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HETEROSIS STUDIES OF F_1 AND F_2 HYBRIDS FOR VARIOUS TRAITS OF *Gossypium hirsutum* L.

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Development of versatile hybrids has been one of the leading objectives of Plant breeders. Difficulties have been observed in the development of F_1 Cotton hybrids thereby triggering the possible utilization of F_2 hybrids for commercial cultivation. An experiment was conducted to determine the heterotic behavior of F_1 and F_2 hybrids. Twelve lines were crossed with four testers for development of 48 hybrids followed by selfing for the generation of F_2 hybrids. Z33 × IUB09 and CIM473 × IUB08 were outstanding F_1 hybrids while Z33 × IUB09 and CRSM2007 × IUB09 were superior hybrid combinations in F_2. Both F_1 and F_2 hybrids performed extraordinarily well for all of the traits studied in present experiment and incurred mild inbreeding depression in F_2 population. In addition to the F_1 and F_2 population analysis, selected elite hybrids performed significantly higher than three commercial varieties and among them Z33× IUB09 was top yielder followed by CRSM2007 × IUB09 and CIM496 × IUB09. Superior hybrids manifested the predominant influence of non-additive gene action other than dominance coupled with best hormonal combinations. It is inferred that Z33 × IUB09 performed well not only in F_1 and F_2 populations but in field comparison as well. Such hybrids must be extracted by breeding efforts and could be launched for commercial cultivation.
Keywords: Cotton, hybrids, heterosis, hybrid vigor, lint yield

INTRODUCTION

Cotton plant in Pakistan is nearly self pollinated due to heavy pollens, absence of insect pollinators owing to intensive use of insecticides for the management of sucking insects *Bemicia tabaci* Genn., *Thrips tabaci* Lind. *Amarasca devastans* Dist. and army worm (*Spodopetra litura*). For improving the lint yield, quality, seed cotton yield and its components superior genes for different cotton genotypes can be accumulated in elite genotype. Main objective of breeding is the utilization of heterosis, its principals in comparison among self pollinated crops (Maize, Sunflower, and Rice). The major constraints for commercialization of hybrid vigor in cotton are lack of effective and dependable crossing system; therefore, F_1 seed is produced only by manual emasculation and pollination (Wu *et al.,* 2004). To avoid this limitation, Olvey (1986) the commercial use of F_2 hybrids is proposed. Seed cotton yield can be increased from 9 to 25% by use of F_1 hybrid and also lint quality can be improved (Iqbal *et al.,* 2008). Recent studies showed 21.4% and 10.7% useful heterosis in F_1 and F_2, respectively (Iqbal *et al*., 2008). F_2 hybrids produce significantly higher seed cotton yield than best commercial variety (Meredith and Brown, 1998) of Pakistan. Wu *et al.* (2004) reported 15.9 to 9.2% yield heterosis in F_1 and F_2, respectively. Tang *et al.* (1993) reported 11.8% higher yield than the commercial variety while studying 64 F_2 hybrids. Weaver (1984) stated 30.2% and 7.1% hybrid vigor over mid parent in F_1 and F_2, respectively, yield and fiber length. International institutes of China, Uzbekstan and Vietnam have produced F_1 and F_2 Cotton hybrids (Baru, 1995).

The major advantage for the use of F_2 hybrids is probable adaptation in wider range of ecological zone. Cotton breeders need to address all possible ways for enhancement of yield including utilization of commercial hybrid vigor (Loden and Richmond, 1951; Meyer, 1975; Meredith, 1984; Sheetz and Quisenberry, 1986; Baru, 1995; Davis, 1998; Iqbal *et al.,* 2008). The cotton yield in Pakistan is nearly stagnant since 1992 (Iqbal *et al.,* 2005). For improving the yield in Pakistan use of hybrid vigor is one of the possible ways as the male sterile cytoplasm system with restoral factor (Olvey, 1986) and genetic male sterility system (Weaver and Weaver, 1977) give encouragement to commercialize hybrid vigor in cotton. However use of cytoplasmic and genetic male sterilities in cotton under Pakistan condition is still a complex problem as the manual pollination has to be attempted because of the absence of insect pollinators in cotton field due to heavy use of insecticides. For commercialization of hybrid vigor in cotton Olvey (1986), Iqbal *et al.* (2003) and Iqbal (2008) purposed the use of F_2 hybrids for reducing the cost of production of seed, and to meet the demands of cotton growers in diverse ecological environment. The objective of this study was to compare the seed cotton yield and its components, lint percentage and fiber quality of F_1 and F_2 with best commercial Bt cotton variety of Punjab prince, N-121.

