Pak. J. Bot., 41(6): 2975-2986, 2009.

GENETICS OF INHERITANCE AND CORRELATIONS OF SOME MORPHOLOGICAL AND YIELD CONTRIBUTING TRAITS IN UPLAND COTTON

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Abstract

Present investigations confined to genetic mechanisms controlling inheritance pattern of five morphological and yield-contributing traits and their interrelationships were made, by examining the six generations of cotton, through generation mean analysis during 2002-2004. While fitting the adequacy of five parameter models *i.e.* m, [d], [i], [j], [l] showed its adequacy for leaf area, m, [d], [h], [i], [j] for number of bolls, seed cotton yield and petiole length, whilst inadequacy of this model for boll weight, indicated the involvement of higher order of gene interaction controlling the boll weight expression. Potence ratio of value greater than unity exhibiting over-dominance was illustrated for four traits *i.e.*, leaf area, number of bolls, boll weight and petiole length but for the trait of seed cotton yield potence ratio value was of 0.75 revealing partial dominance. Higher narrow sense heritability estimates (h^2_{NS}) ranging from 0.62 to 1.24 were observed for leaf area, petiole length, boll weight and seed cotton yield while, the moderate estimates of heritability (h^2_{NS} = 0.44) was revealed for number of bolls per plant. High heritability and significant positive associations measured among traits studied, suggested the possibility of improving seed cotton yield through indirect selection and conventional breeding techniques.

Introduction

Before utilizing the exotic cotton genotypes, having distinct morphological and agronomic traits in our regular breeding programmes it is pre-requisite to understand the genetic mechanisms controlling various agronomic traits and their possible inter-relationships with each other for the simultaneous improvement in seed cotton yield. Allard (1996) emphasized the most readily available genetic resources that led in the development of modern elite cultivars, possessed relatively higher frequencies of favorable alleles. To meet the upcoming challenges of cotton production in coming years it is imperative to exploit the genetic potential of some traits that were not earlier addressed. The breeding strategy should therefore, be based on the gene action involved in that particular germplasm developed and evaluated to get a desirable genotype.

Significance of various leaf morphological attributes *i.e.*, shape, area/ orientation, petiole length and their interrelationships with other yield contributing traits in cotton demands attention in increasing the cotton productivity. Petiole length appears of greater importance in genotypes, which have the potential to produce and retain bolls at very early nodes. Practically longer petiole length (even leaf size is bigger) facilitates solar radiation to penetrate to the maximum, and provides protection to bolls from pests due to maximum penetration of insecticides sprayed, in contrast, smaller petiole length may result in the development of dense foliage resulting in boll rottening at earlier nodes. Trait of petiole length demands due consideration to be paid, while making selection of desirable plants among segregating populations. Previous information on genetics of behavior of petiole length in cotton plant does not exist in the literature, and hence the inheritance of this character has been investigated here. Hammond (1941) emphasized the role of additive and non-additive genes, controlling leaf shape in two different *Gossypium* species (*hirsutum* and *arboreum* L.). The positive effect of leaf area index on productivity of cotton plant, its negative association with harvest index (Dhopte & Jamadar 1989), effect of leaf modification on yield, earliness and fiber traits in *Gossypium hirsutum* L., by using BC_4 and F_2 populations and its exploitation in future breeding programmes was reported by Baloch (2004).The significance of alleles with their positive and negative effects revealing potential for adapting leaf size/ shape to the needs of particular production regimes (Jiang *et al.,* 2000), nature of gene action controlling leaf area in nine genotypes of *hirsutum* cotton (Patil *et al.,* 1999) was reported in their earlier findings.

Studies pertaining to the genetics of primary yield contributing traits in *Gossypium hirsutum* L., (Keerio *et al.,* 1995), involvement of additive (Kalsy & Garg, 1988; Deshpande & Baig, 2003), non-additive (Wang & Pan, 1991; Mei-Zhen *et al*., 2005) genetic effects; both additive and non-additive genetic effects (Rehman *et al*., 1988; Tyagi 1988; and Mert *et al*., 2003a) controlling number of bolls were reported. In some cases, the genes showing overdominance (Salim *et al*., 1986) conditioned maternal inheritance of number of bolls. Involvement of significant effects of (additive × additive), epistatic effects (Kalsy & Garg, 1988; Mert *et al.,* 2003; McCarty *et al.,* 2004), occurrence of heterotic effects for number of bolls (Ansari *et al.,* 1993; Katageri *et al.,* 1992; Sohu *et al.,* 1993), assessment of useful heterosis in glandless *Gossypium hirsutum* (Soomro, 2000), moderate to moderately high heritability (Singh *et al.,* 1971), role of high heritability for the selection of the desirable genotypes in early generations (F_2, F_3) (Basbag & Gencer, 2004) was also reported earlier. The role of boll number as measurement to select indirectly the crosses having high dominance effects of lint yield in cotton (Jun *et al.,* 2007), highest and significant positive association of number of bolls with other economic traits in improving plant yield in cotton (Tyagi, 1987; Tyagi, 1994; Ulloa, 2006; Zhu *et al*., 2007) was identified in earlier findings.

