ISSN 1996-3351

Asian Journal of Biological Sciences

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Asian Journal of Biological Sciences 1 (2): 61-68, 2008
ISSN 1996-3351

Correlation, Path Coefficient and Factor Analysis of Some Quantitative and Agronomic Traits in Cotton (*Gossypium hirsutum* L.)

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Abstract: The present study was carried out to elucidate the nature of interrelationships among various traits affecting cotton yield. Twelve cotton advanced lines were evaluated in Hashemabad cotton research station located at North of Iran, with four replication using RCBD. Data was recorded on 14 quantitative and agronomic traits. The analysis of explanatory statistics revealed presence of substantial variability for most traits. The path analysis revealed that highest direct effect on seed cotton yield was exhibited by First Picking Yield (FPY) followed by Length of Sympodial Branches (LSB). Factor analysis insists importance of yield components and bringing out four latent factors affecting on cotton yield. First four independent factors compose 83.58% values should represented of total variation. Factor 1, which accounted for about 39% of the variation consists of second harvested seed cotton yield, boll weight, boll No., No. of monopodial branches, length of monopodial branches, No. of sympodial branches, length of sympodial branches, length of pedicel, total seed cotton yield and earliness. Factor analysis decreased numerous correlated variables to few main factors. The inference of present study and possible implications in cotton breeding has been discussed.

Key words: Cotton, traits association, variability, yield components

INTRODUCTION

Cotton is the most important renewable natural textile fiber and the sixth largest source of vegetable oil in the world. Cotton belongs to the genus *Gossypium*, which consists of at least 45 diploid and five allotetraploid species (Ulloa *et al*., 2006).

Lint yield of upland cotton (*Gossypium hirsutum* L.) is determined by its component traits, boll No., boll weight and lint percentage. Selecting high yielding lines is based on the ability to manipulate component traits. The existence of correlations between a complex trait and its components is an indication of gene association or pleiotropism (Kebede *et al*., 2001; Dilday *et al*., 1990). Correlation analysis, multiple linear regression analysis and path coefficient analysis are three common methods used to evaluate the relationships between a complex trait and its component traits (Cramer and Wehner, 2000).

The nature of association between yield and its components determine the appropriate traits to be used in indirect selection for seeking improvement in cotton yield. The correlation studies simplify measure the association between yield and other traits, while as path coefficient analysis permits the separation of coefficient into direct effects (path coefficient) and indirect effects (effect exerted through other variables). It is a standardized partial regression analysis and deals with a closed system of

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variable that are linearly related. Such information provides for realistic basis of allocation of appropriate weightage to various yield components (Keim and Kronstand, 1981; Iqbal *et al*., 2006).

Numerous studies conducted so far are available on the genotypes of varying characters. They reported that correlation and direct and indirect effect estimates vary for different traits with variation in genetic material. Hence, correlation and direct and indirect effect estimation would provide useful information for planning a successful breeding programme (Rosielle and Hambiline, 1981; Pace *et al*., 1999; Ahuja *et al*., 2006; Iqbal *et al*., 2006).

Correlation analysis, multiple linear regression analysis and factor analysis have an emphatic and complementary role in detection of association between traits. Factor analysis is a generic term for a family of statistical techniques concerned with the reduction of a set of observable variables in terms of a small number of latent factors. The primary purpose of factor analysis is data reduction and summarization. The communality estimate for a variable is the estimate of the proportion of the variance of the variable that is both error-free and shared with other variables in the matrix (Seiler and Stafford, 1979; Bramel *et al*., 1984).

Factor analysis as a statistical model assumes that a small number of unobserved (i.e., latent) constructs are responsible for the correlation among a large number of observed variables (Bramel *et al*., 1984). The latent constructs, for example, academic ability, cannot be directly observed, but they affect observable variables, such as French, English and Mathematics scores. Factor analysis assumes that the variance of each observed variable comes from two parts: a common part shared with other variables, which causes correlation among them and a unique part that is different from other variables. The common parts are called factors and these factors represent the latent constructs (Seiler and Stafford, 1979). Another using of factor analysis is the introduction of essential multivariate analysis (Bramel *et al*., 1984).