MATERIAL AND METHODS

The line × tester crossing system was used to obtain the breeding material for present study. Out of sixteen upland cotton genotypes (*G. hirsutum* L.) selected as parents twelve cotton genotypes were used as a lines and four Bt cotton genotypes having Cry 1AC gene were used as tester. Lines and testers were crossed manually to obtain 48 F_1 hybrids during 2010. These 48 F_1 hybrids along with parents were grown in green house tunnel in 2011 to develop F_2 seed and fresh 48 F_1 hybrids from the parents in spring season. Total 113 genotypes (16 parents, 48 F_1 hybrids, 48 F_2 hybrids and one commercial Bt cotton variety N-121 were sown in fields using RCBD with three replication on 10th May, 2011 at experimental area of the Department of Plant Breeding and Genetics, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Pakistan. The parents, F_1 genotypes and commercial variety were grown in four rows, while F_2 in ten rows. Each row was of 10 meter long. Row to row and plant to plant distance was kept 75 cm and 30 cm respectively. Within each replication the data were recorded for number of bolls per plant, average boll weight, lint percentage, and fiber length from five single guarded plants of parents, F_1 and commercial variety and fifty guarded plants in F_2. The promising/elite F_2 hybrids identified during 2011 were field planted along with three commercial varieties (N-121, ARS-802 and MNH-886) to compare their yield performance during 2012 in comparative yield trail. The seed of F_2 hybrid were obtained from F_1 hybrids cultivated during 2011.

The seed cotton yield per hectare was obtained from total plot weight. The lint percentage was determined by ginning of seed cotton of single plant on roller ginning machine. Fiber length was determined by fibrograph of lint obtained from ginning of each single plant. Recommended agronomic practices and plant protection measures were adapted for proper management and healthy crop stand. Heterosis of F_1 and F_2 hybrids over the mid parent was computed in Microsoft excel program by using the formula given by Hallauer and Miranda (1981).

$$Ht = [(F_1 - MP) / MP] \times 100$$

Inbreeding depression in F_2 was computed by formula used by Fehr, (1987).

$$\text{Inbreeding depression (\%)} = [(F_2 - F_1)/F_1] \times 100$$

RESULTS

Mean performance of seed cotton yield, number of bolls per plant, average boll weight, lint percentage and fiber length indicated that reasonable genetic diversity existed among the parents (Table 1). Seed cotton yield among the parents ranged from 2043 to 5116 kg/hectare for BH-118 and IUB-09 respectively (Table 1). Heterosis results of F_1 and F_2 hybrids over the mid parent for traits under present study are presented in Table 2 & 3 which showed that maximum hybrid vigor for number of Bolls per plant in F_1 hybrids was observed 18.7%, 18.1%, 16.9%, 16% and 15.2% for CIM473 × IUB08, MNH786 × IUB09, MNH786 × IUB08, Z33 × IUB09 and CIM496 × IUB09, respectively. Maximum hybrid vigor for boll weight in F_1 observed was 16.9%, 13.1%, 12.2% and 12%, in cross combinations of IUB1524 × IUB86, Z33× IUB09, CRSM2007 × IUB09 and CRSM38 × IR3701, respectively. One of the major objectives of this study was to study the hybrid vigor for seed cotton yield. From the Table 2 it is evident that the maximum hybrid vigor 29.1%, 27.6%, 25.9%, 24.9% and 21.2% was recorded in cross combinations of CIM473 × IUB08, CIM473 × IR3701, MNH786 × IUB09, Z33 × IUB09 and MNH786 × IR3701, respectively, for seed cotton yield in F_1 respectively.

Hybrid vigor for seed cotton yield and lint percentage is most determined factor for lint production. Maximum hybrid vigor 4.2%, 3.7%, 2.9%, 2.3% and 2.1% was recorded Z33 × IUB09, NIAB Karishma × IUB09, CIM496 × IUB08, IUB222 × IUB08 and CIM473 × IUB08 cross combinations respectively for lint percentage in F_1 hybrids (Table 2). For fiber length maximum hybrid vigor was observed 6.7%, 5.7%, 4.8%, 3.8% and 3.7% in cross combinations of Z33 × IUB09, IUB1524 × IR3701, IUB222 × IR3701, CRSM38 × IR3701 and MNH789 × IR3701, respectively, in F_1 hybrids. From Table 2 it is evident that the hybrids Z33 × IUB09 and CIM473 × IUB08 are the best genetic compositions for various traits along with MNH786 × IUB09, CRSM38 × IR3701 thereby have good hormonal combinations that showed good hybrid vigor for seed cotton yield and its components with lint percentage and fiber length.

