

Line × Tester Analysis for Earliness Yield and Yield Contributing Traits in *Gossypium hirsutum* L.

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Abstract: The present study was carried out at Agriculture Research Institute (ARI) Tando Jam during 2016. The experimental material consisted of six lines viz., CRIS-134, Sindh-1, Sadori, Malmal, IR-901 and three testers; Bt-3701, Bt-121 and CIM-534. The crosses were made in line × tester mating design. F₁ hybrids along with parents were sown in Randomized Complete Block Design with four replications in 2016. Seven yield and early maturing traits were recorded like, days to 1st flowering, days to 75% boll opening, plant height(cm), sympodial branches plant⁻¹, bolls plant⁻¹, seed cotton yield⁻¹(g) and lint (%) for estimating of combining ability. The analysis of variance showed that genotypes, crosses, parents, parent vs crosses, lines, testers and line × tester were significant which demonstrated that genetic difference were present in genotypes for various yield and early maturing parameters. Among the lines, Sindh-1, CRIS-134 and testers, Bt-121 and Bt-3701 were best combiners and F₁ hybrids like CRIS-134 × Bt-3701, Malmal × Bt-3701, CRIS-134 × Bt-121 were best combiners for all characters.

Keywords: Lines, testers, line × tester, cotton genotypes, phenological and yield traits.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is a cash crop of Pakistan. It is grown chiefly for its fiber which is used in the manufacture of cloth for mankind and also used for several other purposes such as for making threads for mixing with other fibers and for extraction of oil from cotton seed. All these uses give a high industrial value to this crop and as such a handsome remuneration to the growers. Cotton is grown almost all over the world from times immemorial and perhaps earlier than the time when Peruvian mummies were clothed in it. At present cotton is grown all over the world, i.e. in India, USA, Russia, China, Brazil, Egypt, Pakistan, Turkey, Mexico and Sudan are leading cotton growing countries. Cotton is most important fiber crop which plays an important role in economic and social affairs of people. It is also an important cash crop of Pakistan known as “white gold”. It accounts for 8.2 percent of the value added in agriculture and about 3.2 percent to GDP; around two thirds of the country's export earnings are from the cotton made-up and textiles which adds over \$2.5 billion to the national economy; while hundreds of ginning factories and textile mills in the country heavily depends upon cotton. Pakistan is the fourth largest producer of cotton in the world, with average production of 1,610 TMT (Thousand Metric Ton). Pakistan is also the fourth largest consumer of cotton, with average consumption of 1,573 TMT. An

average Pakistan imports 92 TMT and exports 98 TMT. The province of Punjab accounts for the majority of the nation's production, producing 85 percent of Pakistan's total cotton, while the province of Sindh produces the other 15% of Pakistan's cotton.

There are many factors which affect the yield of cotton crop such as plant height, number of fruiting branches, number of bolls plant⁻¹, boll weight, seed index, G.O.T% etc. It is desirable for developing new cotton genotypes because they have strong relationship between yield and its various components which will facilitate to cotton breeders in selection of plants with desirable characteristics. Early maturing varieties increased the possibility that harvest can be completed before cold and rainy weather and also prevent from many pest attacks. In other way early maturity of cotton is preferred because of decreasing inputs of fertilizer, irrigation, crop protection and providing proper time for rotation of the other crops [1-3]. The main objective for a plant breeder is to evolve high yielding varieties.

MATERIALS AND METHODS

The present research was conducted at Cotton Section Agriculture Research Institute (ARI) Tando Jam during 2016. The experimental material consist five lines viz., CRIS-134, Sindh-1, Sadori, Malmal, IR-901 and three testers; Bt-3701, Bt-121 and CIM-534 were crossed in line × tester mating design to produce fifteen F₁ hybrids. These hybrids along with parents were grown in Randomized Complete Block Design

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with four replications at Cotton Section, Agriculture Research Institute Tandojam during 2016. All the cultural practices were done as recommended for cotton crop. The observation were recorded for days to 1st flowering, days to 50% boll opening, plant height (cm), sympodial branches plant⁻¹, number of bolls plant⁻¹, seed cotton yield⁻¹(g) and ginning out turn (%). The collected data were analyzed for analysis of variance through Statistix 8.1 computer software. Whereas combining ability will be estimated according to [4] and adopted by [5].