Considering the scanty review pertaining to genetic studies controlling the traits like leaf area and petiole length, the present studies were undertaken herein to assess the genetic mechanisms controlling these traits and their possible association with other yield contributing traits operative in the present genetic material.

Materials and Methods

Plant material, growing conditions and character measurements: Two cotton genotypes (*Gossypium hirsutum* L.) *i.e*., NuCOTN- 35B (P_1- exotic line from USA) and NIAB-111(P_2- local in its origin) were used and hybridized to develop F_1, F_2, BC_{Nu} (F_1 × NuCOTN-35B) and BC_{N1} (F_1 × NIAB-111) generations. The resulting seeds of each of the six generations *i.e*., two parents, F_1, F_2, BC_{Nu} and BC_{N1} were sown in triplicated randomized complete block design in field during last week of May 2003. The soil analysis results of the experimental were sandy-clay loam type (58:23:19% sand, silt, clay respectively) with pH 7.9, EC 1.2, dS/m, SAR 2.88, organic contents 2.3%, total N 0.06%, water holding capacity 35.5%, bulk density 1.5 g/cm and porosity 44.5%. The seeds were dibbled 45 cm apart in 5.4-meter long rows spaced 75 cm apart. There was one row for each of P_1, P_2 and F_1 generation, 10 rows of F_2 generation, and 5 rows of each of BC_{Nu} and BC_{N1} generations. In total, there were 39 plants for each of P_1, P_2, and F_1, 300 plants of F_2, and 170 plants for each of BC_{Nu} and BC_{N1} in 3 repeats. The growing conditions were identical for all the six generations followed by the standard agronomic and plant protection practices.

The data on leaf area, petiole length, number of bolls, boll weight and seed cotton yield per plant were recorded on 30 guarded plants in each of P_1, P_2 and F_1, 270 plants in F_2, and 150 plants in each of BC_{Nu} and BC_{N1} populations after 150 days of their planting (DAP) in three replications. Leaf area of the fully expanded leaves at 10^{th}, 15^{th} and 20^{th} sympodial nodes of main stem of all the plants was measured with the help of portable leaf area meter (model CI 202,CID Inc. USA) At the same time petiole length for the same fully expanded leaves was measured. Average petiole length per plant in each family was calculated. Number of bolls per plant was counted at the time of each picking, and cumulative record was maintained for each plant separately. Boll weight was recorded by taking the average of twenty bolls/plant in all the generations and replications. Total seed cotton yield/plant was recorded separately for all the generations in each replication.

Statistical analyses: All obtained mean measured for values these traits on six generations were analyzed statistically to determine inheritance pattern and estimation of association in between different traits. The differences in mean values of leaf area, petiole length, number of bolls, boll weight and seed cotton yield per plant were subjected to analysis of variance following the methodology of Steel *et al*., (1996). A weighted least square analysis of generation means was performed following Mather & Jinks (1982). Model fitting was commenced with the simplest model (‘m’ only) to increasing complexity (md, mdh, etc). The best-fitted model was one, which had significant parameters along with non-significant Chi square value (χ^2). Narrow-sense heritability (h^2_{NS}) estimates were computed using function of Warner (1952). Heterosis and inbreeding depression were estimated following Mather & Jinks (1982), whilst expected genetic advance was computed using formula given by Falconer & Mackay (1996). The potence ratio (hp), a measure of average degree of dominance, was calculated using the formula given by Griffing (1950). The correlations among these traits studied were computed using computerized software SPSS 8.0 for windows.

Results and Discussion

Analysis of variance revealed highly significant ($p \leq 0.01$) differences among the six generations in respect of leaf area (LA), petiole length (PL), number of bolls (BN), boll weight (BW) and seed cotton yield (SCY) (Table 1). Further partitioning of mean squares of six generations showed that interaction components due to parents (P_1 vs P_2), parents and F_1 (P’s vs F_1) were highly significant ($p \leq 0.01$) for leaf area, petiole length, number of bolls, boll weight and seed cotton yield. Interaction components due to back crosses (BC_{Nu} vs BC_{N1}) was significant ($p \leq 0.05 - \leq 0.01$) for petiole length, number of bolls and seed cotton yield traits (Table 1). Interaction components due to segregating populations BC’s vs F_2 as well as of P’s, F_1 vs BC’s, F_2 were also highly significant ($p \leq 0.01 - \leq 0.05$) for the traits of seed cotton yield and boll weight.