Maximum hybrid vigor in F_2 hybrids 12.12%, 8.86%, 8.2%, 7.69%, 7.25% and 6.25% for number of bolls per plant in cross combinations CIM496 × IUB09, Z33 × IUB09, MNH786 × IUB09, MNH786 × IUB08, CRSM2007 × IUB09 and CIM473 × IUB-08 were observed, similarly CRSM2007 × IUB09, IUB1524 × IUB86 and Z33 × IUB09 were best genetic combinations for boll weight having heterotic value of 24.56%, 9.43% and 6.67 % respectively (Table 3). The highest magnitude of heterosis in F_2 hybrids was observed 38.77%, 17.8%, 13.7% and 12.66% for seed cotton yield in cross combinations CRSM2007 × IUB09, CIM496 × IUB09, MNH786 × IUB09 and Z33 × IUB09 respectively (Table 3). Maximum heterosis in F_2 hybrids for lint percentage was observed in CRSM2007 × IR3701, NIAB Krishma × IUB09, Z33 × IUB09, IUB222 × IR3701, CIM496 × IUB08 and CIM473 × IUB08 having numerical values 7.25%, 2.65%, 2.91%, 2.67%, 1.33% and 1.07% respectively. Heterotic values of 6.51%, 6.04%, 5.05%, 2.67% and 2.3% were recorded for fiber length in cross combinations CRSM2007 × IUB09, Z33 × IUB09, IUB1524 × IR3701, IUB222 × IR3701, MNH789 × IR3701, respectively (Table 3).

Table 1. Mean Yield, Yield components and lint quality traits of sixteen parents along with Standard Variety N121.

Parents	No. of bolls/plant	Av. Boll weight (g)	Yield (000 kg/h)	Lint percentage	Fiber length (mm)
MNH 786	23.00 ± 1.34	3.20 ± 0.32	3.26 ± 0.12	37.40 ± 0.32	27.60 ± 1.98
CRSM 38	28.00 ± 0.98	2.60 ± 0.45	3.20 ± 0.98	39.20 ± 1.33	31.30 ± 2.12
MNH 789	26.00 ± 1.55	2.80 ± 0.67	3.23 ± 0.12	38.60 ± 2.45	30.40 ± 1.43
IUB 1524	30.00 ± 2.13	1.80 ± 0.44	2.41 ± 0.22	35.80 ± 1.99	29.70 ± 0.88
IUB 222	31.00 ± 1.45	3.10 ± 0.24	4.27 ± 0.91	40.40 ± 3.55	30.40 ± 1.72
FH 1000	25.00 ± 9.98	3.00 ± 0.19	3.31 ± 0.11	37.80 ± 0.98	27.30 ± 1.98
BH 118	21.00 ± 1.99	2.20 ± 0.32	2.04 ± 0.12	36.60 ± 1.42	26.40 ± 0.63
CRSM 2007	38.00 ± 3.54	2.50 ± 0.09	4.21 ± 0.34	37.40 ± 1.91	26.70 ± 1.64
Z 33	41.00 ± 3.99	2.80 ± 0.12	4.91 ± 0.56	35.80 ± 0.95	24.40 ± 0.45
NIAB Krishma	26.00 ± 2.55	2.60 ± 0.13	3.01 ± 0.12	35.80 ± 1.43	27.50 ± 1.23
CIM 473	22.00 ± 1.45	3.10 ± 0.56	3.02 ± 0.21	39.40 ± 0.53	28.40 ± 0.86
CIM 496	28.00 ± 1.98	2.90 ± 0.03	3.60 ± 0.55	39.60 ± 0.95	28.00 ± 0.74
IR 3701Bt	42.00 ± 3.78	2.40 ± 0.12	4.45 ± 0.78	41.80 ± 1.42	25.70 ± 1.45
IUB 86 Bt	34.00 ± 3.24	3.50 ± 0.93	4.98 ± 0.93	38.60 ± 1.29	27.40 ± 1.36
IUB 09 Bt	38.00 ± 2.56	3.20 ± 0.34	5.12 ± 0.34	39.80 ± 1.38	28.60 ± 0.22
IUB 08 Bt	42.00 ± 4.12	2.60 ± 0.33	4.84 ± 0.91	35.40 ± 1.99	26.00 ± 0.97
N 121 (Standard)	34.00 ± 3.12	2.80 ± 0.91	4.23 ± 0.58	39.80 ± 2.12	28.40 ± 1.23

Table 2. Genetic vigor of F_1 hybrids over Mid Parent for different yield and fiber quality traits.

