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# Interrelationship and Path-coefficient Studies for Qualitative Traits, Grain Yield and other Yield Attributes among Maize (*Zea mays* L.)

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## ABSTRACT

In an attempt to study the association of different agronomic traits in improving qualitative and quantitative aspects of maize correlation studies and path analysis were done. Association studies indicated that characters like plant height, ear height, ear length, ear girth, number of grains per row, number of grains per ear, starch content, hundred grain weight and carotene content showed significant positive association with grain yield. While days to tasseling and days to silking showed positive non-significant association with grain yield. Number of rows per ear and crude protein content recorded negative non-significant association with grain yield. Ear length recorded highest correlation (r = 0.871) with grain yield followed by number of grains per row (r = 0.868). Out of the fourteen traits taken for path analysis, ear length had a maximum positive direct effect on grain yield followed by ear height, number of rows per ear, days to silking, crude protein and carotene content and they contributed primarily to yield and could be relied upon for selection of genotypes to improve genetic yield potential of corn. Plant height, days to tasseling, ear girth, number of grains per row, number of grains per ear, hundred grain weight and starch content recorded negative direct effect on grain yield even though genotypic correlation coefficients on grain yield were positive. The study revealed that direct selection for ear length, ear height and number of rows per ear might be rewarding for yield improvement since they revealed true relationship with grain yield.

**Key words:** Correlation coefficient, path analysis, maize grain yield, nutritional characters, total starch, carotene, crude protein

## INTRODUCTION

Maize is a globally important crop and a favored staple food for more than 1 billion people in Sub-Saharan Africa and Latin America, where animal source of protein is not reasonably priced by the common people (Gupta *et al.*, 2009). Maize is an important cereal in Asia as well but here more than half of the produce is used for livestock feed, primarily due to strong economic growth and rapid urbanization experienced by many countries of the subcontinent, including India (Prasanna *et al.*, 2001). The nutritional qualities of maize are on par with other cereals in most of the aspects. The maize kernel contains approximately 60-70% carbohydrates, 9-11.5% crude protein, 2-3.5% crude fibre, 3-5% lipids and 20 mg of calcium/100 g of kernels. A genetic approach to improve the nutritional quality or biological utilization of maize protein yielded the

Quality Protein Maize (QPM) which combines the high nutritional quality of *opaque-2* gene (high lysine and high tryptophan) with the shiny, transparent kernel structure of common maize (Vasal, 2001; Crow and Kermicle, 2002). It also contains other minerals and vitamins. Use of carotene rich varieties, which is a precursor of Vitamin A, can counter Vitamin A deficiency and enhance Vitamin A prophylaxis programme. Adequate amount of carotene are present only in yellow maize but it gets easily destroyed during prolonged storage. The yellow-seeded improved maize varieties were analysed for physical and chemical characteristics and total carotene content; the results showed statistically significant and large genotypic differences in total carotene content among the 16 yellow-seeded improved, open-pollinated maize varieties. The total carotene content ranged from 143 to 278 $\mu g\ g^{-1}$ (Dixon *et al.*, 2000).

The common assumption is that there is an inverse relationship between yield and protein content, that is, yield declines as protein percentage increases. In a study conducted by Idikut *et al.* (2009) the crude protein contents of hybrids ranged from 8.91-11.65% whereas the grain yield ranged from 9561.6-11554.3 kg $ha^{-1}$. The starch yield ranged from 6626.2-8425.2 kg $ha^{-1}$. Crude protein yield ranged from 1065.9-1249.0 kg $ha^{-1}$. There is a significant correlation among starch, protein and yield parameters. The crude protein content decreased with increasing starch content and grain yield. A number of studies suggested that the protein from maize with its content of *opaque-2* gene is almost as effective as milk protein. Feeding trials with opaque-2 maize showed a significant improvement in protein deficiency malnutrition and stopped pellagra, a disease associated with insufficient intake of nicotinamide or its precursor tryptophan, within 100 days (Enwere, 1998; Nelson, 2001).

Correlation studies indicated that corn yield was significantly and positively associated with 100-seed weight, protein percent, ear length and number of seeds per row. Path co-efficient analysis revealed the importance of 100-seed weight, protein percent, days to 50% tasselling and ear length since they exhibited high magnitudes of positive direct effects on corn grain yields (Prakash *et al.*, 2006). In a study conducted by Wannows *et al.* (2010) correlation coefficients among traits in maize indicated that grain yield was positively and significantly associated with number of kernel per row (0.589), ear length (0.465) and leaf area index (0.497). The path coefficient analysis was calculated to detect the relative importance of characters contributing to grain yield. Data showed that each of leaf area index, ear diameter and physiological maturity had high positive direct effects on grain yield.

