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GENETIC VARIABILITY AND CORRELATION STUDIES IN F_4 POPULATIONS OF UPLAND COTTON

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ABSTRACT

Genetic variability, heritability and correlation studies were carried out among F_4 populations of upland cotton during 2014 at the University of Agriculture, Peshawar, Pakistan. Eight upland cotton genotypes i.e. SLH-284, CIM-446, CIM-473, CIM-496, CIM-499, CIM-506, CIM-554 and CIM-707 and their 59 F_4 populations were grown in a randomized complete block design with three replications. Genotype means revealed highly significant differences for all the traits. On average, the F_4 populations showed best performance than parental cultivars for yield attributing traits and eventually increased the seed cotton yield. Heritabilities (broad sense) were moderate to high in magnitude for all the traits. Major yield components i.e., plant height, bolls per sympodia, boll weight and seeds per boll revealed significant ($p \leq 0.01$) positive correlation with seed cotton yield. However, monopodia showed non-significant positive correlation. Overall, the F_4 populations CIM-707 × CIM-506 S_1, CIM-446 × CIM-284 S_2, SLH-284 × CIM-499 S_2 and CIM-554 × CIM-473 S_2 exhibited maximum boll weight and bolls per sympodia and eventually the seed cotton yield. Results further revealed that F_4 populations with larger genetic potential, positive association between yield and yield contributing traits and moderate to high heritability could guide intensive selection for improvement in segregating populations.

Key words: Genetic variability; correlation; heritability; yield related traits; F_4 populations; upland cotton

INTRODUCTION

Upland cotton (*Gossypium hirsutum* L.) leads the world's cotton fiber production and accounting for approximately 90%. Cotton is an important cash crop in Pakistan and sustains millions of people in many sectors such as production, ginning factories, textile mills, export, and business of cotton byproducts (Imran *et al*., 2011; Khan *et al*., 2015). During 2014-15, cotton crop was grown on 2.961 million hectares and seed cotton production was 13.983 million bales with average seed cotton yield of 802 kg ha^{-1} (PBS, 2015). Our national yield is still low than other cotton growing countries due to low yielding genotypes, cotton leaf curl virus (CLCuV), insect pests, rains and floods (Khan *et al*., 2011).

Plant breeders are interested in quantitative rather than qualitative genetics as majority of the characters including seed cotton and lint yields, their components and fiber quality traits are polygenic. The success of cotton programme is largely depends on the choice and exploitation of potential parental cultivars for hybridization, followed by selection for favorable gene combinations. However, variation in a population controlled and modified to a greater extent by the environment (Gul *et al*., 2014). Knowledge about genetic variability provides dependable tool to the breeder for crop improvement. Higher heritability, genetic advance and interdependence of yield and yield components are earnestly required by the breeder to improve yield and fiber quality of cotton genotypes (Abbas *et al.*, 2013). Consequently, in plant breeding, the identification and exploitation of genotypes with better genetic potential is a continuous pre-requisite for production of physiologically efficient and genetically superior genotypes showing promise for enhanced production per unit area under a given set of environmental conditions. Therefore, widespread study of the genetic mechanism of the plant characteristics is necessary.

Before initiating any cotton improvement program, information about the genetic potential of various genotypes, heritability and inheritance pattern of various characters and degree of association of yield with various morphological and yield traits is important for the breeders to handle a problem wisely and enhance the yield to a sufficient extent (Ahmad *et al*., 2008; Makhdoom *et al*., 2010). Similarly, association of heritability with selection response helps in understanding the mode of inheritance of various quantitative traits (Tabasum *et al.*, 2012). Therefore, a research project was planned to quantify the genetic potential, heritability and genetic gain in F_4 populations and their parental genotypes and correlation of seed cotton yield with various morpho-yield traits.

MATERIALS AND METHODS

Breeding material and experimental design: Parental genotypes i.e. SLH-284, CIM-446, CIM-473, CIM-496, CIM-499, CIM-506, CIM-544 and CIM-707 and their 59 F_4 populations (selection made in F_3 during 2013) were grown during the crop season 2014 at The University of Agriculture, Peshawar, Pakistan. The experiment was laid out in a randomized complete block (RCB) design with three replications. Each treatment had four rows, five meters long and having 30 and 75 cm plants and rows spacing, respectively. Thinning was performed after two weeks of germination to ensure single plant per hill. Similarly, other cultural practices including hoeing, irrigation, fertilizer and insecticide applications were carried out as per recommended package for cotton. Two hand pickings were made on individual plant basis during the month of November and to record the data on various variables.

