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Association Analysis of Seed Cotton Yield Components and Physiological Parameters in Derived F_1 Inter Specific Crosses of Cotton

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Abstract The measure of association and path coefficient analysis was done in the study of derived F_1 crosses study. It is necessary to work out path coefficient analysis which partitions the observed correlation into direct and indirect effects and also reveals the cause and effect relationship between yield and their related traits. During 2010~2011 twenty eight F_4 lines of barbadense cross DB 533×DB 534 depending on the higher value of fiber tenacity, were crossed with the selected four hirsutum testers viz., DH 98-27 (T_1), ZCH 8 (T_2), 178-24 (T_3) and DH 18-31 (T_4) selected based on earlier study. Each barbadense F_4 line was involved in a set of crosses (112 crosses refer to as derived F_1 crosses) were subjected to Line x Tester analysis. It has been observed that seed cotton yield exhibited highly significant positive correlation with plant height (0.3495), number of monopodia per plant (0.4058), number of sympodia per plant (0.3506), number of bolls per plant (0.4013), mean boll weight (0.4200), seed index (0.2999), ginning outturn (0.2154), lint index (0.4448) and photosynthetic rate (0.2327) in derived F_1 crosses. Among these, seed cotton yield exhibited highly significant positive strong association with lint index compare to other characters. The direct effect on seed cotton yield was positive in plant height (0.0289), number of monopodia per plant (0.1771), number of sympodia per plant (0.0434), number of bolls per plant (0.1053), mean boll weight (0.1852), sympodial length at 50% plant height (0.1192), seed index (0.0393), ginning outturn (0.0786), lint index (0.2394) and photosynthetic rate (0.1588), while the direct effect on seed cotton yield was negative in reproductive points on sympodia (-0.1411), inter branch distance (-0.0746), stomatal conductance (-0.0309) and transpiration rate (-0.1937).
Keywords Correlation, Path co-efficient analysis, F_1 inter specific crosses

Introduction

Most of the characters of interest to breeders are complex and are the result of the interaction of a number of components. Understanding the relationship between yield and its components is of paramount importance for making the best use of these relationship in selection. The information derived from correlation co-efficient can be augmented by partitioning into direct and indirect effects by path co-efficient analysis.

There have been many factors which effect the cotton yield, like all plants. With regard to plant breeding studies, it is important that locations where plants are grown and determination of some traits which effect morphological and physiological characters of plants. Therefore, determination of direct and indirect relations among the traits is important in order to determine aspect of plant selection criteria. The main objective for a plant breeder is to evolve high yielding varieties. There are many factors on which the yield of cotton crop depends, such as plant height, number of fruiting branches, number of bolls per plant, boll weight, seed index, G.O.T% etc. It is desirable for plant breeder to know the extent of relationship between yield and its various components which will facilitate him in selecting plants of desirable characteristics. The knowledge of relationship among various yield components has been successfully exploited towards cotton improvement.

Correlation coefficient determines simple relations among the traits, so it doesn't determine always decisive results about determination of plant selection criteria (Cakmakci et al., 1998). Path coefficient analysis as to correlation coefficient gives more detailed information on the relations so it is commonly used by researches in plant breeding to determine seed cotton yield and seed cotton yield criteria relations (Williams et al., 1990; Kang et al., 1993; Board et al., 1997). Path coefficients have been used for complex characters in several crop species to provide information on interrelations of complex characters and to develop selection criteria (Kang et al., 1993; Gravois et al., 1991; Diz et al., 1994).

The aim of this study was to determine correlations, direct and indirect effects of component characters on seed cotton yield.

1 Material and Methods

To create recombinational variability for combining ability, the elite barbadense lines DB 533 and DB 534 were crossed during 2007~2008. During two seasons 2008~2009 and 2009~2010 these barbadense crosses were advanced to F_2 and F_3 generations, respectively. The F_3 lines were evaluated for productivity and fiber quality parameters realizing the emphasis laid on developing ELS (Extra Long Stable) cotton hybrids out of 171 F_3 lines, only those F_3 lines with acceptable fiber strength were utilized in the study on recombinational variability of combining ability. During 2010 ~2011 those twenty eight F_4 lines of barbadense cross DB 533×DB 534 depending on the higher value of fiber tenacity, were crossed with the selected four hirsutum testers viz., DH 98-27 (T_1), ZCH 8 (T_2), 178-24 (T_3) and DH 18-31 (T_4) selected based on earlier study. Each barbadense F4 line was involved in a set of crosses (112 crosses refer to as derived F_1 crosses) were subjected to Line x Tester analysis.