Hybrids	No. of bolls/plant	Av. Boll weight (g)	Yield (kg/h)	Lint percentage	Fiber length (mm)
MNH786× IR3701	13.8	3.5	21.2	1.0	-2.4
MNH786×IUB86	1.7	1.5	1.6	0.5	1.1
MNH786×IUB09	18.1	3.1	25.9	1.5	0.7
MNH786×IUB08	16.9	0.0	16.0	1.1	0.4
CRSM38×IR3701	8.5	12.0	18.4	-1.7	3.8
CRSM38×IUB86	0.0	1.6	-0.4	0.2	-0.2
CRSM38×IUB09	6.1	0.0	3.7	-1.2	0.5
CRSM38×IUB08	11.4	3.8	14.1	0.2	-0.2
MNH789×IR3701	8.8	0.0	8.8	0.0	3.7
MNH789×IUB86	0.0	-1.5	-1.7	0.7	0.6
MNH789×IUB09	0.0	0.0	-2.4	0.5	-0.3
MNH789×IUB08	11.7	-3.7	6.4	0.5	3.5
IUB1524×IR3701	5.5	4.7	5.4	1.1	5.7
IUB1524×IUB86	3.1	16.9	17.7	1.1	1.2
IUB1524×IUB09	2.9	1.6	14.6	1.5	o.1
IUB1524×IUB08	5.5	4.5	1.7	0.2	0.8
IUB222×IR3701	1.3	5.4	4.8	0.7	4.8
IUB222×IUB86	1.5	3.0	3.5	0.7	-0.6
IUB222×IUB09	1.4	1.1	-9.2	0.2	1.3
IUB222 ×IUB08	1.3	-1.7	-0.9	2.3	1.4
FH1000×IR3701	7.4	3.7	12.8	0.0	0.7
FH1000×IUB86	8.4	1.5	8.3	0.0	0.9
FH1000×IUB09	-4.7	3.2	-3.4	1.1	0.8
FH1000×IUB08	10.4	3.5	12.2	-0.5	1.7
BH118×IR3701	4.7	0.0	0.8	1.4	0.9
BH118×IUB86	1.8	-1.7	-3.6	0.7	1.1
BH118B×IUB09	11.8	0.0	10.6	0.5	1.4
BH118×IUB08	12.3	4.1	16.3	0.5	0.0
CRSM2007×IR3701	2.5	2.1	5.2	0.0	0.7
CRSM2007×IUB86	2.7	3.3	1.1	0.5	0.5
CRSM2007×IUB09	2.6	12.2	19.6	1.5	2.3
CRSM2007×IUB08	2.5	1.9	4.7	0.0	0.9
Z33×IR3701	1.2	3.8	7.7	0.0	0.9
Z33×IUB86	4.1	1.5	12.1	1.6	1.9
Z33×IUB09	16	13.1	24.9	4.2	6.7
Z33×IUB08	1.2	0.0	3.5	0.0	1.5
KRISHMA×IR3701	5.8	0.0	7.2	1.2	1.8
KRISHMA×IUB86	6.7	1.6	10.3	0.5	0.2
KRISHMA×IUB09	9.3	3.4	14.8	3.7	1.2
KRISHMA×IUB08	5.8	0.0	6.1	0.0	1.7
CIM473×IR3701	15.6	5.4	27.6	1.4	0.9
CIM473×IUB86	0.0	3.1	5.7	0.5	1.1
CIM473×IUB09	6.7	1.5	11.8	0.5	0.3
CIM473×IUB08	18.7	5.2	29.1	2.1	1.1
CIM496×IR3701	5.7	1.8	10.3	-0.2	1.3
CIM496×IUB86	6.4	3.1	12.8	0.2	1.1
CIM496×IUB09	15.2	1.6	20.1	0.0	1.0
CIM496×IUB08	2.8	5.4	10.1	2.9	2.2

Table 3. Genetic vigor studies of F_2 hybrids for different yield and fiber traits.

