Ulloa *et al.*, 2020). Like morphological parameters, excised leaf water loss and relative water content, differentiated drought stress tolerant and sensitive genotypes. The genotypes NIAB-820, AA-703, FH-175, IUB-222 and NIAB-111 showed tolerance to drought stress which maintained high relative water content, whilst IR-3, MG-6, FH-172 and SB-149 proved to be poor retainers regarding leaf water content. Similar decrease in relative water content in wheat plants under drought stress had been reported (Matin *et al.*, 1989; Geravandi *et al.*, 2011), Therefore, high leaf water content during water deficit conditions revealed effective screening criteria to identify drought tolerant genotypes in barley and *Triticum aestivum* (Tavakol and Pakniyat, 2007; Dabbert *et al.*, 2017). For excised leaf water loss, genotypes showing lowest values were desirable due to exhibiting minimum loss of leaf water content under drought stress. Comparison of forty cotton genotypes shown valuable information about potential of the material to withstand water deficit tolerance and allowed the identification of some drought tolerant and sensitive genotypes. Comparison of genotypes based on morpho-physiological traits suggests that they might be important source of genes for enhancing drought tolerance. In previous research related to drought tolerance in cotton, Ullah *et al.* (2019) showed great variations in material tested under normal and water deficit condition which is in according to the present study.

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A Line × Tester analysis for some seed cotton yield and fiber quality traits in upland cotton

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ABSTRACT

The objective of the present study was to estimate general combining ability (GCA) of the parents and specific combining ability (SCA) of crosses for the development of high yielding cotton varieties. The study was carried out at the experimental area of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. A line × tester analysis was made to identify the superior general and specific combiners for seed cotton yield and fiber quality traits in upland cotton. Five lines/females (FH-114, FH-1000, CIM-448, CIM-707, NIAB-111) and three testers/males (TH-41-83, Cocker-307 and Allepo-41) were crossed to develop 15 F_1 hybrids. These genotypes were evaluated along with parents in RCBD with three replications. The general combining ability (GCA) and specific combining ability (SCA) mean squares for seed cotton yield, lint percentage, fiber fineness, fiber strength and fiber length were significant. The fiber fineness showed greater importance of additive gene effect while seed cotton yield, lint percentage, fiber strength and fiber length exhibited non additive genetic effects. Parents FH-114 and NIAB-111 among lines and COKER-307 from testers were found as good general combiners for most of the traits. Hence, these parents proved worth to be used in hybridization and selection program for extracting desirable plants from segregating population. F_1 crosses CIM-707 × COKER-307, CIM-707 × ALLEPO-41 and FH-1000 × COKER-307, by and large, exhibited their superiority for all traits studied and were noted as the best specific combiners. Therefore, these crosses may be preferred to improve several traits simultaneously by selection or may be used for hybrid cotton crop development.

Key word: Fiber, cotton, yield, variety, lint, genotypes.

INTRODUCTION: Cotton is a cash crop and plays an important role in strengthen the economy of Pakistan. It is an important textile fiber crop and ranked second important oil seed crop after soybean in the world (Ullah *et al.*, 2019). It occupies a unique position in the global trade as it is major agricultural and industrial crop. Cotton is a multipurpose crop that supplies five basic products: lint, oil, meal, seed hull and linters. The lint is the most important product of the cotton plant and provides much of the high quality fiber for textile industry. The other most important by-product of seed is oil, which is used primarily for cooking. It contributes about 78% in the total indigenously produced vegetable oil. Its contribution in the agriculture is 5.2% and in the GDP is 1% (Ashraf *et al.*, 2018). The basic objective of any breeding program is to develop varieties with desirable traits. The knowledge about gene action and combining ability effects help the plant breeders in the selection of suitable parents for the hybridization program (Ahmed *et al.*, 2020).

Combining ability is the ability of a parent to produce superior offspring's when combined with another parent. General combining ability (GCA) deals with the additive gene action while specific combining ability deals with dominant gene action. Scientists, Khokhar *et al.* (2018) studied additive and non-additive type of gene action for seed cotton yield per plant. Other scientists (Wang *et al.*, 2016; Bakhsh *et al.*, 2019) studied the Combining ability effect in cotton (*G. hirsuitum*). They found that general combining ability effects were significant for lint percentage while the specific combining ability effects were significant for seed cotton yield and fiber length. They concluded that an additive type of gene action was predominant for ginning out-turn%. The advantage of the present research work was to identify the various genotypes and comparing their combining ability for seed cotton yield and various fiber quality traits. Raza *et al.* (2013) studied gene action and results revealed that there were additive gene action for lint percentage, fibre length, strength and fineness. The findings of Ullah *et al.* (2019) revealed that both types of gene actions (additive and non-additive) were important for lint percentage.

