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Genetic Parameters and Path Analysis of Yield and its Components in Corn Inbred Lines (*Zea mays* L.) at Different Sowing Dates

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ABSTRACT

The present investigation was carried out to estimate the genetic parameters and path analysis of plant characters measured on 13 inbred lines of corn and evaluated at two sowing dates during the 2009 growing season. The experiment was arranged in split-plot design with three replications. The main plots were two sowing dates (June 1st and July 1st) and subplots were thirteen inbred lines of corn. Results showed that, under optimal sowing, ear diameter, ear weight plant^{-1}, number of rows ear^{-1} and number of grains row^{-1} exhibited positive and significant correlations at genotypic and phenotypic levels with yield plant^{-1}. Days to 50% tasseling and silking associated negatively with ear diameter, grains row^{-1}, 100 grain weight and grain yield. Under late sowing conditions, positive and significant genotypic correlations existed between grain yield plant^{-1} against days to 50% tasseling, days to 50% silking, ear length, ear weight plant^{-1} and number of rows ear^{-1}. At optimal sowing, ear weight plant^{-1} had the highest positive direct influence (0.996) on grain yield followed by days to 50% tasseling (0.158) and 100-grain weight (0.126). On the other hand, ear diameter and days to 50% silking exerted high negative direct effect (-0.258 and -0.136, respectively). At late planting, ear weight plant^{-1} (1.093) and ear diameter (0.274) recorded the highest positive direct effect on grain yield. A moderate and positive influence of flowering traits was observed. Grains number row^{-1} (-0.092) recorded negative direct effect on yield and recorded positive and indirect effects through ear weight plant^{-1}, ear diameter and 100-grain weight, respectively. It can be concluded that, ear weight plant^{-1} (at both planting dates), ear length, days to 50% silking and ear diameter as a primary; 100 grain weight and kernels row^{-1} as a secondary could be used as the main criteria for yield improvement when selecting in the studied materials.

Key words: Correlation coefficient, morphological and phenological traits, path analysis, *Zea mays* L.

INTRODUCTION

Corn (*Zea mays* L.) with a remarkable productive potential among the cereals, is the third most important grain crop after wheat and rice and accounts for 4.8% of the total cropped area and 3.5% of the value of the agricultural output (Saleem *et al*., 2008). There are two important components in corn cropping system, plant variety and sowing date. With delay in sowing date there are decreasing in vegetative period, yield and its components (Hefny, 2010). Shah *et al*. (2006) concluded that sowing time of a specific genotype in a particular condition exerts a profound effect on agronomic characters and physiological processes under consideration. Therefore, changes in sowing date causes plant development processes to change. The breeder needs to identify the causes of variability in grain yield in any specific environment before yield improvements can be achieved, (Tyagi and Khan, 2010). Since fluctuation in environment generally affects yield primarily through its components, many researchers have analyzed yield through its components (Esan and Omolaja, 2002). Most of the characters of interest to breeders are complex and the results of the interaction of a number of components. So it is a principle to recognize the relationship between yield and its components for the utilization of their relations in the selection process (Sarawgi *et al.*, 1997). Possibility of achieving improvement in any crop plants depends heavily on the magnitude of genetic variability. Phenotypic variability expressed by a genotype or a group of genotypes in any species can be partitioned into genotypic and phenotypic components. The genotypic components being the heritable part of the total variability, since it influences the selection strategies to be adopted by the breeder. The success of selection depends on the choice of selection criteria. Yield components do not only directly affect the yield but also indirectly by affecting other yield components in negative or positive ways (Bidgoli *et al.*, 2006).

Correlation coefficients generally show relationships among independent variables and the degree of linear relation between these characteristics but it does not sufficiently predict the success of selection. However, path-coefficient analysis that is originally developed by Wright (1929) is the most valuable tool to establish the exact correlation in terms of cause and effect. It allows one to identify the direct, indirect and total (direct plus indirect) causal effect, as well as to remove any spurious effect that may be present.