Comparison of mean values in all the tested six generations for all the traits is presented in Figs. 1-5. The mean values presented in the Figure 1, shows that the maximum leaf area of 224.27 cm^2 was revealed in F_1 generation and minimum (108.5 cm^2) for parent NuCOTN-35B. Data presented in Figure 2, showed that mean petiole length was longest in F_1, measuring 15.3 cm, and shortest (7.84 cm) in exotic cultivar NuCOTN-35B. Figure 3 clearly shows a great contrast in the parents, F_1, F_2 and backcrosses for the trait of number of bolls. Maximum number of bolls were counted in F_1 (73.4) and minimum value for number of bolls per plant (31.5) were recorded for the parent NuCOTN-35B. The mean boll weight values measured in six cotton generations are presented in Figure 4, clearly showing a great degree of differences for their mean values. The highest mean boll weight value of 4.7 was observed for BC_{N1} followed by the minimum value of 3.31 of parent NuCOTN-35B. Mean performance for seed cotton yield presented in Figure 5 shows the striking differences among the six generations *i.e.*, P_1, P_2, F_1, F_2, BC_{Nu} and BC_{N1}. The mean yield of the parents differed significantly ($p \leq 0.01$) with NuCOTN-35B having a yield of 88.93 g and NIAB-111 with 238.5 g.

Table 1. Mean squares from partitioned analysis of variances of five agronomic traits measured in the six generations of *Gossypium hirsutum* L. under field conditions.

Source of variation	df	Leaf area	Petiole length	Number of bolls	Seed cotton yield	Boll weight
Replications	2	399.5	0.798	4.87	19.20	0.01
Generations	5	3521.2**	17.90**	591.74**	9642.7**	0.82**
P_1 vs P_2	1	6945.5**	39.22**	471.71**	33540.3**	1.56**
P's vs F_1	1	10273.2**	48.09**	2178.00**	6339.4**	1.49**
BC_{Nu} vs BC_{N1}	1	149.5 ^{NS}	1.79*	15.47**	5821.9**	0.036^{NS}
BC's vs F_2	1	194.3 ^{NS}	0.13 ^{NS}	150.81^{NS}	874.6**	0.082^{NS}
P's, F_1 vs BC's, F_2	1	43.6 ^{NS}	0.29 ^{NS}	1.70 ^{NS}	1637.1**	0.94*
Error	10	161.1	0.23	14.22	58.7	0.09

P_1= NuCOTN-35B, P_2= NIAB-111, F_1= 1st Filiail generation, F_2= Second Filial generation, P's = Parents interaction, BC_{Nu} = F_1 × NuCOTN-35B, BC_{N1} = F_1 × NIAB-111, BC's = Back crosses interactions, P's, F_1= Parents interaction with F_1 and BC's, F_2 = Back crosses interactions with F_2 generation.

* = Significant at $p \leq 0.05$, ** = Highly significant at $p \leq 0.01$ and NS = Non-significant at $p>0.05$.

Generation means analysis for leaf area revealed the adequacy of five parameter model, m, [d], [i], [j] and [l] indicating that trait was controlled by the genes acting additively and complicated by negative and positive interaction effects of additive × additive [i], negative additive × dominance [j] and positive dominance × dominance [l] interactions (Table 2). The significant additive genetic effects for leaf area suggested that simple selection could be more effective in improving the characters in later generations (Singh & Narayanan, 2000). The negative epistatic component suggests that fixation of additive × additive genes may reduce the leaf area in later generations, suggesting the identification of individual plants with the desired leaf area would be advantageous in early generations. The five-parameter model comprising of m, [d], [h], [i] and [j] was adequate for petiole length, number of bolls and seed cotton yield data (Table 2). The genetic analysis of the data for these three characters revealed that both additive and dominance gene effects controlled these traits. In addition, the significant positive additive × additive interaction [i] for these three traits suggests that fixation of favorable additive alleles would be possible in the later segregating generations, as suggested by Singh & Narayanan (2000). The involvement of both the additive and dominance gene effects, and additive × additive [i] interaction epistatic effect in controlling the inheritance of number of bolls and seed cotton yield are in great conformity with the studies of Wang & Pan (1991), Deshpande & Baig (2003), Mert *et al*., (2003a), McCarty *et al*., (2004), Meredith (2005), and Mei-Zhen *et al*., (2005). The significant Chi-square (χ^2) value suggested the inadequacy of the model for boll weight, indicating the involvement of higher order of gene interaction controlling the boll weight expression (Table 2). The significant χ^2 for boll weight also suggest the need for raising succeeding generations in order to determine the best genetic model (Mather & Jinks, 1982).