The degree of phenotypic association amongst characters was computed as per the formula given by Weber and Moorthy (1952).

$$r_p = \frac{Cov_{p1.2}}{\sqrt{\sigma^2_{p1} \cdot \sigma^2_{p2}}}$$

Where,

r p=Phenotypic correlation coefficient

Cov P1.2=Phenotypic covariance between two traits (1 and 2)

σ P1=Phenotypic standard deviation of first trait (1)

σ P2=Phenotypic standard deviation of second trait (2)

Path coefficient analysis was carried out using phenotypic correlation values of yield components on kapas yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Standard path coefficients which are the standardized partial regression coefficients were obtained using statistical software package called GENRES. These values were obtained by solving the following set of 'P' simultaneous equations by using the above package.

$$P_{01} + P_{02}\, r_{12} + \text{-----------} + P_{0P}\, r_{1P} = r_{01}$$

$$P_{01} + P_{12}\, r_{02} + \text{-----------} + P_{0P}\, r_{2P} = r_{02}$$

$$\downarrow$$

$$P_{01} + r_{1P} + P_{02}\, r_{2P}\ \text{-----------} + P_{0P} = r_{0P}$$

Where P_{01}, P_{02}, --------------------------P_{0P} are the direct effects of variables 1,2, -------------p on the dependent variable 0 and r_{12}, r_{13} ,-------r_{1P}------ $r_{P(P-1)}$ are the possible correlation coefficients between various independent variables and r_{01}, r_{02}, r_{03} ------- r_{0P} are the correlations between dependent and independent variables.

The indirect effect of the i^{th} variable *via* j^{th} variable is attained as (P_{oj} x r_{ij}). The contribution of remaining unknown factor is measured as the residual factor, which is calculated as given below.

$P^2ox=1-[P^2_{01} + 2P_{01} P_{02} r_{12} + 2 P_{01} P_{03} r_{13} +\text{----------}+ P^2_{02} + 2P_{02} P_{03} r_{13} +\ldots\ldots.+P^2_{0P}]$

Residual factor = $(P^2_{ox})^{½}$

2 Results and Discussion

2.1 Correlation co-efficient analysis

2.1.1 Phenotypic correlation coefficient in derived F_1 crosses

The phenotypic correlation coefficients among all characters related to seed cotton yield per plant were estimated and the results are presented in Table 1 & Figure 1.

2.1.2 Seed cotton yield (kg/ha)

It has been observed that seed cotton yield exhibited highly significant positive correlation with plant height (0.3495), number of monopodia per plant (0.4058), number of sympodia per plant (0.3506),

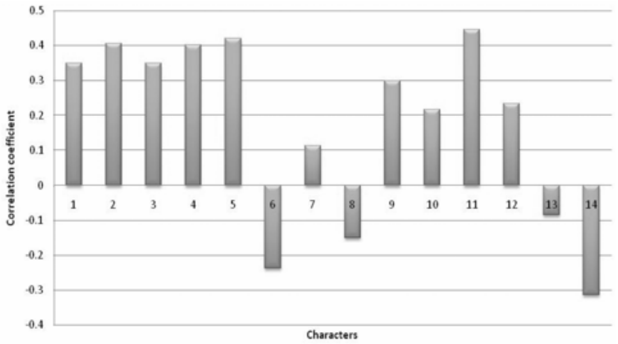

Figure 1 Phenotypic correlation coefficient of seed cotton yield per plant and different quantitative characters in derived F_1 crosses

Note: X1: Plant height (cm); X2: Number of monopodia; X3: Number of sympodia; X4: Number of bolls; X5: Mean boll weight (g); X6: Reproductive points; X7: Sympodial length at 50% plant height (cm); X8: Inter branch distance (cm); X9: Seed index (g); X10: Ginning outturn (%); X11: Lint index (g); X12: Photosynthetic rate (μmol CO_2 $m^{-2}s^{-1}$); X13: Stomatal conductance (μmol $m^{-2}s^{-1}$); X14: Transpiration rate (mmol H_2O $m^{-2}s^{-1}$); X15: Seed cotton yield (kg/ha)

number of bolls per plant (0.4013), mean boll weight (0.4200), seed index (0.2999), ginning outturn (0.2154), lint index (0.4448) and photosynthetic rate (0.2327) in derived F1 crosses. Among these, seed cotton yield exhibited highly significant positive strong association with lint index compare to other characters.

2.1.3 Number of monopodia per plant

Number of monopodia per plant recorded highly significant positive strong correlation with plant height (0.3578).

2.1.4 Number of sympodia per plant

Number of sympodia per plant exhibited highly significant positive correlation with plant height (0.5250) and number of monopodia per plant (0.2903). Number of sympodia per plant had highly significant positive strong correlation with plant height.