Crop yield is one of the complex characters controlled by several interacting genotypic and environmental factors. There are quite few yield components which are less complex, highly inherited and less influenced by the environmental changes (Kashiani and Saleh, 2010). Interrelationships existed between yield and its contributing components can significantly improve the efficiency of crop breeding programmes through the use of proper selection indices (Mohammadi *et al.*, 2003; Kashiani *et al.*, 2010). Direct selection for yield is often misleading as it is highly influenced by unpredictable environmental components (Talebi *et al.*, 2007). The correlation coefficient analysis is useful in the selection of several traits simultaneously influencing yield (Menkir, 2008). Genetic correlation analysis exploits the degree of association among important quantitative traits (Malik *et al.*, 2005). By utilizing genetic correlations between traits, secondary traits can be used to improve primary ones that have low heritability or are difficult to measure (Malosetti *et al.*, 2008).

The progress in breeding for yield and its contributing characters of any crop is polygenically controlled, environmentally influenced and determined by the magnitude and nature of their genetic variability. Association in amalgamation with path analysis would give a better insight into cause and effect relationship between different pairs of traits (Jayasudha and Sharma, 2010). Knowledge of correlation between yield and its contributing characters are basic and fore most endeavor to find out guidelines for plant selection. Partitioning of total correlation into direct and indirect effect by path coefficient analysis helps in making the selection more effective (Priya and Joel, 2009).

The major advantage of path analysis is that, it permits the partitioning of the correlation coefficient into its components. One component being the path coefficient that measures the direct effect of a predictor variable upon its response variable, the second component being the indirect effect (s) of a predictor variable on the response variable through another predictor variable (Dewey and Lu, 1959). In agriculture, path analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Milligan *et al.*, 1990; Surek and Beser, 2003).

Hence, an attempt was made to understand the association of grain yield with yield attributes with quality traits and to determine the intercorrelation between the traits at genotypic level to obtain path values, showing the extent of direct and indirect effects of various biometrical traits upon grain yield.

## MATERIALS AND METHODS

The present investigation was carried out at the Millet Breeding Station, Centre for Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore in the year 2003. Fifteen inbreds maintained by sib mating for five generations at the maize-breeding unit, Department of Millets formed the materials of this study. The details of parents are listed in Table 1. Fifty hybrid combinations were obtained by crossing them in a line x tester design.

Table 1: Details of maize inbreds used for hybridization in this study at Millet Breeding Station, Coimbatore, India

| S.No. | Inbred / Variety | Source | Code No. |
|---|---|---|---|
| **LINES♀** | | | |
| 1. | UMI 585 | MBS, TNAU, COIMBATORE | $L_1$ |
| 2. | UMI 473 | MBS, TNAU, COIMBATORE | $L_2$ |
| 3. | UMI 545 | MBS, TNAU, COIMBATORE | $L_3$ |
| 4. | UMI 526 | MBS, TNAU, COIMBATORE | $L_4$ |
| 5. | UMI 448 | MBS, TNAU, COIMBATORE | $L_5$ |
| 6. | UMI 434 | MBS, TNAU, COIMBATORE | $L_6$ |
| 7. | UMI 810-1 | MBS, TNAU, COIMBATORE | $L_7$ |
| 8. | UMI 593 | MBS, TNAU, COIMBATORE | $L_8$ |
| 9. | UMI 285 | MBS, TNAU, COIMBATORE | $L_9$ |
| 10. | UMI 479 | MBS, TNAU, COIMBATORE | $L_{10}$ |
| **TESTER♂** | | | |
| 11. | UMI 112 | MBS, TNAU, COIMBATORE | $T_1$ |
| 12. | UMI 90 | MBS, TNAU, COIMBATORE | $T_2$ |
| 13. | UMI 51 | MBS, TNAU, COIMBATORE | $T_3$ |
| 14. | UMI 130 | MBS, TNAU, COIMBATORE | $T_4$ |
| 15. | UMI 101 | MBS, TNAU, COIMBATORE | $T_5$ |
| **CHECK #** | | | |
| 16. | COH2 | MBS, TNAU, COIMBATORE | $C_1$ |

UMI: University Maize Inbred, MBS: Millet Breeding Station, TNAU: Tamil Nadu Agricultural University, ♀: Female Parents, ♂: Male Parents, #: Ruling Hybrid [Coimbatore Hybrid 2]

Tassel bag method was used for hybridization (Abidin *et al*., 1979). For crossing, the pollen from desired male parent was collected and dusted over the silk of desired female parents. While for selfing, the pollen from same plant was utilized. All the fifteen parents (10 lines and 5 testers) together with 50 crosses were evaluated during the standard check COH2, each entry was grown in three rows of four meters length adopting randomized block design replicated thrice. The trial was conducted in normal red loamy soil. The recommended dose of fertilizer given was 132.5: 62.5: 60 kg NPK $ha^{-1}$, respectively. Nitrogenous fertilizer was given in 3 split doses. The row to row and plant to plant distance was 60×25 cm, respectively. Border rows were raised all along the field to avoid environmental influence. All other agronomic and plant protection practices applicable for commercial maize crop were being adopted. The biometrical and biochemical observations were recorded on five randomly selected plants from each variant per replication. The following biometrical observations were recorded for both parents and hybrids.