Hybrids	No. of bolls/plant	Av. Boll weight (g)	Yield (kg/h)	Lint percentage	Fiber length (mm)
MNH786× IR3701	4.62	-3.57	5.96	-3.03	-4.32
MNH786×IUB86	-8.77	-7.46	-15.50	0.00	0.73
MNH786×IUB09	8.20	0.00	13.70	0.00	0.00
MNH786×IUB08	7.69	-3.45	5.12	0.00	-1.49
CRSM38×IR3701	0.06	0.08	0.11	-0.03	0.00
CRSM38×IUB86	-6.45	-4.92	-11.01	-0.26	-2.21
CRSM38×IUB09	0.00	-6.90	-7.12	-2.03	-3.84
CRSM38×IUB08	-2.86	0.00	-4.64	-1.34	-3.32
MNH789×IR3701	-2.94	-3.85	-9.69	-1.49	2.32
MNH789×IUB86	-6.67	-7.94	-16.91	0.52	-0.69
MNH789×IUB09	-25.00	-10.00	-18.96	0.00	-3.05
MNH789×IUB08	0.00	-7.41	-11.22	0.00	-1.42
IUB1524×IR3701	-2.78	0.00	-7.64	-1.03	3.0
IUB1524×IUB86	-3.13	9.43	5.47	0.00	-1.23
IUB1524×IUB09	-2.94	0.08	0.00	0.01	-0.02
IUB1524×IUB08	-5.56	-4.55	-15.12	0.00	0.18
IUB222×IR3701	-4.11	1.82	-2.31	0.24	2.67
IUB222×IUB86	-7.69	0.00	-6.96	-1.77	-1.38
IUB222×IUB09	-4.35	-14.29	-19.82	-3.74	-1.02
IUB222 ×IUB08	-4.11	-12.28	-18.90	0.79	0.00
FH1000×IR3701	-4.48	-7.41	-10.97	-3.02	-1.13
FH1000×IUB86	1.69	-7.69	0.22	-0.52	0.18
FH1000×IUB09	-17.46	0.00	-19.74	0.00	0.18
FH1000×IUB08	-4.48	-3.57	-8.19	-2.19	0.56
BH118×IR3701	-4.76	-4.35	-12.71	-1.53	0.19
BH118×IUB86	-12.73	-8.77	-21.52	-1.06	0.37
BH118B×IUB09	-1.69	-11.11	-13.81	-0.52	-1.09
BH118×IUB08	1.59	-4.17	-4.86	0.00	0.38
CRSM2007×IR3701	-2.50	-2.04	-3.83	-2.02	0.00
CRSM2007×IUB86	0.00	-6.67	-9.01	0.00	-0.55
CRSM2007×IUB09	0.00	24.56	38.77	7.25	6.51
CRSM2007×IUB08	0.00	-1.96	-8.33	-1.65	0.19
Z33×IR3701	-1.20	-3.85	-2.13	-1.55	0.60
Z33×IUB86	-1.33	-4.76	0.07	0.00	0.39
Z33×IUB09	8.86	6.67	12.66	2.91	6.04
Z33×IUB08	-1.20	-3.70	-2.48	-0.56	0.40
KRISHMA×IR3701	-5.88	-4.00	-8.50	-1.55	0.75
KRISHMA×IUB86	-3.33	-4.92	-6.43	-0.54	-0.91
KRISHMA×IUB09	3.13	0.00	3.94	2.65	0.18
KRISHMA×IUB08	0.00	-3.85	-3.68	-0.56	0.93
CIM473×IR3701	0.00	-1.82	2.81	-0.99	-0.92
CIM473×IUB86	-14.29	-3.03	-14.67	-0.51	0.36
CIM473×IUB09	0.00	-1.59	1.60	0.00	0.00
CIM473×IUB08	6.25	1.75	7.24	1.07	0.00
CIM496×IR3701	-2.86	-5.66	-6.14	-2.21	0.19
CIM496×IUB86	-3.23	-3.13	-3.66	-0.77	0.36
CIM496×IUB09	12.12	-1.64	17.80	-0.50	-0.71
CIM496×IUB08	-5.71	1.82	-2.62	1.33	0.74

Table 4. Mean Squares of elite F_2 hybrids for yield and fiber traits

SOV	D.F	Yield(Kg/H)	Lint percentage	Fiber Length(mm)
Replication	2	528845.4^{**}	0.019	0.037
Genotypes	12	7973.7^{**}	5.814^{*}	3.977^{*}
Error	24	8051.2	0.172	0.040

*Significant at 0.05 %probability level; **Significance at 0.01% probability level

Table 5. Mean performance of elite F_2 hybrids for yield and fiber traits in field conditions