The present study was conducted to provide information on interrelationships of seed cotton yield with yield components and different agronomic traits.

MATERIALS AND METHODS

Experimental material consisted of twelve new upland cotton (*G. hirsutum* L.) advanced lines obtained from Cotton Research Institute of Iran (CRI-IR) germplasm collections. The experiments were carried out at Hashemabad cotton research station (CRI, Gorgan-Iran) during the cropping season 2004-2005 and 2005-2006. Layout of experiments was randomized block design (RCBD) with four replications. For each entry plot (52.8 m^2) comprised six rows set 80 cm apart. Distance between plants within rows was 20 cm. Recommended agronomic practices such as fertilizer application, weeding, irrigation and plant protection measures were adopted when required. Suitable insecticides/pesticides were applied to prevent economic losses.

Observations on 14 traits were recorded on 10 randomly selected plants in each plot (plot borders not considered for evaluation). The mean values obtained from 2 years data were used for estimating the analysis of variance.

Factor analysis calculations were performed using SPSS factor analysis. The array of communality, the amount of the variance of a variable accounted by the common factor together, was estimated by the highest correlation coefficient in each array as suggested by Seiller and Stafford (1979). The numbers of factors were estimated using the principal component method. The varimax rotation method was used in order to make each factor uniquely defined as a distinct cluster of intercorrelated variables. The factor loadings of the rotated matrix, the variability percentage of each factor as well as the commonalties for each variable were determined.

Statistical associations between different traits and yield were tested using stepwise multiple linear regression (PROC REG in SAS software, SAS Institute, 1999) with $p \leq 0.01$ as the criterion for both entry and staying in the model.

RESULTS AND DISCUSSION

In order to examine possible environmental variations in the field, one-sided analysis of variation was performed for all examined traits in control plants. The results revealed no significant variation between experimental plots (data not shown). On the other hand, the data showed significant variation ($p<0.05$) in examined traits between genotypes, indicating the presence of sufficient genetic variability in the material. The mean performance and descriptive statistics of various characters is given in Table 1. Among the examined traits, the length of the monopodial branches (19.55), yield of the second harvest (18.39), No. of monopodial branches (16.96) and the length of the sympodial branches (15.11) showed the highest coefficients of variation; while plant height (2.89), numbers of sympodial branches (3.59) showed the lowest coefficients of variation. Present data is an agreement with results obtained by Ahuja *et al*. (2006).

Analysis of Variance (ANOVA)

ANOVA showed that the studied genotypes exhibited significant differences in all examined traits (data not shown); while the between-group variation tended to exceed the within-group variation. Therefore, subsequent analysis were conducted.

Correlation Analysis

The results of simple correlation analysis is shown in Table 2 indicating that earliness (ER) showed significantly negative correlation with First (FPY, $p \leq 0.05$) and Second Picking Yield (SPY, $p \leq 0.01$) as well as with the Length of Monopodial (LMB, $p \leq 0.05$) and Sympodial Branches (LSB, $p \leq 0.01$). Early maturity in cotton has many advantages. It enables the cotton crop to develop during periods of more favorable moisture, escapes losses from late season insect injuries (attack of pink bollworms, American bollworms and whitefly), extending the season for harvesting and ginning operation. In addition, the earliness helps to fit the cotton crop in cotton-wheat rotation (Iqbal *et al*., 2006).

Furthermore, Seed Cotton Yield (SCY) association with First Picking Yield (FPY, $p \leq 0.01$) and with the Length of Petiole (LP, $p \leq 0.05$) was significantly positive, whereas it's correlation with No. of Sympodial Branches (NSB) was significantly negative ($p \leq 0.05$). The Length of Sympodial Branches (LSB) positively correlated with Second Picking Yield (SPY, $p \leq 0.01$), Boll Weight (BW, $p \leq 0.05$) and No. of Monopodial Branches (NMB, $p \leq 0.05$), while the length of sympodial