The variances due to SCA were more than GCA variances for various fiber quality parameters which indicates the preponderance of non-additive nature of gene action (Simon *et al.*, 2013). The results of Shaukat *et al.* (2013) showed a higher additive gene effect in the hybrid population (first generation) due to higher GCA variances for fiber strength and fineness whereas lint percentage presented higher SCA variances, pointing towards the gene action of non-additive in nature controlling the various traits. Non-additive gene action for fiber strength and fiber uniformity percentage was also reported by Raza *et al.* (2013).

Samreen *et al.* (2008) studied the combining ability effects in upland cotton genotypes by using analysis related to line × tester and results revealed that GCA and SCA variances for all the traits were significant. However, the higher GCA variance than SCA variance revealed gene action of additive in nature. The previous results (Munawar and Malik, 2013; Raza *et al.*, 2013) revealed that there were significant differences of SCA and GCA for various fiber parameters.

OBJECTIVES: In climate change scenario, the present research was carried out to examine the genetic variation in cotton genotypes.

MATERIALS AND METHODS: The present studies on the combining ability effects of different plant characters of *Gossypium hirsutum* L. were carried out in the experimental area of the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. The experimental material was developed by crossing 8 varieties namely FH-114, FH-1000, CIM-448, CIM-707, NIAB-111, TH-41-83, Cocker-307 and Allepo-41, according to line × tester method. These varieties were grown in 12" × 12" earthen pots during in the green house. At flowering stage five lines i.e. FH-114, FH-1000, CIM-448, CIM-707, NIAB-111 were used as seed parents, and were pollinated by TH-41-83, Cocker-307 and Allepo-41 (testers) following line × tester fashion. The temperature in the greenhouse was maintained between 60°F and 100°F using steam as well as electric heaters. The seed parents were hand emasculated in the evening and pollinated the following morning to produce enough F_1 hybrid seed. Extreme precautionary measures were taken to avoid pollen contamination of the genetic material during selfing and crossing operation. The list of complete sets of parents and their crosses is given in table 1. The seeds of 15 Crosses and their 8 parents were sown in the field in a Randomized Complete Block Design with three repeats. The seeds were sown in single row plot having ten plants spaced 30 cm within the row and 75 cm between the rows. Normal agronomic practices and plant protection measures were adopted during growth and development of the plant. The data were taken on five consecutive middle plants, while one plant at both the end of each row was left as non-experimental. The mature bolls of each plant were picked and seed cotton was obtained. The total produce of each plant was obtained by picking seed cotton twice and added up to record the seed cotton yield of that plant. Picking was done when the dew had evaporated. The harvesting was weighed by electrical balance and mean seed cotton yield was calculated. Clean and dry sample of seed cotton of each plant was weighed and ginned separately with single roller electric gin in the laboratory. The lint obtained from each sample was weighed and ginning % was calculated by the following formula.

$$\text{Lint percentage} = \frac{\text{Weight of lint in a sample}}{\text{Weight of seed cotton in a sample}} \times 100$$

Parents		Crosses
Lines	Testers	
FH-114	TH-41-83	FH-114 × TH-41-83
	Cocker-307	FH-114 × Cocker-307
	Allepo-41	FH-114 × Allepo-41
FH-1000	TH-41-83	FH-1000 × TH-41-83
	Cocker-307	FH-1000 × Cocker-307
	Allepo-41	FH-1000 × Allepo-41
CIM-448	TH-41-83	CIM-448 × TH-41-83
	Cocker-307	CIM-448 × Cocker-307
	Allepo-41	CIM-448 × Allepo-41
CIM-707	TH-41-83	CIM-707 × TH-41-83
	Cocker-307	CIM-707 × Cocker-307
	Allepo-41	CIM-707 × Allepo-41
NIAB-111	TH-41-83	NIAB-111 × TH-41-83
	Cocker-307	NIAB-111 × Cocker-307
	Allepo-41	NIAB-111 × Allepo-41

Table 1: The list of complete set of parents and their crosses.

Fiber length, fiber strength and fiber fineness of each plant were measured using Spin able HVI-900. HVI-900 is a computerized high volume instrument which provides a comprehensive profile of raw fiber. It measured the most important fiber characteristics such as strength, length, fineness, uniformity, elongation and others within a quick period of time according to the international trading standards. Mean values of these characters were then calculated. The data on the above mentioned parameters were statistically analyzed following the analysis of variance technique (Steel *et al.*, 1997) in order to see whether genotypic differences for each of the characters are significant. Combining ability analysis was performed by using line × tester analysis (Kempthorne, 1957).