Genotypes	Yield (000 Kg/H)	Lint percentage	Fiber Length (mm)
MNH-786 × IUB-09	4.46 ± 0.08	39.1 ± 2.42	28.2 ± 1.34
CRSM-2007 × IUB-09	4.74 ± 0.12	39.1 ± 3.24	28.1 ± 1.98
CRSM-2007 × IUB-08	4.29 ± 0.43	36.1 ± 1.33	26.7 ± 2.12
Z-33 × IR-3701	4.17 ± 0.03	39.3 ± 2.56	25.5 ± 1.45
Z-33 × IUB-86	4.62 ± 0.34	37.5 ± 1.45	26.3 ± 1.98
Z-33 × IUB-09	5.14 ± 0.24	38.9 ± 3.23	28.5 ± 2.12
Z-33 × IUB-08	4.48 ± 0.21	35.8 ± 2.54	25.6 ± 1.78
CIM-473 × IR-3701	4.42 ± 0.31	40.5 ± 3.59	27.1 ± 2.98
CIM-473 × IUB-08	4.29 ± 1.13	38.2 ± 2.32	27.6 ± 1.21
CIM-496 × IUB-09	4.84 ± 0.43	40.1 ± 1.22	28.4 ± 3.12
N 121	3.94 ± 0.91	38.4 ± 2.11	28.2 ± 1.98
ARS 802	3.59 ± 0.34	38.4 ± 1.34	28.3 ± 1.34
MNH 886	4.06 ± 0.98	39.7 ± 2.23	28.8 ± 1.12

Table 6. Inbreeding depression for various yield and fiber traits in cotton

Hybrids	No. of bolls/plant	Av. Boll weight (g)	Yield (kg/h)	Lint percentage	Fiber length (mm)
MNH786× IR3701	-8.11	-6.90	-12.60	-4.00	-1.92
MNH786×IUB86	-10.34	-8.82	-16.83	-0.52	-0.36
MNH786×IUB09	-8.33	-3.03	-9.70	-1.53	-0.71
MNH786×IUB08	-7.89	-3.45	-9.41	-1.09	-1.86
CRSM38×IR3701	-2.63	-3.57	-6.38	-1.01	-4.05
CRSM38×IUB86	-6.45	-6.45	-10.63	-0.51	-2.05
CRSM38×IUB09	-5.71	-6.90	-10.46	-0.77	-4.32
CRSM38×IUB08	-12.82	-3.70	-16.39	-1.60	-3.15
MNH789×IR3701	-10.81	-3.85	-17.00	-1.49	-1.37
MNH789×IUB86	-6.67	-6.45	-15.47	-0.26	-1.37
MNH789×IUB09	-25.00	-10.00	-16.89	-0.51	-2.72
MNH789×IUB08	-10.53	-3.85	-16.61	-0.54	-4.79
IUB1524×IR3701	-7.89	-4.55	-12.42	-2.04	-0.68
IUB1524×IUB86	-6.06	-6.45	-10.40	-1.06	-2.42
IUB1524×IUB09	-5.71	-6.90	-12.78	-1.04	-1.71
IUB1524×IUB08	-10.53	-8.70	-16.58	-0.28	-2.77
IUB222×IR3701	-5.41	-3.45	-6.85	-0.48	-2.04
IUB222×IUB86	-9.09	-2.94	-10.17	-1.02	-0.70
IUB222×IUB09	-5.71	-3.57	-11.65	-3.98	-2.34
IUB222 ×IUB08	-5.41	-10.71	-18.11	-1.55	-1.40
FH1000×IR3701	-11.11	-10.71	-21.11	-3.02	-1.87
FH1000×IUB86	-6.25	-9.09	-7.52	-0.52	-0.72
FH1000×IUB09	-13.33	-3.13	-16.84	-1.02	-0.71
FH1000×IUB08	-13.51	-6.90	-18.14	-1.65	-1.11
BH118×IR3701	-9.09	-4.35	-13.44	-3.02	-0.76
BH118×IUB86	-14.29	-7.14	-18.58	-1.85	-0.74
BH118×IUB09	-12.12	-11.11	-22.12	-1.04	-5.51
BH118×IUB08	-11.11	-8.00	-18.22	-0.55	0.38
CRSM2007×IR3701	-4.88	-4.00	-8.62	-2.02	-0.76
CRSM2007×IUB86	-2.70	-9.68	-17.68	-0.52	-1.10
CRSM2007×IUB09	-2.56	-3.13	-5.93	-1.02	-1.06
CRSM2007×IUB08	-2.44	-3.85	-12.51	-1.65	-0.75
Z33×IR3701	-2.38	-7.41	-9.18	-1.55	-0.40
Z33×IUB86	-5.13	-6.25	-10.77	-1.59	-1.52
Z33×IUB09	-6.52	-3.23	-9.84	-1.27	-0.71
Z33×IUB08	-2.38	-3.70	-5.79	-0.56	-1.17
KRISHMA×IR3701	-11.11	-4.00	-14.67	-3.05	-1.11
KRISHMA×IUB86	-9.38	-6.45	-15.22	-1.07	-1.09
KRISHMA×IUB09	-5.71	-3.33	-9.51	-1.02	-1.06
KRISHMA×IUB08	-5.56	-3.85	-9.18	-0.56	-0.74
CIM473×IR3701	-13.51	-6.90	-19.48	-2.43	-1.83
CIM473×IUB86	-14.29	-5.88	-19.33	-1.02	-0.71
CIM473×IUB09	-6.25	-3.13	-9.18	-0.50	-0.35
CIM473×IUB08	-10.53	-3.33	-16.87	-1.05	-1.09
CIM496×IR3701	-8.11	-7.41	-14.91	-1.97	-1.10
CIM496×IUB86	-9.09	-6.06	-14.60	-1.02	-0.71
CIM496×IUB09	-2.63	-3.23	-1.95	-0.50	-1.06
CIM496×IUB08	-8.33	-3.45	-11.48	-1.55	-1.45