The relationships among some morphological and phenological traits have been determined in corn. El-Shouny *et al.* (2005) showed that grain yield per plant correlated positively and significantly with ear diameter, ear length, number of kernels per row, 100-kernel weight, number of rows per ear, ear height, plant height and days to silking under normal and late planting (except plant height at late planting). Sofi and Rather (2007) reported that the greatest genotypic correlation coefficients with grain yield were revealed by ear diameter, 100-grain weight, ear length, number of kernel rows per ear and number of kernels per row. Path analysis indicated that 100-seed weight had greatest direct effect on grain yield, followed by number of kernels per row, number of kernel rows per ear, ear length and ear diameter. Jayakumar *et al.* (2007) reported that the maximum positive direct effect on grain yield was through grains per row followed by ear length, ear girth, days to tasseling, total sugars and plant height. Whereas the maximum negative direct effect on grain yield was presented by kernel rows followed by days to silking, crude protein, grain weight, days to maturity, shelling percentage and leaves above upper most ear.

Keeping these things in view in addition to the little information on the genetic variation and path analysis in corn under different sowing dates, the present study on evaluating thirteen inbred lines of maize under two sowing dates was planned and executed with the following objectives: i) the impact of sowing date on the estimate of the genetic parameters; genotypic and phenotypic coefficients of variation, heritability and genetic advance. Furthermore, estimates of path coefficients to find out the relative contribution of different metric traits, as a selection criteria, in high grain yield at each planting date.

MATERIALS AND METHODS

Plant material and data collected: The present study was carried out at the Experimental Farm of Suez Canal University, Ismaiha, Egypt, during the summer of 2009 season. Thirteen inbred lines of corn (Table 1) were used as material for this study. Including five inbred lines introduced from National Plant Germplasm System, USA and eight lines selected from local germplasm and crosses between local and introduced populations. The materials were evaluated in a randomized complete block design with three replications in two planting dates; 1st of June and 1st of July, 2009. The

Table 1: Pedigree and origin of the parental genotypes

Entry code	Entry name	Pedigree/Origin	Kernel colour
1	L2	S8 Selected from {Giza-2 x AK135 (Ukrainian line)}	White
2	L8	S8 Selected from {Giza-2 x AK135 (Ukrainian line)}	White
3	L9	S8 Selected from {Giza-2 x AK135 (Ukrainian line)}	White
4	L12	S8 Selected from {Giza-2 x AK135 (Ukrainian line)}	White
5	L16	S8 Selected from Nabelgamal	White
6	L31	S8 Selected from {D.C. Youpilini (Ukraine)}x Nabelgamal}	Yellow
7	L39	S8 Selected from Double cross 202	White
8	L41	S8 Selected from Double cross 202	White
9		PI 608777- NPGS	Yellow
10		PI 508277-NPGS	Yellow
11		PI 607527-NPGS	Yellow
12		PI 607525-NPGS	Yellow
13		PI 572413-NPGS	Yellow

Table 2: Monthly rainfall (mm), average maximum (T_{max}) and minimum (T_{min}) temperatures (°C) at Ismailia, Egypt during the experiment growth

Parameters	June	July	August	Sept.	Oct.
Rainfall (mm)	0	0	0	0	0
T_{max} (°C)	26-38	31-38	32-37	30-35	26-37
T_{min} (°C)	16-25	21-25	20-25	18-23	15-23

monthly temperature ranges during the time of the experiment are given in Table 2. Each line was planted in one row 3 m long, 50 cm between rows and 20 cm within row, all agricultural practices were applied as recommended. Days to 50% tasseling and days to 50% silking were recorded on the whole plot basis. At harvest, ten ears from each entry and plot were collected to record the following traits: ear length, ear diameter, ear weight per plant, number of rows per ear, number of grains per row, 100 grain weight and yield per plant.

Statistical analysis: Genotypic (GCV) and Phenotypic (PCV) coefficients of variation were computed according to Burton and Devane (1953) and expressed as percentage:

$$\text{Genotypic coefficient of variation (GCV)} = (\delta g/x) \times 100$$
$$\text{Phenotypic coefficient of variation (PCV)} = (\delta p/x) \times 100$$

Where:

δg = Genotypic standard deviation
δp = Phenotypic standard deviation
x = General mean of the character

PCV and GCV values were categorized as low, moderate and high values as indicated by Sivasubranian and Menon (1973) as follows. 0-10%: Low, 10-20%: Moderate, >20: High.