RESULTS: The analysis of variance following line × tester analysis for each trait was conducted separately. Mean squares were differed significantly among the traits (table 1 & 2).

Seed cotton yield: Regarding general combining ability for seed cotton yield, among the lines CIM-707 (7.54) showed maximum positive and significant GCA, so marked as a good general combiner followed by CIM-448 (5.67), whereas FH-114 (-10.95) has a maximum and negative GCA which revealed that it is a poor general combiner for this character. Among the testers Coker-307 (9.36) has a maximum and significant GCA for this character which showed that it is a good general combiners, whereas Coker-307 (-10.47) having negative significant GCA, showed that it is a poor general combiner for the character under study (table 3). The cross combinations CIM-707 × Coker-307 (60.19) and CIM-448 × Coker-307 (22.60) respectively showed maximum positive and significant SCA so revealed as good specific combiners, while CIM-448 × Allepo-41 (-31.32) showed maximum negative SCA value for this character followed by FH-114 × Allepo-41 (-30.21) which revealed that these crosses are poor specific combiner for the character (table 4). This trait is governed by non-additive genes (table 5).

Fiber length: General combining ability effects for fiber length are given in table 3. Among the lines FH-114 (1.06) showed maximum positive and significant GCA, so marked as a good general combiner for fiber length, whereas FH-1000 (-1.106) has maximum negative and significant GCA which revealed that it is a poor general combiner for this character. Among the testers TH-41-83 (0.56) has a maximum and significant GCA for this character which showed that it is a good general combiners, whereas Allepo-41 (-0.88) having negative GCA, showed that it is a poor general combiner for the character under study. Specific combining ability effects for this character are given in table. 4. FH-114 × Coker-307 (2.26) and CIM-707 × TH-41-83 (2.07) respectively showed max positive and significant SCA so revealed as good specific combiners while FH-1000 × Allepo-41 (-2.93) showed maximum negative SCA value for this character followed by CIM-448 × Allepo-41 (-2.81) which revealed that these crosses are poor specific combiner for the character . The value of ratio of dominant to additive (σ^2H /σ^2D) is more than one i.e. 7.79 so that trait is governed by dominant genes (table. 5).

Fiber strength: Regarding fiber strength NIAB-111 (1.48) showed maximum positive and significant GCA whereas FH-1000 (-0.986) has maximum negative and significant GCA. Among the testers Allepo-41 (-0.69) having significant negative GCA. The combinations NIAB-111 × Coker-307 (3.94) and NIAB-

S.O.V	DF	SCY	FL	FS	FF	LP
Rep.	1	0.09^{ns}	2.26^{ns}	0.35^{ns}	0.08^{ns}	0.70^{ns}
Gen.	22	732.73**	2.70**	0.77*	0.15*	22.29**
Parents (P)	7	469.42**	1.27^{ns}	3.89*	0.15^{ns}	32.64**
P vs C	1	3415.52**	3.56*	2.12^{ns}	0.01^{ns}	15.86**
Crosses	14	672.75**	3.36**	3.82*	0.16*	17.58**
Lines (L)	4	334.79**	3.87**	5.38*	0.22*	9.30**
Testers (T)	2	992.45**	6.07**	3.57^{ns}	0.32**	37.21**
L × T	8	761.81**	2.42^{ns}	3.11^{ns}	0.09^{ns}	16.81**
Error	22	0.49	0.88	1.57	0.07	0.24

Table 2: Mean square values of line × tester analysis for various studied traits.
Significant = *, highly significant = **, DF = degree of freedom, Rep = replications, Gen = genotypes, SCY = Seed cotton yield
FL = Fiber length, FS = fiber strength, FF = fiber fineness, LP = lint percentage

Genotypes	Seed cotton yield	Fiber length	Fiber strength	Fiber fineness	Lint percentage
Lines					
FH-114	-10.953*	1.060*	-0.436	-0.160	1.338*
FH-1000	1.250*	-1.106*	-0.986*	0.256*	0.620*
CIM-448	5.687*	-0.256	0.313	0.156	0.333*
CIM-707	7.542*	0.393	-0.370	-0.110	-0.343*
NIAB-111	-3.526*	-0.090	1.480*	-0.143	-1.948*
S.E. (GCA lines)	0.29	0.38	0.51	0.10	0.19
Testers					
TH-41-83	1.118*	0.56*	0.35	0.093	-1.827*
Coker-307	9.356*	0.33	0.34	-0.206*	2.016*
Allepo-41	-10.474*	-0.89*	-0.69*	0.113	-0.189
S.E. (GCA testers)	0.22	0.30	0.39	0.08	0.15

Table 3: General combining ability estimate of 5 lines and 3 testers for various traits.