From the Table 5 it is evident that certain F_2 hybrids performed better than established commercial variety N121. The highest yielding F_2 hybrids were Z33 × IUB09, CRSM-2007 × IUB-09 and CIM-496 × IUB09 which yielded 5143, 4837 and 4738 kg/hectare respectively (Table 5). The increase of seed cotton yield over the standard variety N121 was 33.4%, 23.9% and 21.3% respectively for the above mentioned F_2 hybrids (Table 5). These three crosses (Z33 × IUB09, CRSM2007 × IUB09 and CIM496 × IUB09) showed -9.84%, -5.93% and -1.95% inbreeding depression for seed cotton yield (Table 6). From the Table 5 it is evident that nine cross combinations (MNH786 × IUB09, CRSM2007 × IUB09, Z33 × IR3701, Z33 × IUB86, Z33 × IUB09, Z33 × IUB08, CIM473 × IR3701, CIM473 × IUB08, CIM496 × IUB09) showed increased in yield over the commercial variety N121.

The results of present study indicated that certain F_2 hybrids could be competitive with commercial variety for yield and yield components. Three elite F_2 hybrids (Z33 × IUB09, CRSM2007 × IUB09 and CIM496 × IUB09) also showed good performance for lint percentage and fiber length which are in acceptable range of quality parameters demanded by the textile and ginning industries (Table 5). Maximum hybrid vigor loss in F_2 for seed cotton yield was observed -22.12%, -21.11% and 9.18% in BH118 × IUB09, FH1000 × IR3701, KARISHMA × IUB08 hybrids respectively (Table 6). Lowest inbreeding depression was observed -25.0% (MNH789 × IUB09), -11.11% (BH118 × IUB09), -22.12% (BH118 × IUB09), - 4 (MNH786 × IR3701) and -26.77% (IUB1524 × IUB08) for number of bolls per plant, Boll weight, seed cotton yield, lint percentage and fiber length respectively (Table 6). Maximum inbreeding depression was recorded -2.38% (Z33 × IR3701), -2.94% (IUB222 × IUB86), -1.95% (CIM496 × IUB09), -0.26 (MNH789 × IUB86) and -0.35 (CIM473 × IUB09) for number of bolls per plant, boll weight, seed cotton yield, lint percent and fiber length in F_2 hybrids. The expected inbreeding depression as per genetic basis is 50%. Low inbreeding depression in genetic basis is 50%. Low inbreeding depression might be due to non additive gene action other than dominance. Least reduction in hybrid vigor in F_2 hybrids for bolls number per plant was recorded -25% for MNH789 × IUB09 and -11.11% for average boll weight in F_2 of BH118 × IUB09. Least decrease percent over N121 for lint percentage was -1.07% for the cross combination Z33 × IUB08 while -0.4% reduction was recorded in cross Z33 × IR3701 of F_2 hybrids. The cross combination of BH118 × IR3701 showed over all hybrid vigor reduction of -9.09%, -4.35%, -13.44%, -3.02% and -0.76% for number of bolls per plant, average boll weight, seed cotton yield per hectare, lint percentage and fiber length respectively (Table 6). Due to hybrid vigor loss in F_2 of cross BH118 × IUB09 resulted decrease of -12.12%, -11.11%, -22.12%, -1.04%, and -2.51% for number of bolls plants, average boll weight, seed cotton yield, lint percentage and fiber length respectively over N121 (Table 6).