RESULTS AND DISCUSSION

The analysis of variance showed that genotypes, hybrids, parents, parent vs hybrids, lines, testers and line × tester were significant for days to 1st flowering, days to 50% boll opening, plant height, sympodial branches plant⁻¹, number of bolls plant⁻¹, seed cotton yield, and ginning out turn % (Table 1). The combining ability effects in the form of gene action it is important. Whereas σ^2 GCA/ σ^2 SCA ratio was more than one which exhibited that over-dominant type of gene action for characters it is indicated that heterozygous were more important. Similar results were reported by [6-8] they also reported over dominant type of gene action for controlling the traits.

For days to initial flowering was varied 44.00 (Sindh-1) to 54.00 days Malmal and in F₁ hybrids 44.00 (CRIS-134 × Bt-3701) to 53.50 (Sindh-1 × CIM-534) which indicated 0.5 days difference was observed in F₁ hybrids as compare to parents. The best general combiner among lines, CRIS-134 and Sindh-1 revealed negative GCA effects of -3.25 and -0.25 which was

attractive effects for earliness parameters whereas, maximum GCA effects (1.42) were given by line Sadori and Malmal which indicated lateness Table 3. However, tester Bt-3701 also recorded negative GCA effects (-1.18) for days to initial flowering and female line CRIS-134 (-3.25) negative GCA effects was showed this trait. The SCA effect of days to initial flowering was mentioned in Table 4. Six F₁ hybrids recorded negative SCA effects out of fifteen F₁ hybrids. Top three negative scorers were Malmal × IR-901 (-3.47) CRIS-134 × CIM-534(-2.30) and CRIS-134 × Bt-3701 (-2.15) for days to initial flowering while Sadori × IR-901 showed highest SCA effects (2.93) for this trait. Similar results were obtained by [7, 9, 10, 11] who reported negative GCA and SCA effects for earlier flowering.

Among the parents Sindh-1 found minimum 50%boll opening (76.50 days) and Sadori reflected maximum 50%boll opening (95.50 days). Whereas, hybrids *per se* Sadori × IR-901 expressed minimum 50%boll opening (33.50 days) and Sadori × Bt-3701 open maximum bolls of 35.00 (Table 2). The GCA effects exposed that lines Bt-121 and Malmal observed negative GCA effects (-4.48 and -4.32) for 50%boll opening and CRIS-134 detected maximum positive GCA effects (5.43) followed by Sindh-1 (1.93) for the same trait. The pollinator CIM-534 and IR-901 also recorded negative GCA effects (-0.42 and -0.17) for 50%boll opening respectively (Table 3) however nine F₁ hybrids exhibited negative SCA effects (-0.08 to -6.58). The F₁ hybrid CRIS-134 × CIM-534 recorded maximum negative SCA effects (-6.58) followed by Sindh-1 × Bt-3701 (-5.83) and Malmal × IR-901 (-3.42) for 50%boll opening (Table 4). While the F₁ hybrid Sadori × Bt-3701 displayed highest SCA effects (6.42)

Table 1: Mean Squares from Analysis of Variance for Earliness and Yield Traits in Upland Cotton Genotypes

Source of variation	D.F	Days to 1 st flowering	Days to 50% boll opening	Plant height	Sympodial branches plant ⁻¹	No. bolls plant ⁻¹	Seed cotton yield plant ⁻¹	Lint %
Replications	3	54.70	15.80	16.50	45.40	3.80	54.85	60.41
Genotypes	22	36.56**	134.09**	763.34**	90.48**	191.66**	2753.42**	21.66**
hybrids	14	31.56**	124.23**	475.12**	94.32**	176.56**	2266.95**	20.37**
Parents	7	49.93**	122.34**	887.78**	69.45**	168.42**	1782.67**	26.06**
P vs H	1	13.08**	354.39**	3799.82**	183.93**	565.76**	16359.28**	8.87**
Lines (L)	4	45.25**	222.14**	865.33**	68.32**	162.97**	4798.30**	10.09**
Testers (T)	2	23.82**	5.42*	512.39**	29.37**	106.94**	1881.47**	10.49**
L × T	8	26.65**	104.98**	270.69**	123.55**	200.75**	1097.65**	27.97**
Error	66	0.39	1.48	2.65	0.65	1.64	0.15	0.06