Days To Tasseling (DTT), Days To Silking (DTS), Plant Height (PH), Ear Height (EH), Number Of Leaves Per Plant (NOLPP), Leaf Length (LL), Leaf Width (LW), Leaf Area (LA), as mentioned by Stickler *et al*. (1961).

De-Husked Ear Length (DHEL), Ear Girth (EG), Number Of grain Rows Per Ear (NORPE), Number Of Grains Per Row (NOGPR), Number Of Grains Per Ear (NOGPE), Ear Weight (EW), Test Weight (TW-100 g) and Grain Yield Per Plant (GYPP). Qualitative traits like Crude Protein (CP) in terms of total nitrogen content was estimated from the representative sample of dried grains by microkjeldahl method (Humphries, 1956). Starch content was recorded in percentage by anthrone reagent method (Clegg, 1956). **β**-carotene was estimated by using the protocol given by Rodriguez *et al*. (1976). The formula for estimating carotene content is given as:

$$\text{Carotene content} = \left[\frac{\text{Absorbency of sample at 453 nm}}{0.2592}\right] \times \left[\frac{\text{Total valume}}{\text{Weight of the sample}}\right] \times \left[\frac{100}{1000}\right]$$

where, 0.2592 is the extinction coefficient of **β**-carotene at 453 nm. i.e., 1 μg $mL^{-1}$ solution would give an extinction of 0.2592. The result was expressed as the amount of carotene present in milligrams per 100 g of the grain.

**Statistical analysis:** The replication-wise mean values of genotypes were subjected to statistical analysis using AGRISTAT software. Mean values of both parents and hybrids were subjected to genotypic correlation co-efficient as per the method suggested by Falconer and Mackay (1996). Path coefficient analysis as applied by Dewey and Lu (1959), was utilized for the partition of the genotypic correlation coefficients into measures of direct and indirect effects.

## RESULTS AND DISCUSSION

In the present study, the mean performances of lines, testers, parents, hybrids and standard check were worked out (Table 2). The overall mean performance of lines, testers, hybrids and standard check [Coimbatore Hybrid 2] were significant for most of the traits studied. When compared to the lines [females] and testers [males], the overall mean values are higher in hybrids for all of the traits except for number of rows per ear and crude protein content, where the overall means of parents were higher. The overall means of the hybrids for some of the yield contributing traits were significant and higher when compared to the ruling variety COH2. The characters are ear girth, number of rows per ear, number of grainsper row, number of grains per ear, ear weight,

Table 2: Mean performances of lines, testers, parents, hybrids and standard check.