2.1.5 Number of bolls per plant

Number of bolls per plant recorded highly significant positive correlation with plant height (0.4670), number of monopodia per plant (0.4460) and number of sympodia per plant (0.5138). Among these number of bolls per plant had highly significant positive strong correlation with number of sympodia per plant.

2.1.6 Mean boll weight (g)

Mean boll weight exhibited highly significant positive correlation with plant height (0.2785), number of monopodia per plant (0.2085), number of sympodia per plant (0.2505) and number of bolls per plant (0.3010). Among these, mean boll weight showed highly significant positive strong correlation with number of bolls per plant.

2.1.7 Reproductive points on sympodia

Reproductive points on sympodia showed highly negative significant correlation with number of bolls per plant (-0.1946) and mean boll weight (-0.2490), while reproductive points on sympodia recorded negative significant correlation with number of sympodia per plant (-0.1216).

2.1.8 Sympodial length at 50 per cent plant height (cm)

Sympodial length at 50% plant height exhibited highly positive significant correlation with plant height (0.5207), number of monopodia per plant (0.1643), number of sympodia per plant (0.2397), number of bolls per plant (0.1695) and reproductive points on sympodia (0.4939). Among these, sympodial length at 50 % plant height recorded highly significant positive strong correlation with plant height.

2.1.9 Inter branch distance (cm)

Inter branch distance exhibited significant positive correlation with sympodial length at 50% plant height (0.1296).

2.1.10 Seed index (g)

Seed index recorded significant positive correlation with plant height (0.1437), highly significant positive correlation with number of monopodia per plant (0.1611), significant positive correlation with number of sympodia per plant (0.1290) and highly significant positive correlation with mean boll weight (0.1788). Among these seed index showed highly significant positive strong correlation with mean boll weight.

2.1.11 Ginning outturn (%)

Ginning outturn showed significant negative correlation with reproductive points on sympodia (-0.1283).

2.1.12 Lint index (g)

Lint index exhibited highly significant positive association with number of monopodia per plant

(0.1593), number of sympodia per plant (0.1651), mean boll weight (0.2190), seed index (0.4726) and ginning outturn (0.4501). Among these, lint index showed highly significant positive strong correlation with seed index (0.4726). Lint index recorded significant negative correlation with reproductive points on sympodia (-0.1328).

2.1.13 Photosynthetic rate (μmol$CO_2m^{-2}s^{-1}$)

Photosynthetic rate recorded highly significant positive correlation with seed index (0.2077), ginning outturn (0.2323) and lint index (0.3031). Among these, photosynthetic rate recorded highly significant positive strong correlation with lint index.

2.1.14 Stomatal conductance (μmol $m^{-2}s^{-1}$)

Stomatal conductance showed highly negative significant correlation with number of monopodia per plant (-0.2157) and number of bolls per plant (-0.1846), while stomatal conductance had highly significant positive strong correlation with photosynthetic rate (0.5401). Stomatal conductance exhibited significant positive correlation with inter branch distance (0.1498) and ginning outturn (0.1265).

2.1.15 Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)

Transpiration rate had highly significant negative correlation with plant height (-0.3070), number of monopodia per plant (-0.2338), number of sympodia per plant (-0.2981), number of bolls per plant (-0.3779), mean boll weight (-0.1755) and seed index (-0.1798), while transpiration rate recorded highly significant positive correlation with inter branch distance (0.2563), photosynthetic rate (0.2858) and stomatal conductance (0.5606). Among these, transpiration rate showed highly significant positive strong correlation with stomatal conductance. Transpiration rate exhibited significant positive correlation with number of reproductive points (0.1258).

2.2 Path co-efficient analysis

2.2.1 Direct and indirect phenotypic effects of component characters on seed cotton yield in derived F_1 crosses

The phenotypic path coefficient analysis among all characters related to seed cotton yield per plant were estimated and the results are presented in Table 2 & Figure 2.

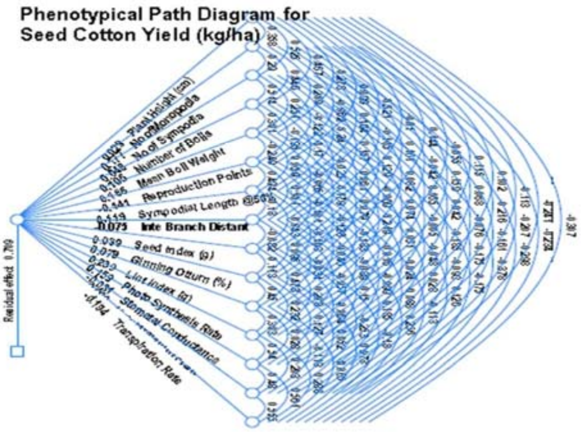

Figure 2 Direct and indirect phenotypic effects of seed cotton yield and different quantitative characters in derived F_1 crosses