Traits measurement and statistical analyses: Data were recorded on plant height, monopodia per plant, bolls per sympodia, boll weight, seeds per boll and seed cotton yield. All the data were subjected to analysis of variance (Steel *et al*., 1997). Means for each trait were further separated and compared by using least significant difference (LSD) test at 5% level of probability. Genotypic (GCV) and phenotypic coefficients of variance (PCV), heritability (broad sense) and genetic advance were computed according to Burton and Devane (1953), Johnson *et al.* (1955) and Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

Analysis of variance revealed that mean values of the F_4 populations and their parental lines showed highly significant differences for all the traits (Table 1). Plant height ranged from 94.73 to 121.20 cm and 76.67 to 159.00 cm in parental cultivars and F_4 populations, respectively (Fig. 1). The F_4 population CIM-446 × CIM-707 S_2 showed minimum plant height (76.67 cm) and was at par with seven other F_4 populations ranging from 77.07 to 93.00 cm. However, maximum plant height (159.00 cm) was observed in F_4 population SLH-284 × CIM-499 S_2 and it was found at par with F_4 population CIM-554 × CIM-506 S_2 (147.33 cm). The later genotype was again at par with six other F_4 populations ranged from 130.70 to 137.80 cm. Other genotypes revealed medium plant height. Genotypic (GCV) and phenotypic coefficients of variation (PCV) values for plant height were 12.73% and 13.82%, respectively. For plant height, the broad sense heritability was 0.85, while the selection response was 18.36 cm (Table 2). High estimates of heritability and selection response suggested that the genetic variance could play an important role in inheritance and improvement of the said trait. Heritability of different genotypes for various morpho-yield traits is earnestly required for the evaluation of parental cultivars for rewarding breeding programs (Bibi *et al*., 2011a, 2011b). High heritability coupled with selection response in cotton crop suggested the feasibility of selection in early segregating generations (Khan *et al*., 2010a; Batool *et al.*, 2010).

Plant height revealed highly significant positive correlation ($r = 0.369^{**}$) with seed cotton yield (Table 3). Significant positive correlation in upland cotton has also been reported between plant height and seed cotton yield in the past (Ahmad *et al*., 2008; Khan *et al*., 2009; 2010a). However, due to lodging threat, negative correlation of plant height with bolls per plants and seed cotton yield had been noticed in some previous studies in upland cotton (Elsiddig *et al*., 2007; Makhdoom *et al*., 2010; Panni *et al*., 2012). Contradictory findings reported in past and present studies about the plant height might be due to genotypic and environmental variations and may be due to different genetic background of the breeding material used under various environmental conditions.

Monopodia per plant varied from 0.47 to 1.80 and 0.40 to 2.40 in parental genotypes and F_4 populations, respectively (Fig. 2). The F_4 population SLH-284 × CIM-707 S_1 revealed minimum monopodia per plant (0.40) and was found at par with five other F_4 populations and parental cultivars ranging from 0.46 to 1.06. However, F_4 population CIM-473 × SLH-284 S_1 exhibited maximum monopodia per plant (2.40) and the said population was found equal in performance with 12 F_4 populations including five promising F_4 populations and one parental cultivar CIM-506 ranging from 1.73 to 2.33 monopodia per plant. All other genotypes including parental cultivars and F_4 populations showed medium number of monopodia. Genotypic coefficient of variability (36.77%) was smaller than phenotypic (42.29%). Heritability (bs) and selection response completely for monopodia per plant were 0.76 and 0.54, respectively (Table 2). Present results revealed that in inheritance of monopodia, the genetic variances played an important role and there is an opportunity in the said genotypes for further decrease in vegetative branches through intensive selection. In past studies, similar genetic variability was exhibited by various cotton populations for monopodia (Ahmad *et al*., 2008). Monopodia per plant manifested non-significant positive correlation (r = 0.113) with seed cotton yield (Table 3) and that is why the breeders are mostly interested in less or no monopodia. However, positive correlation of seed cotton yield with monopodia per plant in *G. hirsutum* L. genotypes was also reported (Bibi *et al*., 2011a). However, it was evident from the past studies that vegetative branches have direct negative effect on agronomic attributes of upland cotton (Ahmad *et al*., 2008; 2011).