Heritability in broad sense was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage (Hanson *et al.*, 1956):

$$\text{Heritability } (h^2) = (Vg/Vp) \times 100$$

Where:
Vg = Genotypic variance
Vp = Phenotypic variance

The extent of genetic advance to be expected by selecting five per cent of the superior progeny was calculated by using the following formula:

$$GA = i\ \delta p\ h^2$$

Where:
i = Efficacy of selection which is 2.06 at 5% selection intensity
δp = Phenotypic standard deviation
h^2 = Heritability in broad sense

Genetic advance as per cent of mean:

$$\text{GA as percent of mean} = (GA/X) \times 100$$

Where:
GA = Genetic advance
X = General mean of character

The genotypic (r_g) and phenotypic (r_p) correlation coefficients were computed using genotypic and phenotypic variances and co-variances to determine the degree of association of the yield attributes with yield and also among yield attributes themselves. The analysis of covariance was conducted by following the method designed by Singh and Narayanan (2000):

$$\text{Genotypic correlation} Vxy\ (g) = \frac{COV\ xy\ (g)}{Vx\ (g) x Vy\ (g)}$$

$$\text{Phenotypic correlation} Vxy\ (g) = \frac{COV\ xy\ (p)}{Vx (g) x Vy\ (p)}$$

Test of significance was carried out with (n-2) degrees of freedom for genotypic and phenotypic correlation by referring to the table given by Snedecor and Cochran (1967).

The relative importance of direct and indirect effects of measured traits on grain yield was determined by path analysis at each sowing date. It is simple standardized partial regression coefficient which splits the correlation coefficient into direct and indirect effects of the yield components on yield as suggested by Wright (1929) and elucidated by Dewey and Lu (1959).

Thus, the correlation coefficient of any character with grain yield was split into the direct and indirect effects adopting the standard formula:

$$riy = r1iP1 + r2iP2 + ri3P3 + \text{..................} + rniPn + \text{...............} riiPI$$

Where:

riy = Correlation of ith character on grain yield
ri_1 = Indirect effect of ith character on grain yield through first character
rniPn = Correlation between nth character and ith character
n = Number of independent variables
Pi = Direct effect of ith character on grain yield

Direct effect of component character on grain yield was obtained by solving the following equations:

riy = (Piy) (rij) which can also be rearranged as
(Pi)=(rij) − 1(rij)

RESULTS

Genetic variability: The results pertaining to genetic parameters were computed and presented in Table 3. Under normal sowing date, moderate estimates of PCV were recorded for ear length (11.80%), ear diameter (16.07%), number of rows ear^{-1} (13.29%) and 100-grain weight (12.44%). Whereas, low PCV of 7.64 and 7.32% were exhibited for the characters viz., days to 50% tasseling and days to 50% silking, respectively. Moderate estimates of GCV were recorded for ear diameter (13.28%) and 100-grain weight (11.32%) traits. In contrast, low GCV values were demonstrated by, days to 50% tasseling, days to 50% silking, ear length and number of rows ear^{-1}. High GCV and PCV values were recorded for ear weight plant^{-1} (29.83 and 30.79%), number of grains row^{-1} (20.81 and 22.34%) and yield plant^{-1} (32.65 and 33.34%).

Table 3: Estimates of genetic parameters for some economic characters measured on corn genotypes and evaluated at two sowing dates

Trait	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Heritability (h^2%)	Genetic advance (GA%)
Sowing date-1st of June				
Days to 50% tasseling (d)	6.97	7.64	83.25	13.11
Days to 50% silking (d)	6.55	7.32	80.24	12.09
Ear length (cm)	9.52	11.80	65.20	15.84
Ear diameter (cm)	13.28	16.07	68.34	22.62
Ear weight plant^{-1}	29.83	30.79	93.81	59.51
Rows ear^{-1}	7.99	13.29	36.18	9.91
Grains row^{-1}	20.81	22.34	86.76	39.93
100-grain weight (g)	11.32	12.44	82.80	21.22
Yield plant^{-1} (g)	32.65	33.34	95.88	65.85
Sowing date-1st of July				
Days to 50% tasseling (d)	8.52	9.15	86.66	16.34
Days to 50% silking (d)	6.47	7.32	78.10	11.78
Ear length (cm)	9.44	13.37	49.91	13.74
Ear diameter (cm)	9.96	14.69	45.99	13.92
Ear weight plant^{-1}	27.30	27.76	96.73	55.32
Rows ear^{-1}	10.04	13.57	54.71	15.29
Grains row^{-1}	13.032	18.279	50.83	19.14
100-grain weight (g)	17.77	19.99	79.03	32.55
Yield plant^{-1} (g)	30.53	31.599	97.33	62.76