**Highly significant at 1% probability.

Table 2: Mean Performance of Parents and Hybrids *per se* for Various Quantitative Traits in Cotton

Parents	Days to 1 st flowering	Days to 50% boll opening	Plant height (cm)	Sympodial branches plant ⁻¹	Number of bolls plant ⁻¹	Seed cotton yield plant ⁻¹ (g)	Lint (%)
CRIS-134	45.5	27.50	145.00	28.30	56.50	150.00	38.00
Sindh-1	40.00	26.50	120.00	20.00	54.20	150.55	36.70
Sadori	43.00	29.50	146.00	21.30	52.00	145.00	36.00
Malmal	44.00	23.25	107.50	22.50	44.30	120.55	37.40
IR-901	41.00	30.00	150.00	23.20	58.75	140.30	38.00
Bt-3701	45.50	32.00	145.00	31.50	59.50	146.80	39.00
Bt-121	46.00	30.00	135.00	25.50	56.00	145.00	38.00
CIM-534	44.00	25.00	130.00	25.75	44.25	148.00	36.00
CRIS-134 × Bt-3701	44.00	37.50	118.00	28.10	56.75	160.00	35.80
Sindh-1 × Bt-3701	47.00	31.25	130.25	27.00	60.50	143.10	41.00
Sadori × Bt-3701	50.00	33.75	120.00	25.30	46.20	150.90	35.58
Malmal × Bt-3701	48.00	34.75	128.00	26.30	44.70	152.35	36.17
IR-901 × Bt-3701	49.00	35.25	110.00	24.38	60.50	136.60	36.26
CRIS-134 × Bt-121	46.00	31.00	125.00	22.65	55.00	148.00	35.05
Sindh-1 × Bt-121	49.50	36.00	135.00	29.50	47.00	129.20	35.56
Sadori × Bt-121	50.00	31.50	109.00	22.30	44.10	110.69	35.35
Malmal × Bt-121	49.00	30.00	100.00	21.60	48.30	160.30	35.42
IR-901 × Bt-121	53.00	37.25	125.30	23.70	47.00	162.30	37.74
CRIS-134 × CIM-534	52.00	32.00	100.00	22.50	46.75	120.37	34.00
Sindh-1 × CIM-534	47.00	38.00	128.00	25.00	38.35	113.30	39.90
Sadori × CIM-534	44.00	33.75	108.20	25.30	45.00	128.00	34.10
Malmal × CIM-534	48.00	32.50	118.00	24.85	48.75	120.08	36.80
IR-901 × CIM-534	47.00	31.25	120.50	24.00	50.50	133.20	40.50
LSD(5%)	2.38	1.35	2.80	0.90	1.40	3.50	1.80

Table 3: General Combining Ability (GCA) Effects for Lines and Testers of Various Traits in Upland Cotton Genotypes

LINES	Days to 1 st flowering	Days to 50% boll opening	Plant height	Sympodial branches plant ⁻¹	Number of bolls plant ⁻¹	Seed cotton yield plant ⁻¹	Lint %
CRIS-134	-3.25	5.43	3.54	-1.96	5.55	1.10	0.43
Sindh-1	-0.25	1.93	1.10	-0.54	1.63	-8.63	-0.80
Sadori	1.42	1.43	10.67	3.96	-3.48	-27.41	-0.34
Malmal	1.42	-4.32	-12.34	-1.71	-0.87	26.47	-0.69
IR-901	0.67	-4.48	-2.97	0.24	-2.84	8.47	1.40
S.E ((gi-gj)	0.25	0.50	0.67	0.33	0.52	0.16	0.10
TESTERS							
Bt-3701	-1.18	0.58	-2.82	-0.66	-0.85	11.08	-0.45
Bt-121	0.22	-0.42	5.84	1.40	2.62	-4.11	0.84
CIM-534	0.97	-0.17	-3.03	-0.74	-1.77	-6.97	-0.39
S.E (gi-gj)	0.20	0.38	0.52	0.26	0.40	0.12	0.08