Bolls per sympodia ranged from 1.40 to 2.07 and 1.23 to 2.50 in parental cultivars and F_4 populations, respectively (Fig. 3). However, on average, parental cultivars (1.72) and their F_4 populations (1.87) produced comparable bolls per sympodia. Maximum bolls per sympodia (2.50) were found in F_4 population CIM-707 × CIM-506 S_1 and it was found at par with seven other genotypes including one parental cultivar (CIM-496) ranging from 1.96 to 2.46. However, F_4 population CIM-506 × CIM-446 S_2 revealed minimum bolls per sympodia (1.23) and found at par with four other F_4 populations and five parental cultivars ranging from 1.26 to 1.76. Other genotypes were having medium number of bolls per sympodia. Genotypic and phenotypic coefficients of variation values were 10.92% and 15.02%, respectively. Heritability (bs) and selection response values were 0.53 and 0.21, respectively (Table 2). Heritability and expected response to selection also exhibited that bolls per sympodia were mostly administered by genetic variance and has span for further improvement.

Correlation between bolls per sympodia and seed cotton yield was highly significant positive (r = 0.437^{**}) (Table 3). Bolls per sympodia also play an important role in managing seed cotton yield and act as a major yield component and showed increase in F_4 population than parental genotypes by comparing the mean ranges as discussed in the former paragraph. Results exhibited that bolls per sympodia were found positively correlated with seed cotton yield, therefore, the genotypes having maximum bolls per sympodia also provided increased seed cotton yield. Seed cotton yield and yield components including bolls per sympodia revealed positive association in *G. hirsutum* L. (Khan *et al*., 2009). Plant type characteristic like bolls per sympodia had positive association with seed cotton yield in cotton (Bibi *et al*., 2011a). Fruiting branches showed positive relationship with plant height and that association may be considered as selection criteria to have indirect improvement in seed cotton yield in upland cotton (Ahmad *et al*., 2011).

Boll weight ranged from 2.50 to 3.29 g and 2.46 to 4.15 g in parental cultivars and F_4 populations, respectively (Fig. 4). On average, F_4 populations (3.15 g) showed increased boll weight than parental cultivars (2.95 g). Maximum boll weight (4.15 g) was shown by F_4 population CIM-707 × CIM-506 S_1 and it was found at par with nine other F_4 populations ranging from 3.53 to 4.11 g. The F_4 population CIM-707 × SLH-284 S_2 revealed minimum boll weight (2.46 g) and was found alike in performance with three other F_4 populations viz., CIM-473 × CIM-707 S_2, CIM-707 × CIM-499 S_2, CIM-473 × CIM-499 S_2 and five parental cultivars (CIM-499, CIM-506, CIM-496, CIM-707 and CIM-446). Other genotypes including parental cultivars and F_4 populations revealed medium boll weight. Genotypic coefficient of variability (9.58%) was smaller than phenotypic coefficient of variability (11.95%) for boll weight. Heritability (bs) and selection response values for boll weight were 0.64 and 0.34 g, respectively (Table 2). High broad sense heritability and significant positive correlation of boll weight with yield was also illustrated in upland cotton (Ahmad *et al*., 2008). In past studies, moderate to high heritability was observed for bolls per plant, boll weight and seed cotton yield in upland cotton and suggested that these traits have much room for further improvement through selection in early segregating generations in upland cotton (Khan *et al*., 2009; Batool *et al*., 2010; Khan *et al*., 2010a; Ahmad *et al*., 2011). Correlation of boll weight with seed cotton yield was significant positive (r = 0.328^{**}) (Table 3). Boll weight is also an imperative yield trait after boll number, and therefore, the trait should be focused during evaluation of genotypes for enhanced seed cotton yield. In early segregating generations, the correlation between boll weight and seed cotton yield was positive in upland cotton (Soomro *et al*., 2010; Khan *et al.*, 2007).