| Character | Lines (range) | Testers (range) | Parents (range) | Hybrids (range) | Standard check |
|---|---|---|---|---|---|
| DTT | 47.0-70.3 | 57.60-65.7 | 47.0-65.7 | 46.7 -68.7 | |
| Overall Mean | 58.33* | 62.33* | 59.73 | 57.09 | 62.67*[a] |
| DTS | 51.0 -75.3 | 61.0-69.7 | 51.0-69.7 | 52.0-73.3 | |
| Overall Mean | 62.23** | 65.93* | 63.47 | 61.03* | 67.33**[a] |
| PH (cm) | 99.1-194.3 | 150.8-190.0 | 99.1-190.0 | 122.08-215.5 | |
| Overall Mean | 154.86 | 172.97* | 160.87 | 181.06** | 196.36** [a] |
| EH (cm) | 62.1-100.8 | 82.1-103.3 | 62.1-103.3 | 64.8-125.4 | |
| Overall Mean | 80.33* | 96.02** | 85.54 | 96.15** | 112.48** [a] |
| NOLPP | 10.7-13.8 | 12.2-13.6 | 10.7-13.6 | 11.1-15.1 | |
| Overall Mean | 12.49* | 12.84* | 12.60 | 13.40** | 13.50** [a] |
| LL (cm) | 45.8-80.4 | 83.1-64.7 | 45.8-64.7 | 57.2-85.8 | |
| Overall Mean | 65.28* | 74.3* | 68.30 | 76.15* | 81.25** [a] |
| LW (cm) | 7.3-9.5 | 7.5-9.1 | 7.3-9.1 | 7.6-10.1 | |
| Overall Mean | 8.44 | 8.46 | 8.45 | 8.81 | 9.42* [a] |
| LA ($cm^2$) | 3608.8-7604.0 | 5365.0-7181.5 | 3608.8-7181.5 | 4140.0-9855.0 | |
| Overall Mean | 5539.3* | 6415.0* | 5831.15* | 7237.60** | 8220.39** [a] |
| DHEL (cm) | 8.19-18.4 | 13.1-16.0 | 8.19-16.0 | 11.5-20.6 | |
| Overall Mean | 13.38* | 14.98* | 13.91 | 16.52** # | 14.85* |
| EG (cm) | 10.1-15.4 | 12.4-14.3 | 10.1-14.3 | 11.6-17.0 | |
| Overall Mean | 12.56 | 13.06 * | 12.73 | 14.11* # | 13.01 |
| NORPE | 11.5-16.0 | 12.9-15.5 | 11.5-15.5 | 11.4-16.5 | |
| Overall Mean | 13.11 | 13.97* | 13.38 | 13.65* # | 12.68 |
| NOGPR | 17.7-39.3 | 26.9-34.1 | 17.7-34.1 | 24.9-42.8 | |
| Overall Mean | 28.11* | 32.06* | 29.43 | 35.59** # | 34.96** |
| NOGPE | 265.7-528.5 | 346.7-514.6 | 365.7-514.6 | 371.8-590.9 | |
| Overall Mean | 365.93 | 446.34* | 392.73 | 484.23** # | 377.55* |
| EW (g) | 57.3-194.2 | 97.3-164.4 | 57.3-164.4 | 84.7-226.1 | |
| Overall Mean | 114.03* | 119.96* | 116.00 | 159.3** # | 147.41** |
| TW (g) | 15.4-31.1 | 18.33-31.1 | 15.4-31.1 | 21.4-34.0 | |
| Overall Mean | 24.2* | 23.74* | 24.05 | 27.91** # | 25.13* |
| GYPP (g) | 45.2-187.1 | 81.6-132.7 | 45.2-132.7 | 76.2-191.0 | |
| Overall Mean | 95.73* | 99.80* | 100.09 | 133.83** # | 128.61** |
| Starch (%) | 52.0-76.0 | 50.1-73.4 | 52.0-73.4 | 52.7-72.2 | |
| Overall Mean | 61.65** | 64.12** | 62.47 | 64.69** # | 56.43 |
| CP (%) | 6.0-10.1 | 6.51-10.8 | 6.0-10.8 | 4.98-10.5 | |
| Overall Mean | 7.87* | 8.89* | 8.21 | 7.68* # | 7.38* |
| β-carotene (mg / 100 g) | 0.70-2.3 | 0.68-1.10 | 0.70-1.10 | 0.80-2.24 | |
| Overall Mean | 1.16* | 0.87 | 1.06 | 1.33* # | 1.23* * - |

*Significance at 5 % Level; ** Significance at 1 % level; # Overall Hybrid mean values are higher than the standard check [COH2]. [a]Overall standard check [COH2] mean values are higher than the hybrids. DTT: Days to tasseling, DTS: Days to silking, PH: Plant height, EH: Ear height, NOLPP: No. of Leaves per plant, LL: Leaf length, LW: Leaf width, LA: Leaf area, DHEL: De-husked Ear length, EG: Ear girth, NORPE: No.of rows per ear, NOGPR: No. of grains per row, NOGPE: No. of grains per ear, EW: Ear weight, TW: Test weight, GY: Grain yield per plant, CP: Crude protein

test weight, grain yield per plant, starch percentage, crude protein content and beta carotene content. For the remaining traits the overall mean value for the standard check [COH2] is comparatively higher than the hybrids.

**Association analysis:** Estimation of genotypic and phenotypic correlations is useful in planning and evaluating breeding programs. Genotypic correlation coefficient provides a measure of genotypic association between the characters and reveals the character that might be useful as an index for selection. This also helps to decide the dependability of the characters that have little or no importance. The relationship of a particular character with yield and other component character could also be helpful for the proper choice of parents for hybridization programme. The genotypic correlation coefficient was estimated based on the genotypic variances and covariance. The correlation coefficients between grain yield, its yield components and quality traits and inter correlation among them are furnished (Table 3).

**Correlation between grain yield and other traits:** Plant height ($0.871^{**}$), ear height ($0.704^{**}$), de-husked ear length ($0.871^{**}$), ear girth ($0.747^{**}$), number of grains per row ($0.868^{**}$), number of grains per ear ($0.864^{**}$), starch content ($0.395^{*}$), hundred grain weight ($0.863^{**}$) and carotene content ($0.299^{**}$) showed significant positive association with grain yield, while days to tasseling (0.051) and days to silking (0.055) showed positive non-significant association with grain yield. Number of rows per ear and crude protein content recorded negative non-significant association with grain yield. De-husked ear length recorded highest correlation (r = 0.871) with grain yield followed by number of grains per row (r = 0.868), number of grains per ear (r = 0.864), hundred seed weight (r = 0.863), ear girth (r = 0.747), plant height (r = 0.727) and ear height (r = 0.704) (Table 3).