Table 4: Specific Combining Ability (SCA) Effects for Various Earliness, Yield and Yield Contributing Traits of Upland Cotton Genotypes

F ₁ hybrids	Days to 1 st flowering	Days to 50% boll opening	Plant height	Sympodial branches plant ⁻¹	Number of bolls plant ⁻¹	Seed cotton yield plant ⁻¹	Lint %
CRIS-134 × Bt-3701	-2.15	-0.58	6.38	1.91	0.43	12.68	-0.17
Sindh-1 × Bt-3701	-0.55	-5.83	-0.03	-5.15	8.72	-10.89	3.37
Sadori × Bt-3701	2.70	6.42	-6.34	3.24	-9.15	-1.80	-3.19
Malmal × Bt-3701	0.85	2.17	-6.18	-1.26	-1.65	-8.04	-1.24
IR-901 × Bt-3701	1.45	4.42	5.16	0.43	4.38	15.55	-0.53
CRIS-134 × Bt-121	-2.30	-6.58	1.03	0.82	-2.73	-7.51	1.76
Sindh-1 × Bt-121	0.18	-3.08	6.75	-6.51	5.21	17.09	0.27
Sadori × Bt-121	1.78	4.92	3.09	9.94	-3.33	2.20	-0.75
Malmal × Bt-121	-1.97	-1.83	-9.84	-3.43	-1.87	-19.30	0.49
IR-901 × Bt-121	-1.82	1.67	-7.37	0.66	0.60	-18.26	-1.22
CRIS-134 × CIM-534	0.78	-0.08	0.31	-0.40	-6.37	-3.20	1.49
Sindh-1 × CIM-534	1.03	-1.58	7.06	-0.26	5.77	21.45	-0.96
Sadori × CIM-534	2.93	-0.17	0.43	5.21	-4.58	-3.48	2.37
Malmal × CIM-534	-3.47	-3.42	-8.53	-4.82	-3.40	-3.67	-3.92
IR-901 × CIM-534	0.53	3.58	8.09	-0.38	7.99	7.15	1.55
S.E (Sij-Skr)	0.44	0.86	1.15	0.57	0.90	0.27	0.18

for same trait. The negative SCA effects showed minimum 50% boll opening and these hybrids recorded the referred for early maturity cotton varieties. Similar results was obtained by [9, 10] they observed negative GCA effects for parents and SCA effects for hybrids which exhibited that negative effects showed minimum days to taken 75% flowering.

Sindh-1 found 40.50 days to first flowering and Bt-121 found highest 44.00 days to first boll opened (Table 2). However in hybrids *per se* CRIS-134 × CIM-534 observed minimum bolls (43.00) the maximum days to 1st flowering in F₁s was detected by the hybrid Sadori × CIM-534 (41.00). The estimates of general combining ability (GCA) effects among the female lines CRIS-134 and Malmal displayed negative effects (-3.90 and -1.57) respectively, on the other hand Sindh-1 (1.43), Sadori (0.10) and Bt-121 (3.93) noted positive GCA effects presented in Table 3. However among the testers Bt-3701 showed negative effects (-2.43) while CIM-534 and IR-901 exhibited positive effects (0.32 and 2.12). Three out of fifteen hybrids exhibited significant SCA effects the crosses, Malmal × CIM-534, Malmal × Bt-3701 and Sadori × IR-901 manifested highest positive and significant SCA effect of (5.55), (3.77) and (3.27) respectively. On the other hand, the

crosses Sindh-1 × CIM-534, Sindh-1 × IR-901 and Malmal × IR-901 showed significant negative SCA effects of (-7.90), (-3.87) and (-2.73) respectively (Table 4). Our results are confirm with [9, 12-14] they reported similar findings.12