Seeds per boll varied from 26.84 to 31.72 and 22.73 to 31.33 in parental cultivars and F_4 populations, respectively (Fig. 5). On average, the parental cultivars showed more seeds per boll (29.87) than their F_4 populations (26.56). Maximum seeds per boll (31.72) were observed in parental cultivar CIM-496, however, it was found at par with 16 F_4 populations (in which the promising ones were SLH-284 × CIM-473 S_1, CIM-554 × CIM-473 S_2, CIM-506 × CIM-499 S_1) and six parental cultivars (CIM-707, CIM-499, CIM-446, SLH-284, CIM-473 and CIM-506) ranging from 27.87 to 31.33. However, F_4 populations viz., CIM-473 × CIM-499 S_2, CIM-446 × SLH-284 S_2, CIM-473 × CIM-707 S_2, CIM-707 × SLH-284 S_2, CIM-473 × CIM-499 S_1 and CIM-707 × CIM-499 S_1) revealed minimum seeds per boll, and were found at par with 32 other F_4 populations ranging from 23.73 to 26.47. All other F_4 populations showed medium seeds per boll. For seeds per boll, the genotypic and phenotypic coefficients of variations values were 5.71% and 7.70%, respectively. Broad sense heritability was 0.55, whereas the selection response value was 1.59 (Table 2). Heritability estimates with expected response to selection were moderate. Seeds per boll had significant ($p \leq 0.01$) positive correlation (r = 0.197^{**}) with seed cotton yield (Table 3). Significant positive association justified that said genotypes have genetic potential to boost up the seeds per boll. Fibers are the direct product of cottonseed, and due to this reason, seeds per boll play an important role in managing the seed cotton and lint yields. Past investigations showed that seeds per boll had positive association with yield in upland cotton (Bibi *et al*., 2011b). The cotton genotypes revealed greater genetic variation for seeds per boll and boll weight and these traits manages the seed cotton and lint yields in upland cotton (Makhdoom *et al*., 2010). Similarly, medium heritability was also observed for seeds per boll in upland cotton populations (Bibi *et al*., 2011a). However, in some other studies, the seeds per boll manifested non-significant negative correlation with seed cotton yield (Khan *et al*., 2010a, 2010b). Therefore, during selection, breeders must keep in mind direct and indirect effects of seeds per boll on seed cotton yield.

Seed cotton yield per plant ranged from 58.32 to 80.96 g and 40.27 to 123.28 g in parental cultivars and F_4 populations, respectively (Fig. 6). On average, the F_4 populations showed more seed cotton yield per plant (80.49 g) than their parental cultivars (73.08 g). The F_4 population CIM-707 × CIM-506 S_1 exhibited maximum seed cotton yield (123.28 g), and it was found at par with eight other F_4 populations (CIM-446 × CIM-284 S_2, SLH-284 × CIM-499 S_2, CIM-554 × CIM-496 S_1, CIM-499 × CIM-707 S_1, CIM-707 × CIM-499 S_1, CIM-446 × CIM-499 S_1, CIM-554 × CIM-473 S_2 and CIM-499 × CIM-506 S_1) ranging from 98.13 to 122.20 g. However, the F_4 population CIM-473 × CIM-499 S_1 revealed minimum (40.27 g) seed cotton yield and found alike with five other F_4 populations (CIM-446 × CIM-707 S_1, CIM-446 × CIM-707 S_2, CIM-506 × CIM-446 S_2, CIM-473 × CIM-499 S_2 and CIM-446 × CIM-554 S_2) and two parental cultivars (CIM-446 and CIM-499) ranging from 44.80 to 65.43 g. All other F_4 populations and parental cultivars were having medium seed cotton yield per plant. Genotypic coefficient of variation (19.43%) was found smaller than phenotypic coefficient of variability (22.63%). Broad sense heritability and selection response values were 0.74 and 18.59 g, respectively, for seed cotton yield per plant (Table 2). Greater genetic variability, heritability and genetic advance values were noted with positive correlation of seed cotton yield with bolls per plant and lint yield at both genotypic and phenotypic levels (Elsiddig *et al*., 2007; Desalegn *et al*., 2009; Khan *et al*., 2009, 2010a). Seed cotton yield is the final output of the crop, which mainly depends on boll number and boll weight. In present study, seed cotton yield was positively interrelated with all the characters. Yield is complex trait and depends on yield components, and that is why the yield management is difficult than all other morphological and yield related traits (Ahmed *et al*., 2006; Magadum *et al*., 2012). The seeds per plant and boll weight executed high positive direct impact on seed cotton yield and these results were in line with findings of past researchers (Iqbal *et al*., 2006; Preetha and Raveendran, 2007; Iqbal *et al*., 2011).