In present study, plant height was positively and significantly correlated with grain yield. This was supported by Rahman *et al.* (1995), Spaner *et al.* (1996), Kumar and Kumar (1997), Gautam *et al.* (1999), Basheeruddin *et al.* (1999), Bello *et al.* (2010), Kashiani *et al.* (2010) and Wannows *et al.* (2010). In contrary to present study, plant height was negatively associated with grain yield as reported by Prakash *et al.* (2006). The study revealed that ear height was positively associated with grain yield. Similar results were reported by Khakim *et al.* (1998), Gautam *et al.* (1999), Basheeruddin *et al.* (1999), Mani *et al.* (1999), Wannows *et al.* (2010) and Bello *et al.* (2010).

The study revealed that de-husked ear length was positively correlated with grain yield as indicated by Sathyanarayana (1996), Khakim *et al.* (1998), Manivannan (1998), Gautam *et al.* (1999), Prakash *et al.* (2006), Aydin *et al.* (2007), Najeeb *et al.* (2009) and Wannows *et al.* (2010). Present results indicated that ear girth was positively correlated with grain yield, as indicated by Saha and Mukherjee (1993), Dwivedi and Godawat (1997), Kashiani and Saleh (2010), Kashiani *et al.* (2010) and Xie *et al.* (2010).

Present study indicated that days to silking and tasseling had positive correlation with grain yield as proved by Spaner *et al.* (1996), Kumar and Kumar (1997) and Nawar *et al.* (1998). Days to silking and tasseling was also reported to be negatively correlated with grain yield by Lee *et al.* (1986) and Tyagi *et al.* (1988).

Results of present study shows that number of grains per row was positively correlated with grain yield. Similar results were reported by Mahajan *et al.* (1990), Dwivedi and Godawat (1997), Khakim *et al.* (1998) and Prakash *et al.* (2006). Number of rows per ear and number of grains per ear was positively correlated with grain yield was confirmed by Saha (1985), You *et al.* (1998), Manivannan (1998) and Gautam *et al.* (1999).

Hundred grain weight was positively correlated with grain yield was in confirmation with the findings of Dwivedi and Godawat (1997), Jin and Wang (1997), Gautam *et al.* (1999) and Prakash *et al.* (2006).

Table 3: Genotypic correlation between different traits in maize

| Character# | PH | EH | DTT | DTS | EL | EG | NORPE | NOGPR | NOGPE | TW | GYPP | Starch | CP | Carotene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | 1.00 | 0.922** | 0.199** | 0.245** | 0.868** | 0.472** | 0.473** | 0.851** | 0.612** | 0.651** | 0.726** | 0.238* | 0.201* | 0.180* |
| EH | | 1.00 | 0.382* | 0.421** | 0.802** | 0.433** | -0.343** | 0.801** | 0.612** | 0.571** | 0.704** | 0.291** | -0.214** | 0.271** |
| DTT | | | 1.00 | 0.988** | 0.176** | -0.170* | -0.221** | 0.141* | 0.012 | -0.108 | 0.051 | 0.077 | 0.055 | 0.041 |
| DTS | | | | 1.00 | 0.195** | -0.170* | -0.237* | 0.164* | 0.025 | -0.081 | 0.055 | 0.068 | 0.040 | 0.029 |
| DHEL | | | | | 1.00 | 0.715** | -0.241** | 0.945** | 0.835** | 0.764** | 0.871** | 0.399** | -0.092 | 0.084 |
| EG | | | | | | 1.00 | 0.076 | 0.564** | 0.664** | 0.777** | 0.747** | 0.358** | -0.166* | 0.133 |
| NORPE | | | | | | | 1.00 | -0.260** | 0.259** | -0.174* | -0.007 | 0.081 | 0.088 | 0.065 |
| NOGPR | | | | | | | | 1.00 | 0.855** | 0.522** | 0.868** | 0.410* | -0.052 | 0.124 |
| NOGPE | | | | | | | | | 1.00 | 0.500** | 0.864** | 0.455* | -0.0074 | 0.124 |
| TW | | | | | | | | | | 1.00 | 0.863** | 0.246* | -0.036 | 0.049 |
| GYPP | | | | | | | | | | | 1.00 | 0.395* | -0.020 | 0.299** |
| Starch | | | | | | | | | | | | 1.00 | 0.194** | 0.183** |
| CP | | | | | | | | | | | | | 1.00 | -0.160** |
| Carotene | | | | | | | | | | | | | | 1.00 |

* Significance at 5 % Level; ** Significance at 1 % level # - NOLPP: No. of leaves per plant, LL: Leaf length, LW: Leaf width, LA: Leaf area, were not taken for both correlation and path analysis PH: Plant height, EH: Ear height, DTT: Days to tasseling, DTS: Days to silking, EL: Ear length, EG: Ear girth, NORPE: No.of rows per ear, NOGPR: No. of grains per row, NOGPE: No. of grains per ear, TW: Test weight, GY: Grain yield; CP: Crude protein