Table 1: Summary of descriptive analysis for new cotton genotypes

Traits	Mean±SD	Phenotypic variation coefficient
No. of plants	74.64±3.616	4.84
First picking yield	3247.39±423.070	13.02
Second picking yield	1376.04±253.146	18.39
Height	135.90±3.938	2.89
Boll weight	172.75±15.028	8.69
Boll No.	20.68±2.467	11.92
No. of monopodial branches	1.22±0.207	16.96
No. of sympodial branches	15.22±0.536	3.52
Length of monopodial branches	57.21±11.189	19.55
Length of sympodial branches	37.46±5.661	15.11
Length of internode	8.12±0.545	6.71
Length of petiole	3.71±0.370	9.97
Seed cotton yield	4623.43±485.977	10.51
Earliness	0.69±0.054	7.83

Table 2: Simple correlation analysis of traits in new cotton genotypes

Trait	PD	FPY	SPY	HP	BW	BN	NMB	NSB	LMB	LSB	LI	LP	SCY	ER
PD	1.000													
FPY	0.241	1.000												
SPY	0.120	-0.032	1.000											
HP	-0.063	-0.118	0.251	1.000										
BW	0.486	0.251	0.402	-0.118	1.000									
BN	-0.582*	0.016	-0.252	-0.374	-0.515	1.000								
NMB	0.439	-0.067	0.505	0.315	0.700*	0.693*	1.000							
NSB	-0.491	-0.727**	-0.325	0.155	-0.663*	0.432	-0.414	1.000						
LMB	0.075	-0.118	0.636*	0.158	0.733**	-0.383	0.846**	0.333	1.000					
LSB	0.107	0.020	0.876**	0.001	0.590*	-0.181	0.626*	-0.395	-0.800**	1.000				
LI	0.080	0.153	-0.101	0.246	0.078	-0.551	0.085	-0.327	-0.031	0.334	1.000			
LP	0.229	0.398	0.443	0.192	0.342	-0.136	0.408	-0.282	375/0	0.371	0.034	1.000		
SCY	0.272	0.854**	0.493	0.028	0.428	-0.117	0.204	-0.802*	0.228	0.474	0.081	0.577*	1.000	
ER	0.050	-0.584*	-0.811**	-0.237	-0.283	0.247	0.511	0.113	-0.671*	-0.718**	0.109	-0.176	0.086	1

PD: Plants density, FPY: First picking yield, SPY: Second picking yield, HP: Height of plant, BW: Boll weight, BN: Boll No., NMB: No. of monopodial branches, NSB: No. of sympodial branches, LMB: Length of monopodial branches, LSB: Length of sympodial branches, LI: Length of internode, LP: Length of petiole, SCY: Seed cotton yield, ER: Earliness, *, **: Significant at the level of $p\leq 0.05$ and $p\leq 0.01$, respectively

branches negatively associated with the Length of Monopodial Branches (LMB, $p\leq 0.01$). Similarly, length of monopodial branches exhibited positive correlation with Second Picking Yield (SPY, $p\leq 0.05$), Boll Weight (BW, $p\leq 0.01$) as well as with No. of Monopodial Branches (NMB, $p\leq 0.05$). Furthermore, No. of Sympodial Branches (NSB) showed negative association with First Picking Yield (FPY, $p\leq 0.01$) as well as with Boll Weight (BW, $p\leq 0.05$). The correlation between boll No. and No. of sympodial branches was positive (r = 0.43).

No. of monopodial branches showed positive association with Boll Weight (BW, $p\leq 0.05$) and Boll No. (BN, $p\leq 0.05$). In addition, the correlation between Boll No. (BN) and Plant Density (PD, $p\leq 0.05$) was significantly negative (Table 2). Since, the No. of Bolls per plant (BN) have positive association with seed cotton yield (Ahuja *et al*., 2006), we can conclude that in newly examined cotton genotypes excessively increased plant density might decline seed cotton yield per plant. Accordingly, Babar *et al*. (2002) indicated that most cultivars planted at high density form a columnar shape aiding in efficient harvest; however, extremely early maturing cultivars planted at high densities did not perform well in limited testing.