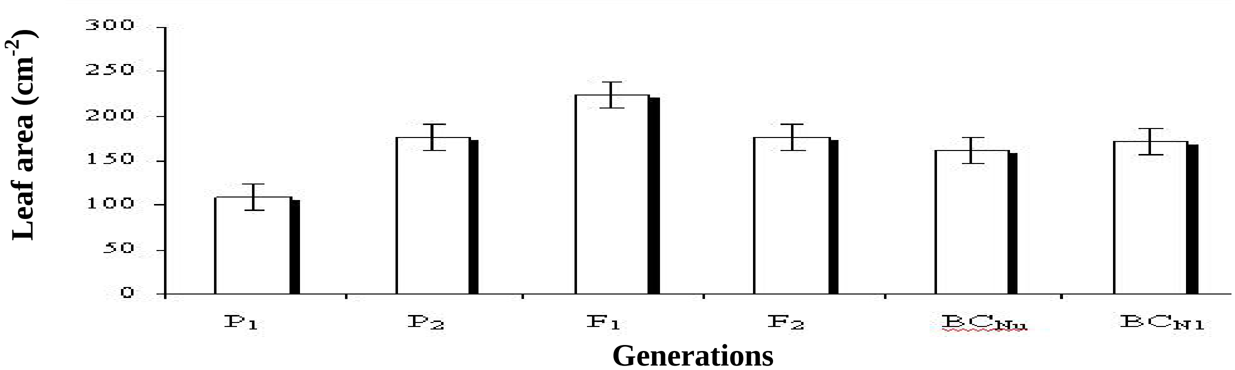

Fig. 1. Mean values for leaf area (cm^2) of six cotton generations.

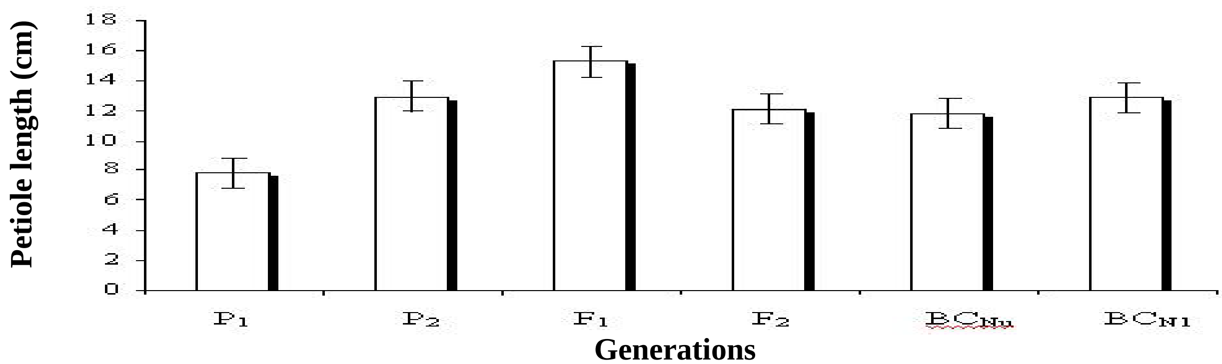

Fig. 2. Mean values for petiole length (cm) of six cotton generations.

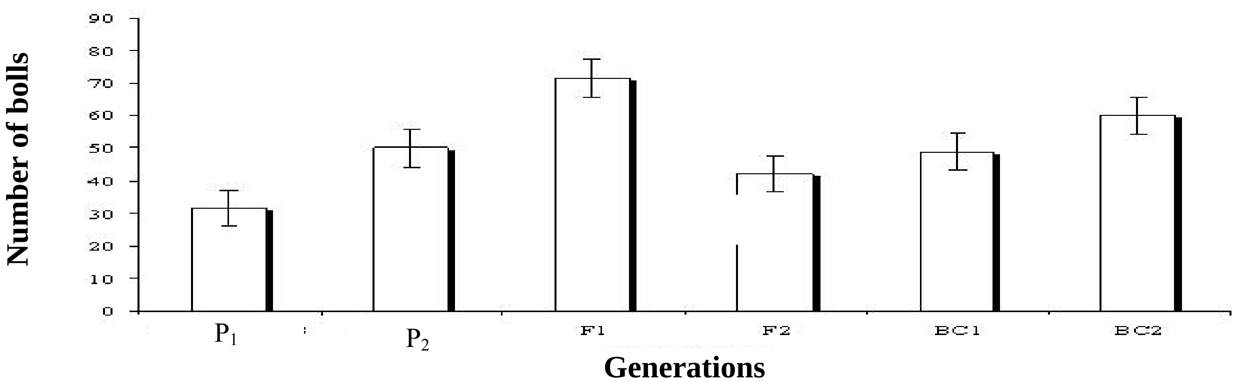

Fig. 3. Mean number of bolls of six cotton generations.