**Inter-correlation among the yield attributes:** Troyer and Larkins (1985) observed that plant height was positively correlated with days to flowering morphologically, as internode's formation stops at floral initiation and that early flowering maize varieties are usually shorter in height. Similarly in this study, plant height was significantly and positively associated with ear height, days to tasseling, days to silking, de-husked ear length, ear girth, number of rows per ear, number of grains per row, number of grains per ear, hundred-grain weight, grain yield, starch, crude protein and carotene content (Table 3). Similarly in accordance with our results, plant height was positively correlated with ear height (Khayatnezhad *et al.*, 2010; Bello *et al.*, 2010; Reddy *et al.*, 1990).

Ear height was significantly and positively correlated with all the characters mentioned above, except crude protein and number of rows per ear, where both of them were negatively and non-significantly associated with ear height. Days to tasseling were significantly but negatively associated with ear girth and number of rows per ear. It had a positive significant association with days to silking, ear length, and number of grains per row and had a positive non-significant association with number of grains per ear, grain yield, starch, crude protein and carotene content. It was negatively and non-significantly associated with hundred-grain weight (Table 3). Such results are in accordance with the findings of (El-Nigoly *et al.*, 1981; Salama *et al.*, 1994; Amin *et al.*, 2003; Ojo *et al.*, 2006; Asrar-ur-Rehman *et al.*, 2007; Najeeb *et al.*, 2009). While it exhibited significant and negative correlations with number of kernel per row and 100-kernel weight (Sadek *et al.*, 2006).

In this report, days to silking was significantly and positively associated with ear length and number of grains per row but, it was positive and non-significant for number of grains per ear, grain yield, starch, crude protein and carotene content. It was significant but negatively associated with ear girth and number of rows per ear. It was negative and non-significantly associated with number of grains per row (Table 3). Hundred grain weight was negatively correlated with days to silking and tasseling (Kim, 1975). Ear height was positively correlated with days to tasseling and silking (Singh *et al.*, 1981; El-Nagouly *et al.*, 1983).

In this study, ear length had a positive significant association with ear girth, number of grains per row, number of grains per ear, hundred-grain weight, grain yield and starch content. It was positive, but non-significantly associated with carotene content. Ear length was negatively and non-significantly associated with crude protein. There was a positive correlation between ear length and ear weight (Table 3). The results are in accordance with Amin *et al.* (2003), Sadek *et al.* (2006) and Abou-Deif (2007).

Ear diameter was indicated to have positive genetic correlation with grain yield by Kashiani *et al.* (2010) and Xie *et al.* (2010). In this study, ear girth was positively and significantly associated with number of grains per row, number of grains per ear, hundred-grain weight, grain yield and starch content. It had a positive and non-significant association with number of rows per ear and carotene content. Ear girth was negatively and significantly associated with crude protein (Table 3).

In this study, number of rows per ear had a negative and significant association with number of grains per row and hundred-grain weight, whereas it was negatively and non-significantly associated with grain yield. It was positively and significantly associated with number of grains per ear. It had a positive but non-significant association with starch, crude protein and carotene content (Table 3). Wang *et al.* (1998) reported that there was positive correlation between number of grains per ear and number of rows per ear.

Numbers of kernels per row and kernel rows per ear have a positive genetic correlation with grain yield (Wang *et al.*, 1999; Yousuf and Saleem, 2001; Liu, 2009; Kashiani *et al.*, 2010; Xie *et al.*, 2010). In this study, grains per row had a positive and significant association with grains per ear, hundred-grain weight, grain yield and starch content and were positively but non-significantly associated with carotene content. It was negatively and non-significantly associated with crude protein (Table 3).

Khatun *et al.* (1999) found that grain yield per plant was positive and significantly correlated with number of kernels ear per year, ear weight and ear insertion height. In this study, grains per ear had a positive association with hundred-grain weight, grain yield and starch content and it was positive, but non-significantly associated with carotene. It was negatively and non-significantly associated wit crude protein. In this study, hundred-grain weight had a positive and significant association with grain yield and starch content and it was positively and non-significantly associated with carotene content (Table 3). It had a negative and non-significant association with crude protein. Our results agreed with those mentioned by Salama *et al.* (1994), Soliman *et al.* (1999), Yasien (2000), El-Beially (2003), Mohammadi *et al.* (2003) and Sadek *et al.* (2006).