Diverse correlation between plant traits has been reported in various genotypes of cotton. For instance, Ahuja *et al*. (2006) reported that relationship between seed cotton yield per plant and plant height was positive. On the other hand, the relationship between seed cotton yield per plant and No. of monopodial branches per plant was not found to be significant. Because of negative correlation between length of monopodial and sympodial branches with earliness (r = -0.67 and r = -0.72, respectively), an increase in the length of branches may induce negative impacts on seed cotton yield via delay in crop maturity and increase more square shedding. This suggests that, due to true correlation, direct selection for early maturity, boll weight and sympodial characters will be effective for seed cotton yield improvement.

Path Analysis

The path coefficient analysis (Table 3) revealed positive and negative direct effect of traits on seed cotton yield. The highest direct effect on seed cotton yield was exhibited by FPY (0.597) followed by LSB (0.201), NSB (-0.381) and NMB (-0.315), respectively. Plant Density (PD), Boll Weight (BW), Boll No. per plant (BN), No. of Monopodial Branches (NMB), No. of Sympodial Branches (NSB), Length of Internodes (LI) and Earliness (ER) showed negative direct effect on seed cotton yield, even though mostly of these characters (except NSB and BN) had positive correlation with seed cotton yield. These traits also shared positive indirect effects on seed cotton yield through other yield traits such as NSB and FPY.

Table 3: Direct and indirect effects of different agronomic traits on seed cotton yield

Trait	PD	FPY	SPY	HP	BW	BN	NMB	NSB	LMB	LSB	LI	LP	ER	Correlation with seed cotton yield
PD	-0.005	-0.002	-0.001	0.000	-0.003	0.002	-0.003	0.002	-0.001	0.001	-0.0010	0.002	-0.001	0.272
FPY	0.143	0.597	-0.020	-0.071	0.149	0.009	-0.041	-0.434	-0.071	0.011	0.0900	0.237	0.348	0.852
SPY	0.018	-0.005	0.150	0.037	0.060	-0.038	0.075	-0.049	0.095	0.131	-0.0160	0.066	-0.122	0.492
HP	-0.009	-0.017	0.035	0.140	-0.017	-0.053	0.044	0.021	0.022	0.000	0.0340	0.026	0.034	0.028
BW	-0.035	-0.018	-0.029	0.008	-0.071	0.036	-0.050	0.046	-0.052	0.042	-0.0060	0.025	0.019	0.426
BN	0.043	-0.002	0.018	0.028	0.038	-0.076	0.052	-0.033	0.028	0.013	0.0410	0.010	-0.019	-0.117
NMB	-0.139	0.021	-0.159	-0.099	-0.220	0.217	-0.315	0.129	-0.266	0.197	-0.0270	0.128	0.160	0.203
NSB	0.187	0.276	0.123	-0.060	0.252	-0.165	0.157	-0.381	0.126	0.150	0.0124	0.107	0.043	-0.801
LMB	0.003	-0.007	0.032	0.008	0.037	-0.020	0.043	-0.018	0.051	0.041	-0.0020	0.019	-0.035	0.228
LSB	0.021	0.004	0.176	0.000	0.119	-0.037	0.126	-0.080	0.161	0.201	-0.0680	0.074	-0.145	0.472
LI	-0.008	-0.014	0.009	-0.023	-0.008	0.049	-0.008	0.029	0.002	0.030	-0.0910	0.004	-0.010	0.079
LP	0.052	0.069	0.077	0.033	0.059	-0.024	0.071	-0.050	0.065	0.064	0.0050	0.174	-0.031	0.577
ER	-0.005	-0.055	0.075	0.022	0.026	-0.023	0.047	0.010	0.062	0.066	-0.0110	0.016	-0.093	0.038

PD: Plants density, FPY: First picking yield, SPY: Second picking yield, HP: Height of plant, BW: Boll weight, BN: Boll No., NMB: No. of monopodial branches, NSB: No. of sympodial branches, LMB: Length of monopodial branches, LSB: Length of sympodial branches, LI: Length of internode, LP: Length of petiole, SCY: Seed cotton yield, ER: Earliness