2.2.2 Plant height (cm)

The direct effect of this character on seed cotton yield was positive (0.0289), although plant height exhibited highly significant positive association with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through plant height appeared to be positive value in respect of number of monopodia per plant (0.0104), number of sympodia per plant (0.0152), number of bolls per plant (0.0135), mean boll weight (0.0081), reproductive points on sympodia (0.0029), sympodial length at 50% plant height (0.0151), seed index (0.0042), lint index (0.0033) and photosynthetic rate (0.003). The contribution had negative indirect effects via inter branch distance (-0.0003), ginning outturn (-0.0016), stomatal conductance (-0.0033), and transpiration rate (-0.0089).

2.2.3 Number of monopodia per plant

This character appeared to influence seed cotton yield directly as positive value (0.1771). Balakotaiah (1973), Gill and Singh (1981), Vijendaradradas (1981) represented the same result in their study. Although number of monopodia per plant recorded highly significant positive correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through number of monopodia per plant appeared to be positive value in respect of plant height (0.0634), number of sympodia per plant (0.0514), number of bolls per plant (0.079), mean boll weight (0.0369), sympodial length at 50% plant height (0.0291), seed index (0.0285), lint index (0.0282) and photosynthetic rate (0.012). The association recorded negative indirect effects via reproductive points on sympodia (-0.011), inter branch distance (-0.0186), ginning outturn (-0.0074), stomatal conductance (-0.0382) and transpiration rate (-0.0414).

2.2.4 Number of sympodia per plant

The direct influence of number of sympodia per plant towards seed cotton yield was positive (0.0434). Tomar and Singh (1992), Bhatade (1982) found the same result. Although number of sympodia per plant recorded highly significant positive correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through number of sympodia per plant showed to be positive value in respect of plant height (0.0228), number of monopodia per plant (0.0126), number of bolls per plant (0.0223), mean boll weight (0.0109), sympodial length at 50% plant height (0.0104), inter branch distance (0.0046), seed index (0.0056), ginning outturn (0.0036), lint index (0.0072) and photosynthetic rate (0.0018). The contribution showed negative indirect effects via reproductive points on sympodia (-0.0053), stomatal conductance (-0.0033) and transpiration rate (-0.0129).

2.2.5 Number of bolls per plant

The direct effect of number of bolls per plant on seed cotton yield was positive (0.1053), although number of bolls per plant exhibited highly significant positive association with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through number of bolls per plant appeared to be positive value in respect of plant height (0.0492), number of monopodia per plant (0.047), number of sympodia per plant (0.0541), mean boll weight (0.0317), sympodial length at 50% plant height (0.0179), seed index (0.0064) and lint index (0.0078). The contribution exhibited negative indirect effects via reproductive points on sympodia (-0.0205), inter branch distance (-0.0026), ginning outturn (-0.0073), photosynthetic rate (-0.0005), stomatal conductance (-0.0194) and transpiration rate (-0.0398). The importance of number of bolls per plant towards seed yield has also been reported by Dedaniy and Pethani (1994), Tyagi et al. (1988), Muthu et al. (2004) and Verma et al. (2006). Therefore this trait appears to be most important in influencing seed cotton yield in cotton and selection should be oriented towards high boll number.

2.2.6 Mean boll weight (g)

The direct contribution of mean boll weight on seed cotton yield was positive (0.1852), although mean boll weight showed highly significant positive association with seed cotton yield. The highest contribution of mean boll weight has been reported by Balakotaiah (1973), Gill and Singh (1981), Vijendaradradas (1981), Salimath (1975) and Krishnarao and Mary (1990). The contribution of other characters indirectly on seed cotton yield through mean boll weight appeared to be positive value in respect of plant height (0.0516), number of monopodia per plant (0.0386), number of sympodia per plant (0.0464), number of bolls per plant (0.0557), sympodial length at 50% plant height (0.0109), seed index (0.0331), ginning outturn (0.0146), lint index (0.0406) and photosynthetic rate (0.0094). The association exhibited negative indirect effects via reproductive points on sympodia (-0.0461), inter branch distance (-0.012), stomatal conductance (-0.0089) and transpiration rate (-0.0325).