In this study, grain yield had a positive significant association with starch and carotene content and it was negatively and non-significantly associated with crude protein (Table 3). In contrary, grain yield was positively significantly correlated with crude protein as reported by Prakash *et al.* (2006). Starch content was positively correlated with crude protein and carotene content. Crude protein had a negative and non-significant association with carotene content. Starch content was positively correlated with grain yield as indicated by Gupta *et al.* (1983) and was reported to be negatively associated with grain yield (Geetha and Jayaraman, 2000; Prakash *et al.*, 2006). Zaika *et al.* (1978) reported that there was a positive correlation between 100 g weight and starch content.

**Path analysis:** The estimates of correlation coefficients revealed only the relationship between yield and yield associated characters but did not show the direct and indirect effects of different

Table 4: Path coefficient analysis (genotype) showing the direct and indirect effects of traits on yield in maize

| Character# | PH | EH | DTT | DTS | EL | EG | NORPE | NOGPR | NOGPE | TW | Starch | CP | Carotene |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PH | -3.046 | -2.450 | -0.529 | -0.650 | -2.304 | -1.253 | 1.256 | -2.259 | -1.624 | -1.727 | -0.632 | 0.533 | -0.479 |
| EH | 2.674 | 2.900 | 1.106 | 1.223 | 2.326 | 1.256 | -0.994 | 2.233 | 1.774 | 1.656 | 0.843 | -0.621 | 0.785 |
| DTT | -0.624 | -1.197 | -3.237 | -3.098 | -0.553 | 0.533 | 0.693 | -0.443 | -0.038 | 0.339 | -0.242 | -0.173 | 0.128 |
| DTS | 0.228 | 0.394 | 0.921 | 0.932 | 0.182 | -0.159 | -0.221 | 0.153 | 0.023 | -0.076 | 0.063 | 0.037 | 0.026 |
| EL | 10.445 | 9.656 | 2.124 | 2.345 | 12.038 | 8.607 | -2.904 | 11.378 | 10.046 | 9.191 | 4.805 | -1.102 | 1.009 |
| EG | -0.518 | -0.476 | 0.187 | 0.187 | -0.786 | -1.099 | -0.193 | -0.619 | -0.730 | -0.854 | -0.393 | 0.184 | -0.146 |
| NORPE | -1.058 | -0.767 | -0.494 | -0.531 | -0.540 | 0.394 | 2.238 | -0.582 | 0.580 | -0.389 | 0.180 | 0.197 | 0.144 |
| NOGPR | -2.638 | -2.485 | -0.438 | -0.508 | -2.934 | -1.749 | 0.806 | -3.201 | -2.653 | -1.713 | -1.272 | 0.160 | -0.384 |
| NOGPE | -3.038 | -3.039 | -0.060 | -0.125 | -4.146 | -3.300 | -1.288 | -4.250 | -4.968 | -2.482 | -2.261 | 0.037 | -0.614 |
| TW | -1.976 | -1.735 | 0.329 | 0.247 | -2.320 | -2.361 | 0.528 | -1.678 | -1.518 | -3.038 | -0.747 | 0.109 | -0.147 |
| Starch | -0.036 | -0.044 | -0.012 | -0.010 | -0.061 | -0.055 | -0.012 | -0.063 | -0.070 | -0.038 | -0.155 | -0.030 | -0.027 |
| CP | -0. 142 | -0.154 | 0.309 | 0.029 | -0.065 | -0.118 | 0.063 | -0.036 | -0.005 | -0.025 | 0.138 | 0.710 | -0.113 |
| Carotene | -0.067 | 0.101 | 0.015 | 0.010 | 0.031 | 0.050 | 0.024 | 0.046 | 0.046 | 0.018 | 0.065 | -0.059 | 0.372 |
| Genotypic correlation coeff. | 0.727 | 0.704 | 0.051 | 0.050 | 0.871 | 0.747 | -0.007 | 0.868 | 0.864 | 0.863 | 0.394 | -0.020 | 0.298 |

PH: Plant height, EH: Earheight, DTT: Days to tasseling, DTS: Days to silking, EL: Ear length, EG: Ear girth, NORPE: No.of rows per ear, NOGPR: No. of grains per row, NOGPE: No. of grains per ear, TW: Test weight, CP: Crude protein, # - NOLPP: No. of Leaves per plant, LL: Leaf length, LW: Leaf width, LA: Leaf area were not taken for both correlation and path analysis

traits on yield per se. This is because, the attributes that are in association do not exist by themselves, but are linked to other components. The path coefficient analysis suggested by Dewey and Lu (1959) specified the effective measure of direct and indirect causes of association and also depicts the relative importance of each factor involved in contributing to the final product i.e., yield. In order to find out the cause and effect relationship between grain yield and its related characters, path analysis was taken up in the present investigation. Path values based on fifty hybrids and 15 parents involved in the study at genotypic level showing the extent of direct and indirect effects on grain yield are presented. Out of the fourteen traits taken for path analysis, ear length had a maximum positive direct effect on grain yield (12.038) followed by ear height (2.900), number of rows per ear (2.238), days to silking (0.932), crude protein (0.710) and carotene content (0.372) (Table 4).