Mean of seed cotton yield, number of bolls per plant, boll weight, lint percentage, and fiber length of nine promising F_2 hybrid with three commercial varieties (standard) was presented in Table 5, which showed that the all nine F_2 hybrid genotypes gave significantly higher yield than the commercial varieties. The analysis of variance indicated that significant differences existed among the genotypes for number of bolls per plant, average boll weight, seed cotton yield, lint percentage and fiber length (Table 4). From Table 5 it is clearly evident that selected nine F_2 hybrids showed significantly higher yield than commercial varieties N121, ARS802 and MNH886. The F_2 hybrid Z33 × IUB09 gave the maximum yield 5143.6 kg per hectare with 38.9% lint and 28.5 mm fiber length which is good hormonal combination for yield and fiber quality traits. The F_2 hybrid CIM496 × IUB09 gave yield 4837.6 kg per hectare with 40.1% lint and 28.2 mm fiber length. These two cross combinations showed significant higher yield within F_2 acceptable lint percentage and fiber length, so these two crosses can be further tested on commercial scale for improvement in seed cotton yield. These traits showed that inbreeding depression in these two cross combinations is less than 50% (Table 6).

The inbreeding depression of vigour and productiveness from F_1 to F_2 are expected to be decreased up to 50% (Falconor, 1989) but in present study several cross combinations showed minute inb

DISCUSSION

Breeding depression and their yield was also higher than the commercial variety (Table 1). Similar behavior was observed in the studies undertaken by Meyer (1986), Sheets and Quinsberry (1986), Iqbal *et al.* (2003), Iqbal *et al.* (2008) and Karademir *et al.* (2011) who have reported high yielding F_2 hybrids in *Gossypium hirsutum* L. Cross combinations IUB1524 × IUB86, Z33 × IUB09, CRSM2007 × IUB09 were best F_1 hybrids for boll weight and these hybrids performed well in F_2 generation and none of these cross combinations exhibited distinguished inbreeding depression. For seed cotton yield Z33 × IUB09 and MNH786 × IUB09 performed significantly well in F_1 as well as in F_2 generation along with other cross combinations (Tables 3 and 4) but both of these depicted decreased inbreeding depression as compared to BH118 × IUB09 (Table 6). For lint percentage NIAB Krishma × IUB09, CIM496 × IUB08 and CIM473 × IUB08 were superior cross combinations along with other Hybrids in F_1 and F_2 generation but these three combinations did not showed peculiar inbreeding depression in F_2 generation. In case of fiber length CRSM2007 × IUB09, Z33 × IUB09 and IUB1525 × IR3701 were superior combinations having huge vigor in F_1 and F_2 generation having mild inbreeding depression in F_2 (Table 6). The deviation of F_2 hybrid performance from expected pattern in case of almost all of the traits in this study, is perhaps due to non-additive gene action other than dominance along with possibility of presence of plant competition within the plant population. However Somroo and Kalhoroo (2000) reported dominance type of gene action for bolls per plant, GOT, seed cotton yield, staple length due to the pronounced inbreeding depression in F_2 against vigorous impression of the same traits in F_1. Meanwhile owing to the existence of mild vigor and inbreeding depression in F_1 and F_2 generation of *Gossypium hirsutum* L. Somroo and Kalhoroo (2000) attributed that lint percentage and staple length were predominantly controlled by additive type of gene action.

The results of present study indicated that most of the F_2 hybrids did not show heterosis over the mid parents but few hybrids showed reasonable hybrid vigor for seed cotton yield that can be exploited commercially with low cost of seed production. Our results are truly inconsistence with the prediction that inbreeding depression in F_2 is almost midway to that hybrid vigor observed in F_1. These observation are also analogous with general observation that selfing of segregating generation imparts 50 percent in the production and vigor of the preceding generation. So the commercial utilization of hybrid vigor among F_2 hybrids were compared with commercial variety. Increased inbreeding depression was peculiar in the decendents of Vigorous F_1 hybrids as has been reported by Gunaseelain and Swami (1988), Wang and Pan (1991) and, Somroo and Kalhoro (2000). Most of the F_1 and F_2 hybrids showed decrease in seed cotton yield, number of bolls and boll weight than the commercial variety.

From the present study it is concluded that F_2 generation can be cultivated in field for commercial use of hybrid vigor and cost of seed production can be reduced. These findings are similar to previous findings of Meyer (1975), Sheets and Quinsberry, (1986), Iqbal *et al.* (2003), Iqbal *et al.* (2008) and Karademir *et al.* (2011) who suggested that F_2 hybrid can be used for commercial purpose instead of F_1 hybrid owing to its good performance and low cost. The significant difference of hybrid vigor loss in F_2 from expected 50% may be due to non-additive gene action other than dominance. It's further concluded that F_2 can produce a better combination for yield and fiber quality traits as in F_2 there is more genetic variation so it might be adapted in wider ecological zone than conventional varieties and F_1. So the question related to its stability in multiple environmental conditions remains open as to test its performance wide range of environmental conditions are required.

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