2.2.7 Reproductive points on sympodia

It was observed that this character appeared to influence seed cotton yield directly as negative value (-0.1411), reproductive points on sympodia recorded non significant negative correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through reproductive points on sympodia to be positive value in respect of number of monopodia per plant (0.0088), number of sympodia per plant (0.0172), number of bolls per plant (0.0275), mean boll weight (0.0351), seed index (0.0143), ginning outturn (0.0181), lint index (0.0187), photosynthetic rate (0.0022) and stomatal conductance (0.0033). The association exhibited negative indirect effects via plant height (-0.014), sympodial length at 50% plant height (-0.0697), inter branch distance (-0.0142) and transpiration rate (-0.0178).

2.2.8 Sympodial length at 50% plant height (cm)

The direct effect of sympodial length at 50% plant height on seed cotton yield was positive (0.1192), although sympodial length at 50% plant height recorded non significant positive correlation with seed cotton yield. The indirect contribution to seed cotton yield through sympodial length at 50% plant height was positive value in respect of plant height (0.0621), number of monopodia per plant (0.0196), number of sympodia per plant (0.0286), number of bolls per plant (0.0202), mean boll weight (0.007), reproductive points on sympodia (0.0589) and inter branch distance (0.0155). The association exhibited negative indirect effects via seed index (-0.0051), ginning outturn (-0.0123), lint index (-0.0055), photosynthetic rate (-0.0047), stomatal conductance (-0.0118) and transpiration rate (-0.0135).

2.2.9 Inter branch distance (cm)

It expressed a considerably negative direct effect of inter branch distance on seed cotton yield (-0.0746) and had non significant negative correlation with seed cotton yield. The indirect effect of inter branch distance was positive through plant height (0.0007), number of monopodia per plant (0.0078), number of bolls per plant (0.0018), mean boll weight (0.0049), seed index (0.0061), lint index (0.0023) and photosynthetic rate (0.0042). The association recorded negative indirect effects via number of sympodia per plant (-0.008), reproductive points on sympodia (-0.0075), sympodial length at 50% plant height (-0.0097), ginning outturn (-0.0071), stomatal conductance (-0.0112) and transpiration rate (-0.0191).

2.2.10 Seed index (g)

It was observed that this character appeared to influence seed cotton yield directly as positive value (0.0393), seed index recorded highly significant positive correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through seed index to be positive value in respect of plant height (0.0056), number of monopodia per plant (0.0063), number of sympodia per plant (0.0051), number of bolls per plant (0.0024), mean boll weight (0.007), ginning outturn (0.0044), lint index (0.0186) and photosynthetic rate (0.0082). The association exhibited negative indirect effects via reproductive points on sympodia (-0.004), sympodial length at 50% plant height (-0.0017), inter branch distance (-0.0032), stomatal conductance (-0.0025) and transpiration rate (-0.0071). Similar results were also reported by Tyagi et al. (1988), Sumathi and Nandarajan (1995).

2.2.11Ginning outturn (%)

The direct effect of ginning outturn on seed cotton yield was positive (0.0786), ginning outturn recorded highly significant positive correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through ginning outturn to be positive value in respect of number of sympodia per plant (0.0065), mean boll weight (0.0062), inter branch distance (0.0075), seed index (0.0089), lint index (0.0354), photosynthetic rate (0.0183), stomatal conductance (0.0099) and transpiration rate (0.0057). The association exhibited negative indirect effects via plant height (-0.0043), number of monopodia per plant (-0.0033), number of bolls per plant (-0.0054), reproductive points on sympodia (-0.0101) and sympodial length at 50% plant height (-0.0081). Similar findings of high indirect effect of ginning out turn in seed cotton yield is also reported by Tomar et al. (1992).

2.2.12 Lint index (g)

It expressed a considerably positive direct effect of lint index on seed cotton yield (0.2394) and had highly significant positive correlation with seed cotton yield. The indirect effect of lint index was positive through plant height (0.0274), number of monopodia per plant (0.0381), number of sympodia per plant (0.0395), number of bolls per plant (0.0177), mean boll weight (0.0524), seed index (0.1131), ginning outturn (0.1078), photosynthetic rate (0.0726) and stomatal conductance (0.0067). The association recorded negative indirect effects via reproductive points on sympodia (-0.0318), sympodial length at 50 % plant height (-0.0111), inter branch distance (-0.0073) and transpiration rate (-0.0155). These findings are in line with the earlier findings of Dedaniya and Pethani (1994) and Tomar and Singh (1991).

2.2.13 Photosynthetic rate (μmol$CO_2m^{-2}s^{-1}$)

The direct contribution of photosynthetic rate on seed cotton yield was positive (0.1588), although photosynthetic rate showed highly significant positive association with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through photosynthetic rate appeared to be positive value in respect of plant height (0.0162), number of monopodia per plant (0.0107), number of sympodia per plant (0.0067), mean boll weight (0.0081), seed index (0.0330), ginning outturn (0.0369), lint index (0.0481), stomatal conductance (0.0858) and transpiration rate (0.0454). The association exhibited negative indirect effects via number of bolls per plant (-0.0008) reproductive points on sympodia (-0.0025), sympodial length at 50 % plant height (-0.0062) and inter branch distance (-0.009).