A highly significant and positive direct effect of ear length for grain yield was indicated by Tyagi *et al.* (1988), Dash *et al.* (1992), Kumar *et al.* (1999), Arais *et al.* (1999), Gautam *et al.* (1999) and Nemati *et al.* (2009). Ear height had a positive direct effect on grain yield as indicated by El-Nagouly *et al.* (1983), Tyagi *et al.* (1988) and Rahman *et al.* (1995). Favorable influence of number of rows per ear on grain yield was noticed by Singh and Singh (1993), Manivannan (1998) and Arais *et al.* (1999). Days to silking had a small amount of direct effect on grain yield Gautam *et al.* (1999). Kumar *et al.* (1999) reported a high positive direct effect of days to flowering. Direct effect of crude protein on grain yield was reported by Basheeruddin *et al.* (1999).

In this study, plant height, days to tasseling, ear girth, number of grains per row, number of grains per ear, test weight and starch content recorded negative direct effect on grain yield even though genotypic correlation coefficients on grain yield were positive (Table 4). Tyagi *et al.* (1988) indicated that there was negative direct effect of plant height on grain yield. Days to silking and tasseling had an indirect effect on grain yield via ear height was indicated by Reddy *et al.* (1990) and El-Nagouly *et al.* (1983). Ear girth had a negative indirect effect on grain yield as suggested by Saha and Mukherjee (1993) and Debnath and Khan (1991). Number of grains per row showed indirect effect on grain yield. Arais *et al.* (1999), Saha and Mukherjee (1993). Manivannan (1998) noticed indirect effect of number of rows per ear on grain yield. Starch content was observed to have a high negative direct effect on grain yield (Geetha and Jayaraman, 2000).

**Indirect effects:** The indirect effect of plant height on grain yield via number of rows per cob and crude protein were positive but via ear height, days to tasseling, days to silking, ear length, ear girth, number of grains per row, number of grains per ear, hundred seed weight, starch and carotene were negative. The indirect effect of ear height through plant height, days to tasseling, days to silking, ear length, ear girth, number of grains per row, number of grains per ear, hundred grain weight, starch and carotene content were positive and through number of rows per ear and crude protein were negative (Table 4).

Positive indirect effect of days to tasseling on grain yield was noticed for ear girth, number of rows per ear and hundred grain weight, but it was negative through plant height, ear height, days to silking, ear length, number of grains per row, number of grains per ear, starch, crude protein and carotene content. Indirect influence of days to silking on grain yield via plant height, ear girth, days to tasseling, ear length, number of grains per row, number of grains per ear, starch and crude protein were positive and via ear girth, number of rows per ear and hundred grain weight were negative (Table 4).

The indirect effect of de-husked ear length on grain yield via plant height, ear height, days to tasseling, days to silking, ear girth, number of grains per row, number of grains per ear, hundred seed weight, starch and carotene were positive and via number of rows per ear and crude protein were negative. Indirect influence of this ear girth on grain yield via plant height, ear height, ear length, number of rows per cob, number of grains per row, number of grains per cob, hundred grain weight, starch and carotene were negative and via days to tasseling, days to silking and crude protein were positive (Table 4).

Positive indirect effect of number of rows per ear on grain yield was noticed through ear girth, number of grains per cob, starch, crude protein and carotene but it was negative through plant height, ear height, days to tasseling, days to silking, ear length, number of grains per row and hundred grain weight. Indirect effect of number of grains per row on grain yield was noticed through number of rows per cob and crude protein but it was negative through plant height, ear height, days to tasseling and silking, ear length and girth, number of grains per cob, hundred grain weight, starch and carotene content (Table 4).

Positive indirect effect was noticed for number of grains per ear on grain yield via crude protein and it was negative through all the characters studied. Indirect influence of hundred grain weight on grain yield via days to tasseling, days to silking, number of rows per cob and crude protein were positive and via plant height, ear height, ear length, ear girth, number of grains per row, number of grains per cob, starch and carotene were negative. The indirect effect of starch content (%) trait was negative for all the fourteen characters studied. Positive indirect effect was noticed for carotene content on all the characters studied except via crude protein which showed negative indirect effect (Table 4).

## CONCLUSION

To conclude, correlation studies showed that grain yield having positive association with all the characters except for number of rows/ear and crude protein content, as they were negatively correlated. Ear length recorded maximum correlation with grain yield followed by number of grains per row, number of grains per ear, hundred seed weight, ear girth, plant height and ear height. Direct selection for ear length, ear height and number of rows per ear might be rewarding for yield improvement since they revealed true relationship with grain yield. The direct effect for number of rows per ear was positive but the correlation was negative, in such a situation direct selection for this trait should be practiced to reduce the undesirable indirect effect.

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