Genotypes	Seed cotton yield	Fiber length	Fiber strength	Fiber fineness	Lint percentage
FH-114 × TH-41-83	17.517*	-1.210*	-0.483	-0.110	-0.424
FH-114 × Coker-307	-19.501*	2.256*	-0.683	-0.526*	2.724*
FH-114 × Allepo-41	-30.213*	0.756	-0.083	-0.376*	4.905*
FH-1000 × TH-41-83	0.237	-0.893	-0.700	0.290	-1.692*
FH-1000 × Coker-307	-7.289*	-2.310*	-2.900*	0.223	4.982*
FH-1000 × Allepo-41	6.149*	-2.930*	-1.073	0.690*	1.161*
CIM-448 × TH-41-83	-16.769*	1.086	2.426*	0.323*	-3.950*
CIM-448 × Coker-307	22.604*	0.936	0.026	0.773*	-0.128
CIM-448 × Allepo-41	-31.321*	-2.813*	-1.490	0.930*	-1.581*
CIM-707 × TH-41-83	-17.902*	2.070*	-2.790*	0.523*	-1.311*
CIM-707 × Coker-307	60.199*	-0.310	1.656*	-0.480*	1.757*
CIM-707 × Allepo-41	5.150*	1.006	1.006	-0.346*	-3.124*
NIAB-111 × TH-41-83	12.034*	0.856	2.606*	-0.446*	-1.947*
NIAB-111 × Coker-307	0.124	1.406*	3.940*	-0.530*	2.764*
NIAB-111 × Allepo-41	-1.017*	0.090	-1.460	0.303	-4.135*
S.E.(SCA)	0.50	0.66	0.89	0.18	0.34

Table 4: Specific combining ability estimate of 15 crosses for various traits.

-111 × TH-41-83 (2.60) respectively, showed maximum positive and significant SCA while FH-1000 × Coker-307 (-2.90) showed a maximum negative SCA value for this character followed by CIM-707 × TH-41-83 (-2.79).

Fiber fineness: Among the lines FH-1000 (0.256) showed maximum positive and significant GCA, so marked as a poor general combiner. Among the testers, Coker-307 (-0.206) having negative significant GCA, showed that it is a good general combiner for the character under study. CIM-448 × Allepo-41 (0.93) and CIM-448 × Coker-307(0.77) respectively showed maximum positive and significant SCA so revealed as poor specific combiners, while NIAB-111 × Coker-307 (-0.53) showed maximum negative SCA value for this character followed by FH-114 × Coker-307 (-0.52) which revealed that these crosses are good specific combiner for the character.

Lint percentage: General combining ability effects for lint percentage are given in table 3. Among the lines FH-114 (1.338) showed maximum positive and significant GCA, so marked as a good general combiner for lint percentage followed by FH-1000 (0.62), whereas NIAB-111 (-1.948) has a maximum and negative GCA which revealed that it is a poor general combiner for this character. Among the testers, Coker-307 (2.02) has a maximum and significant GCA was showing good general combiners whereas TH-41-83 (-1.827) having negative GCA, showed that it is poor general combiner for the character under study. FH-1000 × Coker-307 (4.982) and FH-114 × Allepo-41 (4.905) respectively showed maximum positive and significant SCA so revealed as good specific combiners ,while NIAB-111 × Allepo-41 (-4.135) showed maximum negative and significant SCA value for this character followed by CIM-448 × TH-41-83 (-3.95) which revealed that these crosses are poor specific combiner for the character (table 4). The value of ratio of dominant to additive (σ^2H / σ^2D) is more than one i.e. 101.80 so that trait is governed by dominant genes (table 5).

Traits	Genetic components					
	σ^2GCA	σ^2D	σ^2SCA	σ^2H	σ^2SCA /σ^2GCA	σ^2H /σ^2D
Seed Cotton Yield	-4.72	-9.44	380.66	380.66	-80.65	-40.32
Fiber length	0.0495	0.0990	0.7710	0.7710	15.58	7.79
Fiber strength	0.0380	0.0760	0.7668	0.7668	20.18	10.08
Fiber fineness	0.038	0.076	0.0106	0.0106	0.279	0.139
Lint percentage	0.0407	0.0814	8.2862	8.2862	203.59	101.80

Table 5: Estimation of variances due to GCA (σ^2GCA), SCA (σ^2SCA), additive (σ^2D), dominant (σ^2H), ratio of SCA to GCA (σ^2SCA/ σ^2GCA) and degree of dominance (σ^2H/ σ^2D) for various traits.