2.2.14 Stomatal conductance (μmol $m^{-2}s^{-1}$)

It was observed that this character appeared to influence seed cotton yield directly as negative value (-0.0309), stomatal conductance recorded non significant negative correlation with seed cotton yield. The contribution of other characters indirectly on seed cotton yield through stomatal conductance to be positive value in respect of plant height (0.0035), number of monopodia per plant (0.0067), number of sympodia per plant (0.0023), number of bolls per plant (0.0057), mean boll weight (0.0015), reproductive points on sympodia (0.0007), sympodial length at 50 % plant height (0.003) and seed index (0.002). The association exhibited negative indirect effects via inter branch distance (-0.0046), ginning outturn (-0.0039), lint index (-0.0009), photosynthetic rate (-0.0167) and transpiration rate (-0.0173). Wong et al. (1979) and Kuroda and Kumura (1990) found the same result.

2.2.15 Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)

It expressed a considerably negative direct effect of transpiration rate on seed cotton yield (-0.1937) and had non significant negative correlation with seed cotton yield. The indirect effect of transpiration rate was positive through plant height (0.0595), number of monopodia per plant (0.0453), number of sympodia per plant (0.0577), number of bolls per plant (0.0732), mean boll weight (0.0340), sympodial length at 50% plant height (0.0218), seed index (0.0348) and lint index (0.0125). The association recorded negative indirect effects via reproductive points on sympodia (-0.0244), inter branch distance (-0.0496), ginning outturn (-0.0141), photosynthetic rate (-0.0553) and stomatal conductance (-0.1086).

Yield is a complex polygenically inherited character resulting from multiplicative interaction of its contributing characters. It is highly influenced by the environment, hence selection based on yield alone may limit the improvement. Whereas, the component characters of yield are less complex in inheritance and are influenced by the environment to a lesser extent. Thus, effective improvement in yield may be brought about through selection for yield component characters. Yield component characters show association among themselves and also with yield. Favorable associations between desirable attributes will help improvement in a joint manner. Whereas, unfavorable associations between the desirable attributes under selection may limit genetic advance. Hence, knowledge of associations between the yield components and also among themselves are essential for planning a sound breeding programme.

Grafius (1959) reported that there may not be genes for yield as such, but operate only through its components. So, correlation analysis provides the information on nature and magnitude of the association of different components characters with seed yield, which is regarded as highly complex trait in which the breeder is ultimately interested. So, it is a matter of great importance to the plant breeders to find out as to which of the characters are correlated with yield and also how they are associated among themselves, if negative association between characters is due to pleiotropic effects it would be very difficult to obtain the desired combinations while if linkage is involved, special breeding programmes are needed to break these linkage blocks.

In the present investigation, character association among different quantitative characters in cross population study is estimated by using correlation coefficient at phenotypic level.

At phenotypic level, seed cotton yield exhibited highest positive association with lint index, mean boll weight, number of monopodia per plant, number of bolls per plant, number of sympodia per plant, plant height, seed index, photosynthetic rate, ginning outturn and sympodial length at 50 per cent plant height. Similar results of association of these traits with seed cotton yield were reported by Bhatade (1982), Gulamov et al. (1974), Manivasakam (1985), Nazir and Khan (1974), Verma et al. (2006) and Muthu et al. (2004). Whereas seed cotton yield recorded negative correlation with stomatal conductance, inter branch distance, reproductive points on sympodia and transpiration rate. Negative correlation between seed cotton yield and stomatal conductance the same results confirmed with the findings of Penman and Schofield (1951), Jones (1977), Austin (1977) and Jing and Ma (1990).

The phenotypic correlation values also revealed that seed cotton yield per plant had highly significant and positive phenotypic correlation with bolls per plant. Similar results were represented by Musande et al. (1981), Govilla and Sharma (1981), Gill and Singh (1981), Bhatade (1982), Gawand et al. (1984), Kumar and Choudhary (1986), Shandhu et al. (1986). Significant and positive phenotypic correlation found between seed cotton yield per plant and mean boll weight. The same findings were reported by Griffee, Ligon and Brannon (1929). The association of seed cotton yield with monopodia appeared positive association was found by Singh et al. (1968).