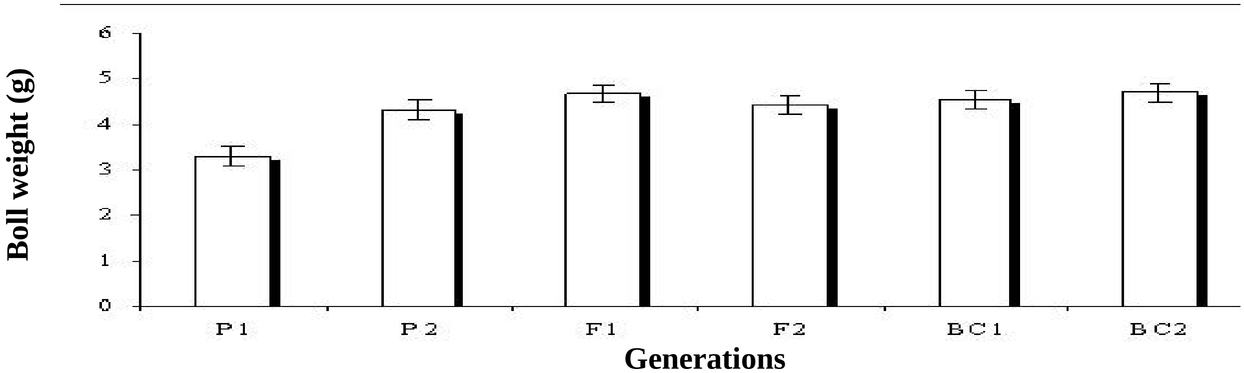

Fig. 4. Mean values for boll weight (g) of six cotton generations.

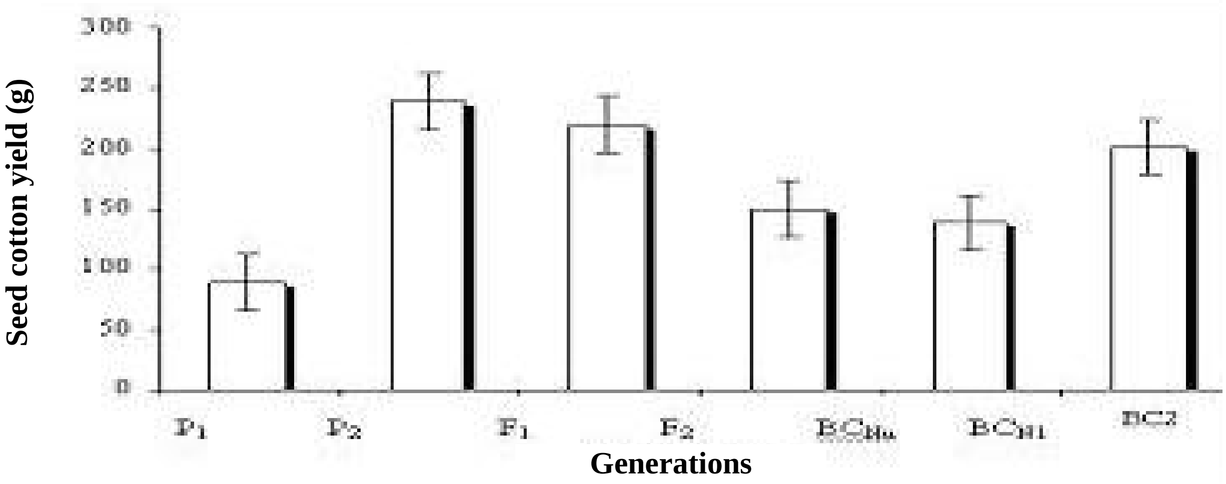

Fig. 5. Mean values for seed cotton yield (g) of six cotton generations.
Legends: P_1= NuCOTN-35B, P_2= NIAB-111, F_1= 1st Filial generation, F_2= Second Filial generation, BC_{Nu}= F_1= NuCOTN-35B, BC_{NI}= F_1= NIAB-111 and vertical base are standard error mean.