Medium tall plants are desirable for higher yielding because they set the more number of the sympodial branches and cannot be lodged. Among the parents plant height was varied from 106.0 (Bt-121) to 146.00 cm (Sadori) and 85.38 (Malmal × CIM-534) to 127.63 (Sindh-1 × CIM-534) in F₁ hybrids (Table 2). The female line Sadori recorded highest GCA effects (10.67) followed by CRIS-134 (3.54) and Sindh-1 (1.10) whereas Minimum plant height is needed to protect the crop from lodging. Therefore, Malmal is a potential female parent and has highly significant GCA effect of -12.34 in the desirable direction (negative direction) for plant height (Table 3). However two testers like Bt-3701 and IR-901 depicted negative GCA effects (-2.82 and -3.03) while CIM-534 recorded positive GCA effects (5.84) for this trait. The data recording SCA effects for plant height is presented in Table 4 which revealed that six F₁ hybrids displayed negative SCA effects and rest were showed positive SCA effects. Three top scoring combinations which noted negative

effects like Malmal × CIM-534 (-9.84), Malmal × IR-901 (-8.53) and Bt-121 × CIM-534 (-7.37) whereas, positive SCA effects (8.90) was reflected from the hybrid Bt-121 × IR-901 followed by Sindh-1 × IR-901 (7.06). Negative SCA effects were more valuable than the positive because it reflects medium plant height. Similar results were also obtained by [9, 12-14] they reported significant GCA and SCA effects for plant height.

Sympodial branches plant⁻¹ was ranged from 15.50 (CIM-534) to 29.23 (Sadori) in parents whereas in F₁ hybrids 17.00 (Sindh-1 × Bt-37.01) to 28.00 (Sindh-1 × TS-50.1) Table 2. Sindh-1, Malmal and CRIS-134 were recorded negative GCA effects (-0.54, -1.17 and -1.96) for number of sympodial branches plant⁻¹ (Table 3). These lines set minimum number of sympodial branches whereas, Sadori and Bt-121 exhibited positive GCA effects (3.96 and 0.24) for this trait and set more number of sympodial branches whereas, tester CIM-534 recorded highest GCA effects (1.40) for this trait presented in Table 3. However, SCA effects showed that eight F₁ hybrids manifested negative SCA effects and seven showed positive SCA effects for number of sympodial branches plant⁻¹ (Table 4) The F₁ hybrids Sadori × CIM-534 displayed highest SCA effects (9.94) followed by Sadori × IR-901 (5.21) and Sadori × Bt-3701 (3.24) for sympodial branches plant⁻¹ Whereas, F₁ hybrids Bt-121 × Bt-3701 depicted minimum SCA effects (0.43) for sympodial branches plant⁻¹. The researchers like [9, 12-14] who also reported significant GCA and SCA effects for sympodial branches plant⁻¹.

Number of bolls plant⁻¹ it have strong correlation with seed cotton yield plant⁻¹. It is assumed that the cultivar having the more number of sympodia bearing the more number of bolls plant⁻¹ but it is not necessary that more number of sympodia to set the maximum bolls plant⁻¹ because it depends upon boll bearing types like chain boll bearing, cluster boll bearing and sparsely boll bearing. By comparing with parent cultivars, 9.95% enhancement for bolls plant⁻¹ was noticed in F₁ hybrids. The range (38.30 to 54.25) in parents and 33.35 to 58.50 in F₁ hybrids (Table 2) the line Sindh-1 set maximum (54.25) followed by Bt-121 (51.75) and Malmal set minimum (38.30) bolls plant⁻¹. The hybrid Sindh-1 × Bt-3701 and Bt-121 × IR-901 expressed highest (58.50) and minimum (33.35) number of boll plant⁻¹ was recorded from the cross Sindh-1 × IR-901 (Table 2). Two lines including CRIS-134 and Sindh-1 exposed positive GCA effects (5.55 and 1.63) while Sadori, Malmal and Bt -121 showed negative GCA