Number of monopodia per plant recorded highly significant positive strong correlation with plant height. Number of sympodia per plant exhibited highly significant positive correlation with plant height and number of monopodia per plant. Number of sympodia per plant had highly significant positive strong correlation with plant height. Number of bolls per plant recorded highly significant positive correlation with plant height, number of monopodia per plant and number of sympodia per plant. Among these number of bolls per plant had highly significant positive strong correlation with number of sympodia per plant.

Mean boll weight exhibited highly significant positive correlation with plant height, number of monopodia per plant, number of sympodia per plant and number of bolls per plant. Among these, mean boll weight showed highly significant positive strong correlation with number of bolls per plant. Reproductive points on sympodia showed highly negative significant correlation with number of bolls per plant and mean boll weight, while reproductive points on sympodia recorded negative significant correlation with number of sympodia per plant. Sultan et al. (1999) and Jagtap and Kolhe (1984) reported the same results.

Sympodial length at 50% plant height exhibited highly positive significant correlation with plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant and reproductive points on sympodia. Among these, sympodial length at 50% plant height recorded highly significant positive strong correlation with plant height. Inter branch distance exhibited significant positive correlation with sympodial length at 50% plant height.

Seed index recorded significant positive correlation with plant height, highly significant positive correlation with number of monopodia per plant, significant positive correlation with number of sympodia per plant and highly significant positive correlation with mean boll weight. Among these seed index showed highly significant positive strong correlation with mean boll weight. Ginning outturn showed significant negative correlation with reproductive points on sympodia. Similar results have been also reported by Sambamurthy et al. (1994).

Lint index exhibited highly significant positive association with number of monopodia per plant, number of sympodia per plant, mean boll weight, seed index and ginning outturn. Among these, lint index showed highly significant positive strong correlation with seed index. Lint index recorded significant negative correlation with reproductive points on sympodia. The same result of significant positive correlation between seed index and lint index confirmed by Sambamurthy et al. (1994).

Seed cotton yield exhibited highly significant positive correlation with plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, mean boll weight, seed index, ginning outturn, lint index and photosynthetic rate in cross population. Among these, seed cotton yield exhibited highly significant positive strong association with lint index compare to other characters. Similar results of association of these traits with seed cotton yield were reported by Bhatade (1982), Gulamov et al. (1974), Manivasakam (1985), Nazir and Khan (1974), Verma et al. (2006) and Muthu et al. (2004).

Stomatal conductance showed highly negative significant correlation with number of monopodia per plant and number of bolls per plant, while stomatal conductance had highly significant positive strong correlation with photosynthetic rate. Stomatal conductance exhibited significant positive correlation with inter branch distance and ginning outturn.

Transpiration rate had highly significant negative correlation with plant height, number of monopodia per plant, number of sympodia per plant, number of bolls per plant, mean boll weight and seed index, while transpiration rate recorded highly significant positive correlation with inter branch distance, photosynthetic rate and stomatal conductance. Among these, transpiration rate showed highly significant positive strong correlation with stomatal conductance. Transpiration rate exhibited significant positive correlation with number of reproductive points.

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Table 1 Phenotypic correlation coefficient of seed cotton yield per plant and different quantitative characters in derived F_1 crosses

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	1.0000	0.3578**	0.5250**	0.4670**	0.2785**	0.0990	0.5207**	-0.0098	0.1437*	-0.0553	0.1146	0.1022	-0.1133	-0.3070**	0.3495**
X2		1.0000	0.2903**	0.4460**	0.2085**	-0.0621	0.1643**	-0.1048	0.1611**	-0.0416	0.1593**	0.0676	-0.2157**	-0.2338**	0.4058**
X3			1.0000	0.5138**	0.2505**	-0.1216*	0.2397**	0.1068	0.1290*	0.0822	0.1651**	0.0421	-0.0755	-0.2981**	0.3506**
X4				1.0000	0.3010**	-0.1946**	0.1695**	-0.0248	0.0608	-0.0689	0.0739	-0.005	-0.1846**	-0.3779**	0.4013**
X5					1.0000	-0.249**	0.0591	-0.065	0.1788**	0.0791	0.219**	0.0508	-0.0482	-0.1755**	0.4200**
X6						1.0000	0.4939**	0.1008	-0.1014	-0.1283*	-0.1328*	-0.0155	-0.0235	0.1258*	-0.2390
X7							1.0000	0.1296*	-0.0428	-0.1032	-0.0465	-0.0391	-0.0986	-0.1128	0.1125
X8								1.0000	-0.0816	0.0951	-0.0306	-0.0567	0.1498*	0.2563**	-0.1508
X9									1.0000	0.1131	0.4726**	0.2077**	-0.0636	-0.1798**	0.2999**
X10										1.0000	0.4501**	0.2323**	0.1265*	0.0728	0.2154**
X11											1.0000	0.3031**	0.0279	-0.0646	0.4448**
X12												1.0000	0.5401**	0.2858**	0.2327**
X13													1.0000	0.5606**	-0.0861
X14														1.0000	-0.3150
X15															1.0000