Table 1. Mean squares with CV (%) for various traits in upland cotton.

Variables	Mean squares			F. Ratio	CV (%)
	Replications (d.f. = 02)	Genotypes (d.f. = 66)	Error (d.f. = 132)		
Plant height	918.571	718.192	109.452	6.5617^{**}	9.35
Monopodia per plant	0.732	0.786	0.197	3.9895^{**}	36.83
Bolls per sympodia	1.032	0.233	0.110	2.1282^{**}	17.85
Boll weight	0.186	0.445	0.176	2.5346^{**}	13.40
Seeds per boll	22.479	12.936	5.840	2.2152^{**}	8.97
Seed cotton yield per plant	4399.794	967.456	249.829	3.8725^{**}	19.86

*,** = Significant at p≤0.05 and p≤0.01, d.f. = degree of freedom, CV = coefficient of variation

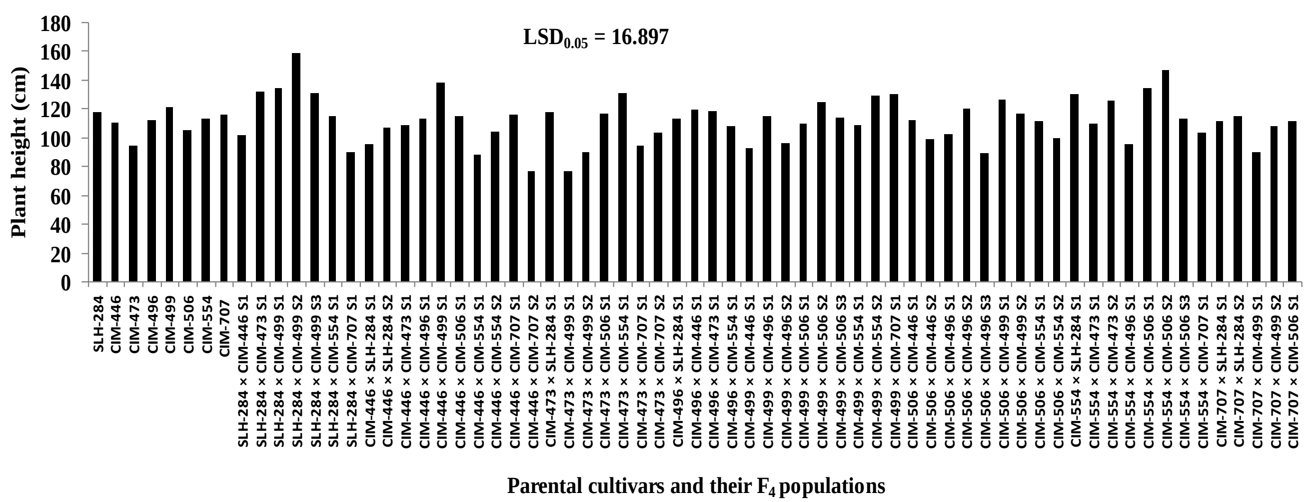

Fig. 1. Mean performance of parental cultivars and their F_4 populations for plant height in upland cotton.