Discussion: For any genetic change to occur in a plant character, either through natural or deliberate selection, genetic variation in the character must be present. Thus the availability of information on the relative contribution of different genetic components of variation in a character is essential before subjecting the breeding population to selection. Biometric analysis of the data revealed that variation in seed cotton yield, lint percentage, fiber length, fiber strength and fiber fineness were genetically manifested. The genetic variability in each character was further partitioned into various casual components, i.e. due to general and specific combining ability as outlined by Kempthorne (1957). The relative contribution of general and specific combining ability provided some understanding on the genetic control of the character. It was revealed that non additive genetic effects were important to control seed cotton yield, fiber strength, fiber length and lint percentage as had been discussed (Ali *et al.*, 2016; Kaleem *et al.*, 2016), while additive genetic component appeared to be predominantly for fiber fineness (Khokhar *et al.*, 2018; Mahrous, 2018).

For seed cotton yield non-additive genetic component appeared to be predominant, this confirms the finding of Ali *et al.* (2016) while Munir *et al.* (2016) showed that non additive effects controlled the seed cotton yield. For lint percentage non additive genetic effects were important similar results were found by Ullah *et al.* (2019) while opposite results were shown by Ali *et al.* (2016). For fiber fineness additive genetic effects were important which confirms the finding of Khan *et al.* (2017), while finding of Kamaran *et al.* (2018) reflected it as controlled by additive gene effects. For fiber strength, non-additive genetic components appeared to be predominant this confirms the finding of Kamaran *et al.* (2018), while Nasimi *et al.* (2016) found that additive effects controlled the character. For fiber length non additive genetic components appeared to be predominant this confirms the finding of Kaleem *et al.* (2016), while Coban and Unay (2017) showed that fiber length is controlled by additive gene action.

Among the lines FH-114 proved to be a good general combiner for fiber length and lint percentage, FH-1000 for fiber fineness, CIM-707 for seed cotton yield. Among testers TH-41-83 proved to be a good general combiner for fiber strength and fiber length, COKER-307 for seed cotton yield and lint percentage, ALLEPO-41 for fiber fineness. Thus, on the basis of these results it is concluded that four parental lines i.e. FH-114, FH-1000, COKER-307, NIAB-111 may hold good promise to a breeder for exploiting variability in the characters investigated here. It had been reported that parents having good GCA for a particular character are expected to yield good hybrids (Temiz *et al.*, 2016; Ullah *et al.*, 2019) and this behavior of the parents studied here was found to be valid in the present studies e.g. CIM-707, TH-41-83, COKER-307 which were good combiners for seed cotton yield and produced good hybrids i.e. NIAB-111 × COKER-307 , NIAB-111 × TH-41-83, CIM-707 × ALLEPO-41. For lint percentage FH-114 and COKER-307 exhibited best general combining ability (GCA) and therefore their crosses, i.e. FH-114 × COKER-307 and NIAB-111 × COKER-307 gave the best performance. For fiber length TH-41-83 was the best general combiner and when it was crossed with NIAB-111 the combination yielded the best performance. Variety NIAB-111 being best general combiner for fiber strength nicked well with COKER-307. For fiber fineness CIM-448 best produced varietal combination with ALLEPO-41.

BY contrast, varieties FH-114 and COKER-307 showed poor general combining ability for fiber length, but they produced best cross combination, FH-114 × COKER-307. For fiber strength and fiber length the cross combination NIAB-111 × COKER-307 and NIAB-111 × COKER-307 were the best respectively, and had parents with poor combining ability. For seed cotton yield varietal combination CIM-707 × COKER-307 displayed best, but these crosses had originated from parents those were poor general combiner. For the fiber fineness CIM-448 and CIM-707 were revealed to have a poor general combining ability, but they yielded best cross combination. Thus, from all the results it seems that it is not always necessary that good hybrids are produced by parents having high GCA, sometimes the parents with poor GCA nick well to produce potential hybrids as had been examined in the present case. Similar opinion had been made in previous studies (Imran *et al.*, 2016; Coban and Unay, 2017).

Greater role of lines towards variation in seed cotton, fiber fineness, indicates the predominant maternal influence for these traits. By contrast testers appear to be more important for variation in number of seed cotton yield and revealed the preponderance paternal influence for this trait, the contribution of maternal and paternal influence was relatively higher for variation in lint percentage, fiber strength and fiber length. Similar results were obtained in the previous studies (Khokhar *et al.*, 2018; Bakhsh *et al.*, 2019).

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