Significant positive heterotic affects and inbreeding depression were present for four traits *i.e.*, leaf area, number of bolls, boll weight and petiole length whilst, negative heterotic effect was found for the trait of seed cotton yield. The occurrence of high magnitude of hybrid vigor for leaf area and number of bolls under field conditions might be due to genes with pleiotropic effects. Potence ratio of value greater than unity exhibiting over-dominance was illustrated for four traits *i.e.*, leaf area, number of bolls, boll weight and petiole length but for the trait of seed cotton yield potence ratio value was of 0.75. Higher narrow sense heritability estimates (h^2_{NS} = 0.62 to 1.24) were observed for leaf area, petiole length, boll weight and seed cotton yield whilst, the moderate estimates of heritability (h^2_{NS} =0.44) was revealed for number of bolls per plant. High narrow sense heritability (h^2_{NS}) estimates for leaf area and seed cotton yield reflected high genetic advance. The moderate heritability estimate for number of bolls per plant suggested that gradually improvement in this trait through slow progress. The high narrow sense heritability estimates *i.e.* exceeding unity for the trait of boll weight might have occurred due to various factors such as poor variance estimates, presence of non-allelic interaction, sampling error, and probable presence of non-genetic sources of variations (Coates & White, 1998). The higher estimates of heritability for leaf area and petiole length examined here suggest the possibility of improvement in these traits through conventional breeding (Saranga *et al.*, 1992).

Highly significant ($p \leq 0.01$) positive associations were revealed between leaf area and petiole length (r = 0.99**, Fig. 6), leaf area and number of bolls (r = 0.90**, Fig. 7), petiole length and number of bolls (r = 0.93**, Fig. 10), petiole length and boll weight (r = 0.90**, Fig. 11). The significant positive correlations also existed between leaf area and boll weight (r = 0.87*, Fig. 8), leaf area with seed cotton yield (r = 0.81*, Fig. 9) and petiole length with seed cotton yield (r = 0.86*, Fig. 12).

Correlation coefficients for these selected varieties among six-generation means show that there was good association among traits, reflecting the effectiveness of indirect selection that can be used to improve any of these traits. Leaf area exhibited highly significant positive associations with petiole length, number of bolls, and significant positive associations with boll weight and seed cotton yield, suggesting that selection of plants with medium leaf area with desirable petiole length is possible. The positive associations between leaf area and petiole length may be of great value while making the plant selection with high number of bolls at the lower plant canopy, leading to increased seed cotton yield.

Table 2. Summary for the estimation of different genetic parameters of five agronomic traits for six generations of cotton.

Traits	Genetic effects							
	m	[d]	[h]	[i]	[j]	[l]	χ^2 (DF)	Probability
Leaf area	160.47 ± 3.04	34.12 ± 3.60	-	-20.40 ± 4.96	-43.40 ± 4.86	52.24 ± 7.16	3.627 (1)^{NS}	0.057
Petiole length	8.94 ± 0.36	2.54 ± 0.17	6.26 ± 0.57	1.41 ± 0.39	-3.61 ± 0.26	-	0.654 (1)^{NS}	0.91
Number of bolls	16.06 ± 4.18	8.68 ± 1.63	59.89 ± 6.06	25.03 ± 4.44	-18.56 ± 2.83	-	2.843 (1)^{NS}	0.092
Seed cotton yield	79.00 ± 6.81	74.75 ± 3.13	140.68 ± 0.86	84.58 ± 7.32	-137.03 ± 4.57	-	0.013 (1) NS	0.9092
Boll weight	3.82 ± 0.079	0.51 ± 0.08	2.17 ± 0.32	-	-0.68 ± 0.13	-1.31 ± 0.34	4.319 (1)*	0.0477

Estimation of heterosis, potence ratio (hp), inbreeding depression, genotypic, phenotypic and environmental variances, narrow-sense heritability (h^2_{NS}) and genetic advance (G.A)

Traits	Heterosis	Potence ratio	Inbreeding depression	$\left(\hat{\sigma}^2_g\right)$	$\left(\hat{\sigma}^2_p\right)$	$\left(\hat{\sigma}^2_e\right)$	(h^2_{NS})	GA ($_{NS}$)
Leaf Area	38.10 ±13.71	2.11	17.78 ± 3.58	1120.03	1173.74	161.13	0.82	58.01
Petiole length	2.347 ± 0.520	192	20.83 ± 0.193	5.89	5.97	0.23	0.62	3.12
Number of bolls	24.134 ± 4.07	3.72	28.404 ± 2.26	192.50	197.23	14.22	0.44	12.76
Seed cotton yield	-18.467± 8.288	0.75	70.548 ±3.741	3194.65	3214.22	58.73	0.71	82.65
Boll weight	0.354 ± 0.334	1.69	0.255 ± 0.106	0.24	0.27	0.096	1.24	1.33

*mean (m); additive[d]; dominance[h]; additive × additive [i]; additive × dominance[j]; and dominance × dominance [l] epistasis