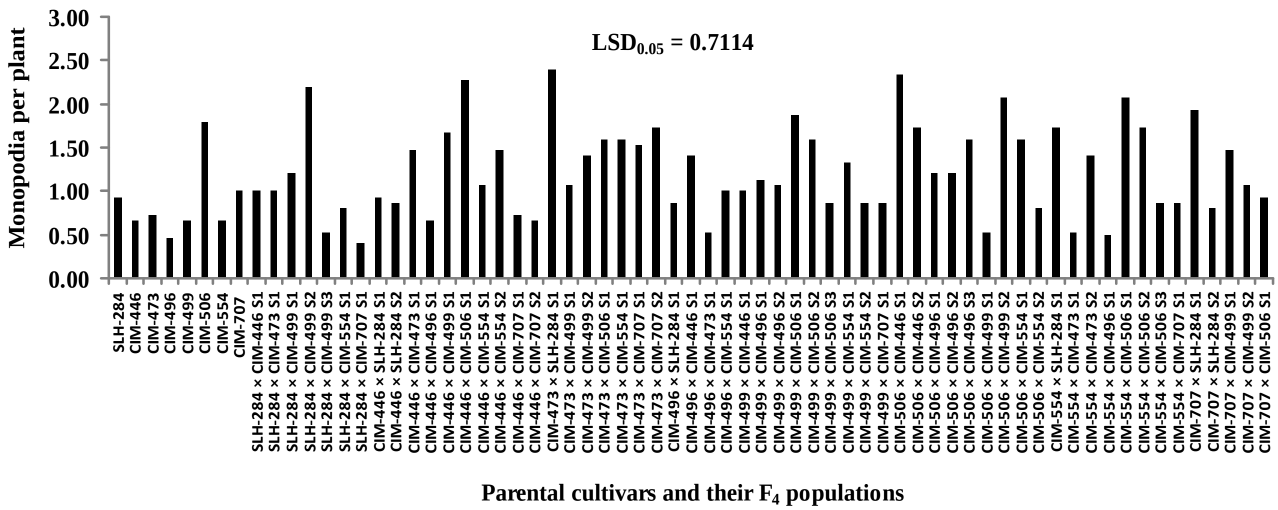

Fig. 2. Mean performance of parental cultivars and their F_4 populations for monopodia in upland cotton.

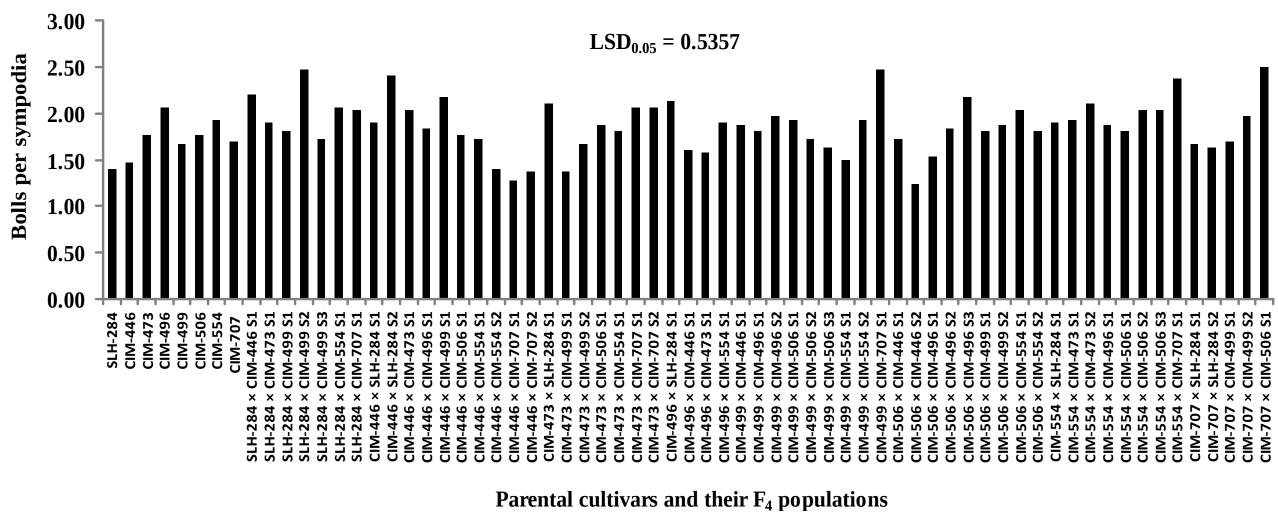

Fig. 3. Mean performance of parental cultivars and their F_4 populations for bolls per sympodia in upland cotton.