No. of Sympodial Branches (NSB) had positive indirect effect on seed cotton yield through FPY (0.276) followed by BW (0.252). First Picking Yield (FPY) had negative indirect effect on seed cotton yield through NSB (-0.434). Similar results in cotton have been reported by Ahuja *et al*. (2006). Thus in light of the results obtained in the present study, it can be suggested that the traits such as FPY, LSB, NSB and NMB should be considered as target traits for improvement of cotton yield. Thus it can be emphasized that the ideal plant type should have higher values of the traits with positive effect, whereas, the traits showing negative effects on cotton yield should be selected for lower values such No. of Sympodial Branches (NSB). The positive direct effect of average first picking yield (FPY) reflected its importance and effectiveness in a selection at this region, comparable with results obtained by Iqbal *et al*. (2006).

Correlation and direct and indirect effect estimates vary for different traits with variation in genetic material (Ahuja *et al*., 2006). The knowledge of the relationship among various traits affecting seed cotton yield is imperative to arrive at potentially effective selection index. The path analysis revealed that most of the traits exerted their positive indirect effects through Boll Weight (BW), Earliness (ER) and Boll No. (BN) on cotton yield.

Factor Analysis

In order to identify vital components that contribute to total variation, factor analysis was conducted. Table 4 shows total variance of each factor in percentage, which shows its importance in interpretation of total variation of data. Therefore, the contribution of each trait according to other traits is obtained. Four classes of independent factors were chosen based on Eigen values >1, which together compose 83.58% of total variation. Contribution of these four factors in total variation was 38.90, 21.30, 14.03 and 9.35%, respectively.

A principal factor matrix after Varimax rotation with Kaiser Normalization for these four factors is given in Table 5. The values in the Table 5 for factor loadings indicate the contribution of each variable to the factors. To interpret the result, only those factor loadings having greater values (boldface in Table 5) are considered. Factor 1, which accounted for about 39% of the variation consists of second harvested seed cotton yield, boll weight, boll No., No. of monopodial branches, length of monopodial branches, No. of sympodial branches, length of sympodial branches, length of pedicel, total seed cotton yield and earliness. All variables in factor 1 had positive loadings except boll No., No. of sympodial branches and earliness. The sign of the loading in Table 5 indicates the direction of the relationship between the factor and the variable. Factor 1 plays crucial roles in horizontal

Table 4: Specific variance values and accumulative percentage of variances for 14 factors

Factors	Eigen values	Variation (%)	Cumulative (%)
No. of plants	5.446	38.90	38.90
First picking yield	2.982	21.30	60.20
Second picking yield	1.963	14.03	74.23
Height	1.308	9.35	83.58
Boll weight	0.856	6.12	89.70
Boll No.	0.624	4.46	94.16
No. of monopodial branches	0.518	3.70	97.86
No. of sympodial branches	0.172	1.23	99.09
Length of monopodial branches	0.099	0.71	99.80
Length of sympodial branches	0.021	0.15	99.95
Length of internode	0.006	0.05	1.00
Length of petiole	0.000	0.00	1.00
Seed cotton yield	0.000	0.00	1.00
Earliness	0.000	0.00	1.00

Table 5: Factor analysis for morphological and quantitative traits in new cotton genotypes

			Factors after varimax rotation (Kaiser standardization method)			
Traits	Means	Communality	1	2	3	4
PD	74.64	0.59822	-0.009	0.197	0.747**	-0.0355
FPY	3247.39	0.97677	-0.278	0.935**	0.137	-0.0690
SPY	1376.04	0.86284	0.878**	0.273	0.000	0.1250
HP	135.90	0.81352	0.222	-0.017	-0.131	0.8640**
BW	172.75	0.84727	0.470	0.267	0.722**	-0.1810
BN	20.68	0.92426	-0.182	0.046	-0.793**	-0.5090
NMP	1.22	0.86178	0.658*	0.020	0.617*	0.2160
NSB	15.22	0.88722	-0.098	-0.706**	-0.611*	0.0710
LMB	57.21	0.83393	0.840**	0.035	0.354	0.0220
LSB	37.46	0.96085	0.916**	0.249	0.121	-0.2100
LI	8.12	0.68208	-0.300	0.093	0.392	0.6540*
LP	3.71	0.56484	0.395	0.599*	0.033	0.2190
SCY	4623.43	0.97656	0.215	0.957**	0.119	0.0050
ER	0.69	0.91049	-0.892**	0.309	0.010	-0.1340
Variances explained by each factor			1.653	2.809	3.004	4.2330