effects (-3.48, -0.87 and -2.84) for number of bolls plant⁻¹ respectively (Table 3). However, pollinator CIM-534 displayed positive GCA effects (2.62) while Bt-3701 and IR-901 noted negative GCA effects (-0.85 and -1.77) for number of bolls plant⁻¹. Among the fifteen F₁ hybrids eight recorded negative (-1.65 to -9.15) and seven crosses exhibited positive SCA effects (0.43 to 8.72). The three top scoring for SCA effects like Sindh-1 × Bt-3701 (8.72), Bt-121 × IR-901 (7.99) and Sindh-1 × IR-901 (5.77) while CRIS-134 × Bt-3701 advocated minimum SCA effects (0.43) for number of bolls plant⁻¹. These results suggested that above parents and hybrids should be preferred for developing high yielding varieties through selection in later generation. Similar results were obtained by [11-17] they suggested that a significant GCA and SCA effect for number of bolls plant⁻¹ was very important.

The range of seed cotton yield plant⁻¹ in parents of 98.50 to 150.55g and in F₁ hybrids 103.69 to 198.37, line Sindh-1 found maximum (150.55) followed by IR-901 (148.55) and Sadori gave minimum (98.50) seed cotton yield plant⁻¹ (Table 2). The hybrid CRIS-432 × IR-901 (198.37) and Malmal × IR-901, CRIS-134 × Bt-3701 depicted highest (182.08) and minimum (103.69) seed cotton yield plant⁻¹ was existed from the cross Sadori × CIM-534 (Table 2). Only three lines among five female lines including Malmal, Bt-121 and CRIS-134 reflected positive GCA effects (26.47, 8.47 and 1.10) while Sadori, and Sindh-1 revealed poorest general combining ability as it showed negative GCA effects (-27.41 and -8.63) for this trait respectively (Table 3). However, pollinator Bt-3701 exposed positive GCA effects (11.08) while CIM-534 and IR-901 noted negative GCA effects (-4.11 and -6.97) for seed yield. Among the fifteen F₁ hybrids nine observed negative (-1.80 to -19.30) and six crosses explicated positive SCA effects (2.20 to 21.45). Whereas in SCA effects the top three scoring of Sindh-1 × IR-901 (21.45), Sindh-1 × CIM-534 (17.09) and Bt-121 × Bt-3701 (15.55), while Sadori × CIM-534 detected minimum SCA effects (2.20) for seed cotton yield plant⁻¹. These results suggested that above parents and hybrids should be preferred for developing high yielding varieties through selection in later generation. Our results are confirmed with [6, 8-10, 12-15] they reported that seed cotton yield was controlled by additive and non-additive variance hence both (GCA and SCA) the variances was very important.

Lint percent is very important character because cotton is fibre crop more ginning out turn percentage was preferred. The ranged from 35.00 to 38.50% in

parents and 32.58 to 40.00 in F₁ hybrids (Table 2). Among the parents, line; CRIS-134 displayed maximum (38.00%) followed by Bt-3701 (38.00%) and IR-901 found minimum (35.00) G.O.T%. The hybrid Sindh-1 × Bt-3701 and Bt-121 × IR-901 recorded highest (40.00%) and minimum (32.58%) ginning out turn % was showed by the cross Sadori × Bt-3701 (Table 2). Two lines including CRIS-134 and Bt-121 exhibited positive GCA effects (0.43 and 1.40) while three parent lines in the sequence Sindh-1, Sadori and Malmal manifested negative GCA effects (-0.80, -0.34 and -0.69) for ginning out turn percentage respectively (Table 3). However, tester CIM-534 displayed positive GCA effects (0.84) while Bt-3701 and IR-901 depicted negative GCA effects (-0.45 and -0.39) for this trait. Out of eight combination among all F₁ hybrids expressed negative (-0.17 to -3.92) and seven crosses divulged positive SCA effects (0.27 to 3.37). The two top scoring for SCA effects like; Sindh-1 × Bt-3701 (3.37), Sadori × IR-901 (2.37) while Sindh-1 × CIM-534 reflected minimum SCA effects (0.27) for ginning out turn percentage. These results suggested that above parents and hybrids should be preferred for developing high yielding varieties through selection in later generation. Similar results were obtained by [6, 9, 13, 11, 17-19] they suggested that significant GCA and SCA effects for ginning out turn percent.

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