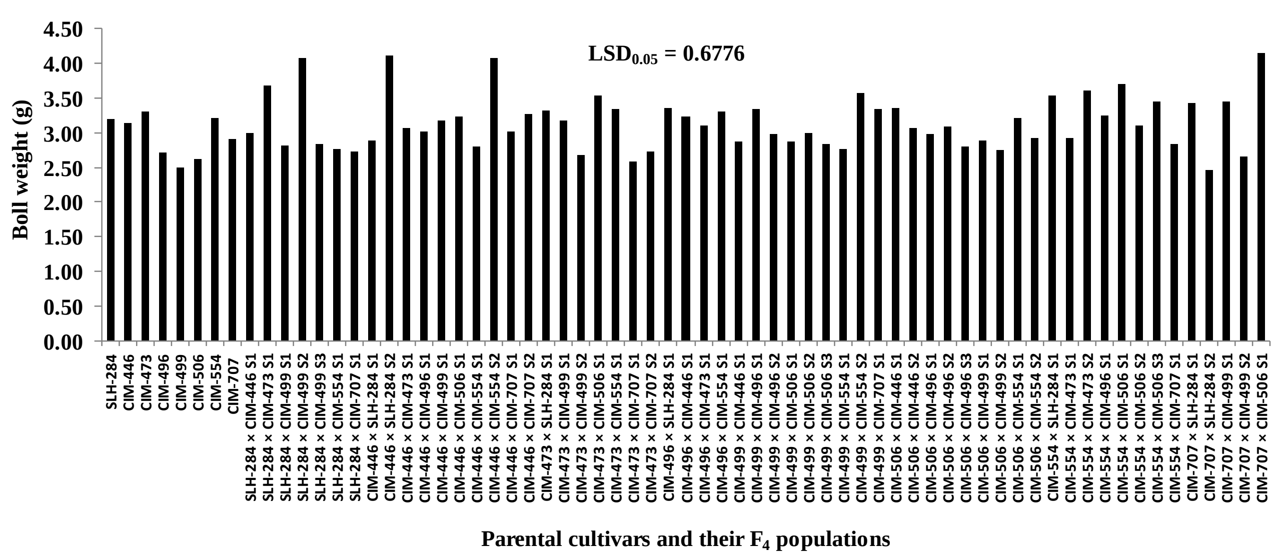

Fig. 4. Mean performance of parental cultivars and their F_4 populations for boll weight in upland cotton.

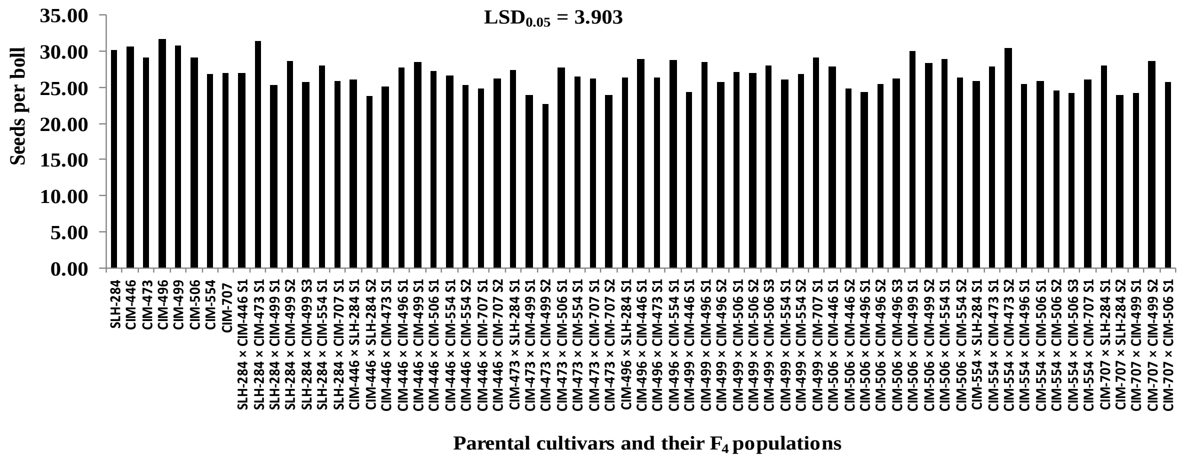

Fig. 5. Mean performance of parental cultivars and their F_4 populations for seeds per boll in upland cotton.