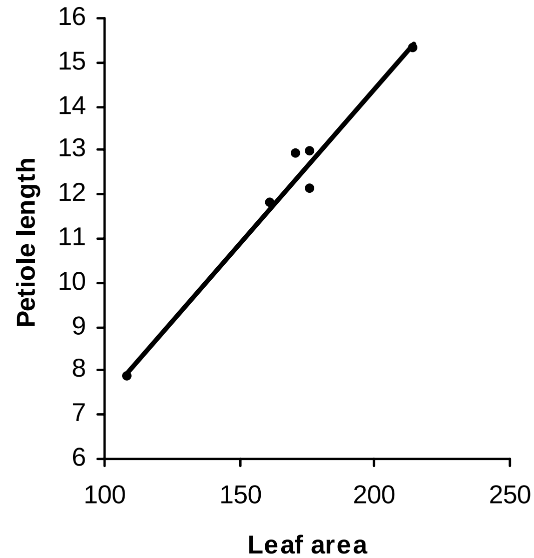

Fig. 6. Scatter diagram for mean leaf area (cm^2) and petiole length (cm) of six cotton generations.

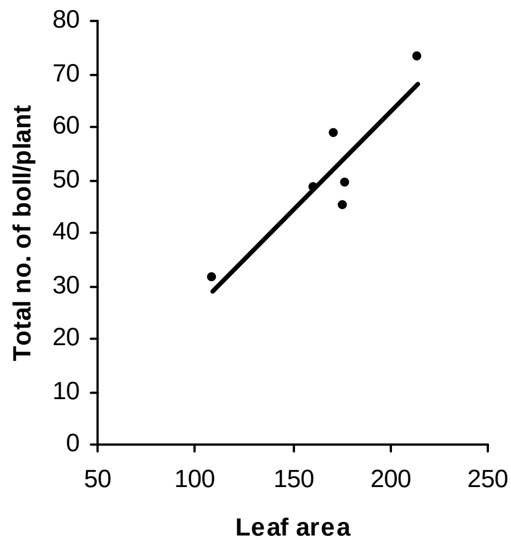

Fig. 7. Scatter diagram for mean leaf area (cm^2) and bolls number of six cotton generations.

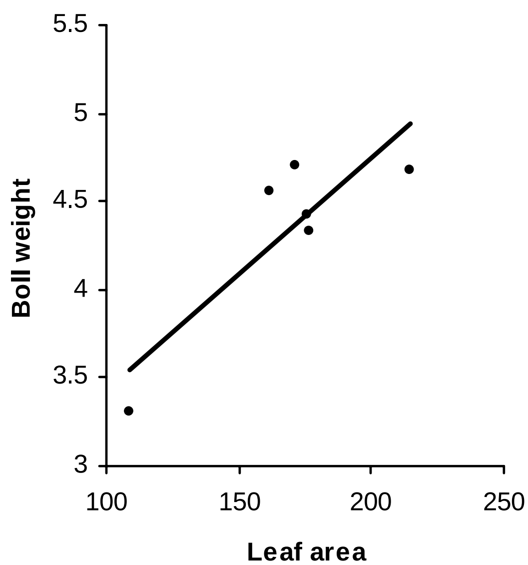

Fig. 8. Scatter diagram for mean leaf area (cm^2) and boll weight (g) of six cotton generations.

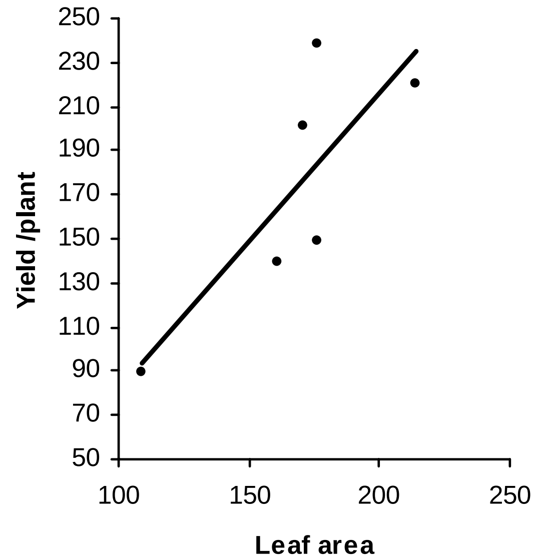

Fig. 9. Scatter diagram for mean leaf area (cm^2) and seed cotton yield (g) of six cotton generations.