Note: * Significant at P=0.05; ** Significant at P=0.01; X1: Plant height (cm); X2: Number of monopodia; X3: Number of sympodia; X4: Number of bolls; X5: Mean boll weight (g); X6: Reproductive points; X7: Sympodial length at 50% plant height (cm); X8: Inter branch distance (cm); X9: Seed index (g); X10: Ginning outturn (%); X11: Lint index (g); X12: Photosynthetic rate (μmol CO_2 m^{-2} s^{-1}); X13: Stomatal conductance (μmol m^{-2} s^{-1}); X14: Transpiration rate (mmol H_2O m^{-2} s^{-1}); X15: Seed cotton yield (kg/ha)

Table 2 Direct and indirect phenotypic effects of seed cotton yield and different quantitative characters in derived F_1 crosses

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	Phenotypic correlation with seed cotton yield
X1	0.0289	0.0104	0.0152	0.0135	0.0081	0.0029	0.0151	-0.0003	0.0042	-0.002	0.0033	0.003	-0.0033	-0.0089	0.3495**
X2	0.0634	0.1771	0.0514	0.079	0.0369	-0.011	0.0291	-0.0186	0.0285	-0.007	0.0282	0.012	-0.0382	-0.0414	0.4058**
X3	0.0228	0.0126	0.0434	0.0223	0.0109	-0.0053	0.0104	0.0046	0.0056	0.0036	0.0072	0.0018	-0.0033	-0.0129	0.3506**
X4	0.0492	0.047	0.0541	0.1053	0.0317	-0.0205	0.0179	-0.0026	0.0064	-0.007	0.0078	-0.0005	-0.0194	-0.0398	0.4013**
X5	0.0516	0.0386	0.0464	0.0557	0.1852	-0.0461	0.0109	-0.012	0.0331	0.0146	0.0406	0.0094	-0.0089	-0.0325	0.4200**
X6	-0.014	0.0088	0.0172	0.0275	0.0351	-0.1411	-0.0697	-0.0142	0.0143	0.0181	0.0187	0.0022	0.0033	-0.0178	-0.2390
X7	0.0621	0.0196	0.0286	0.0202	0.007	0.0589	0.1192	0.0155	-0.005	-0.012	-0.0055	-0.005	-0.0118	-0.0135	0.1125
X8	0.0007	0.0078	-0.008	0.0018	0.0049	-0.0075	-0.0097	-0.0746	0.0061	-0.007	0.0023	0.0042	-0.0112	-0.0191	-0.1508
X9	0.0056	0.0063	0.0051	0.0024	0.007	-0.004	-0.0017	-0.0032	0.0393	0.0044	0.0186	0.0082	-0.0025	-0.0071	0.2999**
X10	-0.0043	-0.003	0.0065	-0.005	0.0062	-0.0101	-0.0081	0.0075	0.0089	0.0786	0.0354	0.0183	0.0099	0.0057	0.2154**
X11	0.0274	0.0381	0.0395	0.0177	0.0524	-0.0318	-0.0111	-0.0073	0.1131	0.1078	0.2394	0.0726	0.0067	-0.0155	0.4448**
X12	0.0162	0.0107	0.0067	-0.0008	0.0081	-0.0025	-0.0062	-0.009	0.033	0.0369	0.0481	0.1588	0.0858	0.0454	0.2327**
X13	0.0035	0.0067	0.0023	0.0057	0.0015	0.0007	0.003	-0.0046	0.002	-0.004	-0.0009	-0.017	-0.0309	-0.0173	-0.0861
X14	0.0595	0.0453	0.0577	0.0732	0.034	-0.0244	0.0218	-0.0496	0.0348	-0.014	0.0125	-0.055	-0.1086	-0.1937	-0.3150

Note: Residual effect=0.7086; X1: Plant height (cm); X2: Number of monopodia; X3: Number of sympodia; X4: Number of bolls; X5: Mean boll weight (g); X6: Reproductive points; X7: Sympodial length at 50% plant height (cm); X8: Inter branch distance (cm); X9: Seed index (g); X10: Ginning outturn (%); X11: Lint index (g); X12: Photosynthetic rate (μmol CO_2 m^{-2} s^{-1}); X13: Stomatal conductance (μmol m^{-2} s^{-1}); X14: Transpiration rate (mmol H_2O m^{-2} s^{-1}); X15: Seed cotton yield (kg/ha)