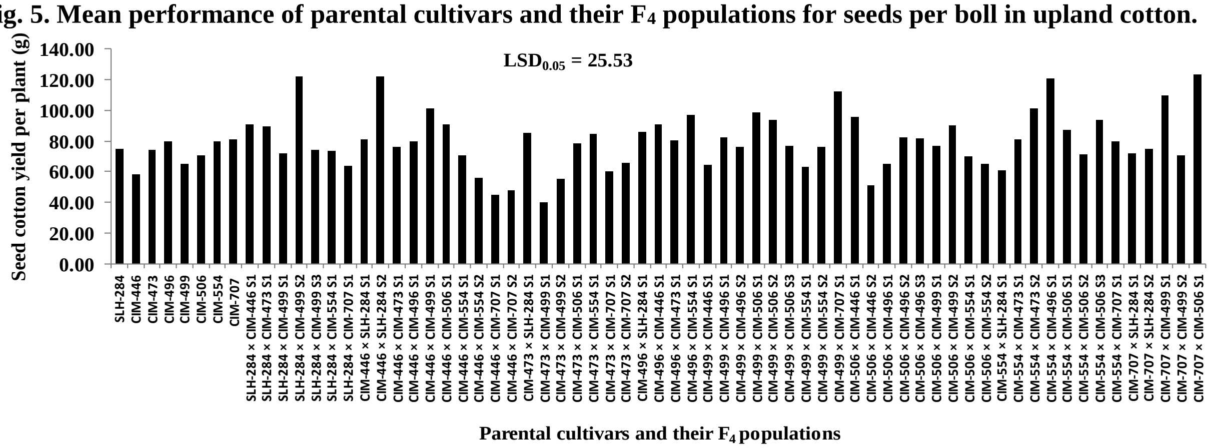

Fig. 6. Mean performance of parental cultivars and their F_4 populations for seed cotton yield in upland cotton.

Table 2. Genetic, environmental and phenotypic variances with heritability for various morpho-yield traits in upland cotton.

Parameters	Vg	Ve	Vp	GCV (%)	PCV (%)	h^2	Re (20%)
Plant height	202.913	109.450	239.40	12.73	13.82	0.85	18.36
Monopodia per plant	0.196	0.190	0.26	36.77	42.29	0.76	0.54
Bolls per sympodia	0.041	0.110	0.08	10.92	15.02	0.53	0.21
Boll weight	0.090	0.150	0.14	9.58	11.95	0.64	0.34
Seeds per boll	2.365	5.840	4.31	5.71	7.70	0.55	1.59
Seed cotton yield per plant	239.209	255.940	324.52	19.43	22.63	0.74	18.59

Vg = Genetic variance, Ve = Environmental variance, Vp = Phonotypic variance, GCV = Genotypic coefficient of variation, PCV = Phenotypic coefficient of variation, h^2 = Heritability (broad sense), Re = Selection response

Table 3. Correlation of seed cotton yield with various traits in upland cotton.

Variables	Correlation with seed cotton yield
Plant height	0.369^{**}
Monopodia per plant	0.113^{NS}
Bolls per sympodia	0.437^{**}
Boll weight	0.328^{**}
Seeds per boll	0.197^{**}

*, ** = Significant at *p≤0.05 and p≤0.01,* NS = Non-significant

Conclusion: Parental cultivars and their F_4 populations exhibited highly significant differences for all the traits. Almost all the traits were highly heritable having prominent broad sense heritability with moderate to high genetic advance which can be utilized for improvement in future breeding programs. All the traits revealed positive association with seed cotton yield. The F_4 population CIM-707 × CIM-506 S_1, CIM-446 × CIM-284 S_2 and SLH-284 × CIM-499 S_2 exhibited maximum seed cotton yield; and therefore, these populations can be used in future breeding programs to enhance the seed cotton yield.

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