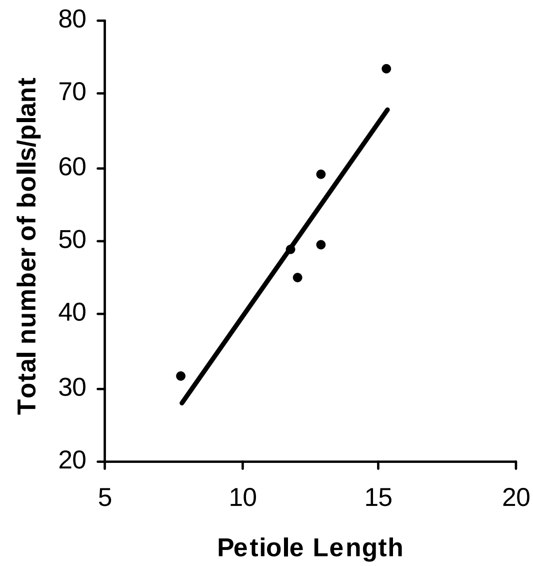

Fig. 10. Scatter diagram for petiole length (cm) and number of bolls of six cotton generations.

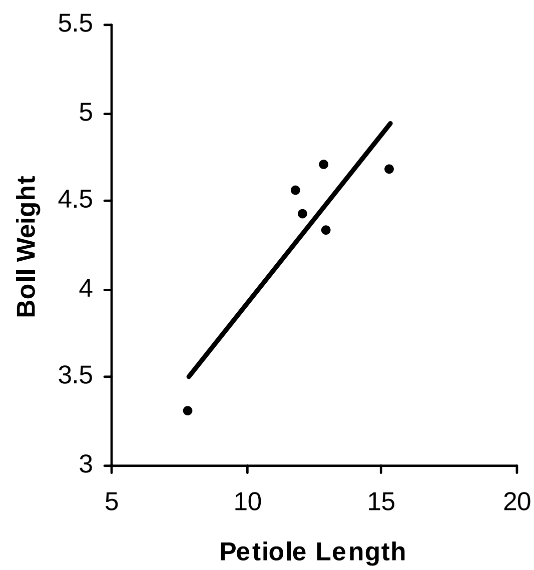

Fig. 11. Scatter diagram for mean petiole length (cm) and boll weight (g) of six cotton generations.

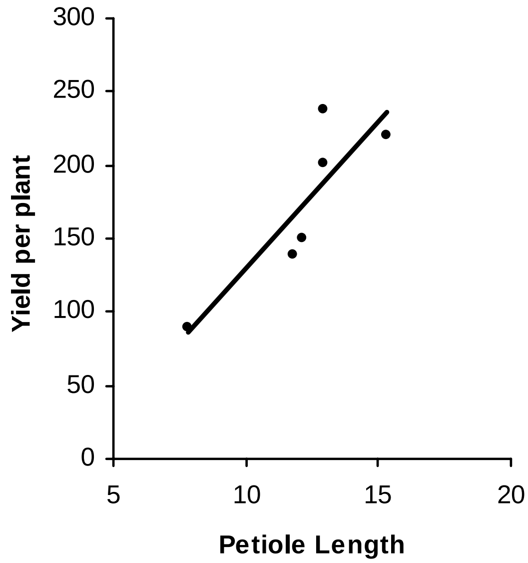

Fig. 12. Scatter diagram for mean petiole length (cm) and seed cotton yield (g) of six cotton generations.

The positive association of leaf area with seed cotton yield investigated under reported study is in conflict with the earlier findings of Dhopte & Jamadar (1989), who reported negative correlation between leaf area and harvest index and seed cotton yield. The strong positive association between seed cotton yield and leaf area may be due to longer petioles that could have facilitated maximum harvestable bolls from the lower half of the cotton plant at maturity. These results suggested that leaf size could be exploited easily in future breeding programmes as suggested by Jiang *et al*., (2000). The high significant positive association between petiole length and number of bolls and significant positive associations of petiole length with boll weight and seed cotton yield, further supports that advances may be made by exploiting the potential of plant material studied under the present investigations. The positive association obtained for seed cotton yield with number of bolls and boll weight is similar to the findings reported by various workers (Tyagi, 1987; Tomar *et al.*, 1992; Tyagi, 1994).

Conclusion

From the results presented here, it is amply clear that a considerable genetic variation exists in the set of breeding material examined herein showing a clear relationship between the morphological and yield contributing traits. Previous information on genetic behavior of petiole length in plant production does not exist in the literature, and therefore the inheritance pattern investigated herein for this character is new one. The genetic information developed here, in controlling the inheritance pattern, as well as their significant positive inter-relationships among selected variates in six-generations show that, there was good association among triats, reflecting the effectiveness of indirect selection by breeders while making selection of desirable plants among segregating populations.

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(Received for publication 12 September 2008)