PD: Plants density, FPY: First picking yield, SPY: Second picking yield, HP: Height of plant, BW: Boll weight, BN: Boll No., NMB: No. of monopodial branches, NSB: No. of sympodial branches, LMB: Length of monopodial branches, LSB: Length of sympodial branches, LI: Length of internode, LP: Length of petiole, SCY: Seed cotton yield, ER: Earliness, *, **: Significant at the level of $p \leq 0.05$ and $p \leq 0.01$, respectively

distribution of branches, growth period as well as seed cotton yield. Thus positive loadings in factor 1 lead to increased growth of branches, bolls and seed cotton yield. Therefore, we named this factor as plant horizontal growth (or branching potential).

Any decrease in this factor correlates with increase of boll No. and No. of sympodial branches. Considering the results shown in Table 2 together with negative correlation between boll No. and boll weight (-0.515) as well as between seed cotton yield and No. of sympodial branches (-0.802), we concluded that acceleration of vegetative growth and increasing of plant height compensate for the generative growth and leads to decline of total seed cotton yield. In this conditions increase of boll size and horizontal growth of branches would compensate for any possible decrease in total yield. The results indicated that branching potential and on time maturity of bolls (boll opening) have major role on the cotton genotype yield.

The second factor, which accounts for about 21.3% of the variation, contains first picking yield, No. of sympodial branches, total seed cotton yield and earliness. Among these, No. of sympodial branches had negative significant loading while others had significant positive loading. Therefore, we named this factor as yield and earliness.

The third factor, which accounted for about 14% of total variation was named fertility factor and is positively associated with boll No. with positive loading as well as length of internodes with negative loading.

The forth factor which is named plant vertical growth accounts for about 9.3% of the variation and includes height of plant and length of internodes both with significant positive loadings.

CONCLUSION

The cotton plant has perhaps the most complex structure of any major field crops. Its indeterminate growth habit and sympodial fruiting branch cause it to develop a four dimensional occupation of space and time, which often defies analysis. Furthermore, the No. of Sympodial Branches (NSB) which plants make it in a season is influenced not only by the characteristics of the season, but also by the rapidity of new leaf development and by the growth habit of the cultivar.

Increases in cotton yield have been primarily through changes in partitioning of dry matter from vegetative to reproductive structures. Generally, plant breeders have made considerable progress in improving partitioning in plants between vegetative and reproductive structures for more efficient and higher yielding plant (Iqbal *et al*., 2006; Ulloa *et al*., 2006).

Correlation and factor analysis would provide useful information for planning a successful breeding programme. The true picture of correlation between seed cotton yield and traits is reflected from direct effect of that trait which will help for identifying the traits that contribute directly to improve seed cotton yield. If the correlation is mainly due to indirect effect of the character through another component trait, the breeder has to select for the trait through which the indirect effect is expected. A great yield response is obtained when the character for which indirect selection is practiced has a high heritability and a positive correlation with yield.

The results showed that most of the traits exerted their positive indirect effects through Boll Weight (BW), Earliness (ER) and Boll No. (BN) on cotton yield. Also, present study confirm that correlation coefficients, path analysis and factor analysis results could be complementary to cotton breeders for cotton yield improvement. The result of present study indicated that for evolving a superior genotype possessing high yield breeder should focus on improving desirable branching potential, No. of boll and boll weight with on time opening of bolls. This is a very important field where cotton is cultivated after wheat is harvested.

ACKNOWLEDGMENT

The authors acknowledge their gratitude towards director of Cotton Research Institute (CRI) for consistent encouragement and facilities provided.

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