Under late sowing, high PCV and GCV values were represented by ear weight plant^{-1} (27.76 and 27.30%) and yield plant^{-1} (31.60 and 30.53%). Moderate PCV and GCV of 13.57% and 10.04; 18.28% and 13.03; 19.99 and 17.77% were represented by number of rows ear^{-1}, number of grains row^{-1} and 100-grain weight. Days to 50% tasseling and silking showed low GCV and PCV values, whereas moderate PCV for ear length and diameter compared with low GCV values were recorded.

Under optimal sown, all traits exhibited high h^2 except number or rows ear^{-1} which showed moderate value (36.18%). Whereas, when planting was delayed, high values were observed for flowering traits, ear weight plant^{-1}, 100-grain weight and grain yield plant^{-1}. The expected GA varied from 9.91 to 65.85% in optimal planting date, whereas, under late sowing it ranged from 11.78 to 62.76%. Yield plant^{-1}, 100-grain weight and ear weight plant^{-1} showed the highest GA at both planting dates coupled with high heritability values. In contrast, number of grains row^{-1} demonstrated both high GA and h^2 under optimal sowing only. Although other traits showed high h^2 values, expected GA was low. However, a suitable selection procedure could be followed only when the high broad-sense heritability estimate was coupled with high genetic advance.

The genotypic and phenotypic correlation coefficients between yield and yield attributes are given in Table 4. Under optimal sowing, ear diameter, ear weight plant^{-1}, number of rows ear^{-1} and number of grains row^{-1} exhibited positive and significant correlations with yield plant^{-1} at genotypic and phenotypic levels. The four traits presented positive and significant phenotypic and genotypic correlations among them. Days to 50% tasseling and silking which were highly correlated with each other genotypically and phenotypically, associated negatively with ear diameter, grains row^{-1} and 100 grain weight (only days to 50% tasseling revealed significant value). 100-grain

Table 4: Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among nine characters in 13 genotypes of corn evaluated under two sowing dates

Character	50% tasseling	50% silking	Ear length	Ear diameter	Ear weight plant^{-1}	Number of rows ear^{-1}	Number of grains row^{-1}	100-grain weight	Yield plant^{-1}
Sowing date-1st of June									
Days to 50% tasseling (d)		0.761**	-0.175	-0.408*	-0.007	-0.185	-0.351*	-0.334*	-0.055
Days to 50% silking (d)	0.718**		-0.177	-0.526**	-0.263	-0.176	-0.420**	-0.208	-0.230
Ear length (cm)	-0.116	-0.142		0.151	0.345*	0.202	0.338*	0.098	0.361*
Ear diameter (cm)	-0.287	-0.399*	0.252		0.731**	0.203	0.579**	0.385*	0.574**
Ear weight plant^{-1}	0.010	-0.225	0.273	0.602**		0.575**	0.620**	0.396*	0.962**
Rows ear^{-1}	0.030	0.031	0.361*	0.338*	0.346*		0.999**	-0.492**	0.554**
Grains row^{-1}	-0.239	-0.336*	0.262	0.458**	0.595**	0.662**		-0.196	0.574**
100-grain weight (g)	-0.280	-0.169	-0.068	0.239	0.319	-0.356*	-0.201		0.378*
Yield plant^{-1} (g)	-0.019	-0.180	0.275	0.460**	0.950**	0.327*	0.535**	0.319	
Sowing date-1st of July									
Days to 50% tasseling (d)		0.734**	0.105	0.443**	0.246	0.531**	-0.216	-0.211	0.453**
Days to 50% silking (d)	0.655**		0.060	0.287	0.114	0.454**	-0.224	0.156	0.234
Ear length (cm)	0.055	0.048		0.503**	0.506**	-0.332*	0.375*	0.482**	0.339*
Ear diameter (cm)	0.211	0.171	0.510*		0.200	0.351*	0.133	0.616**	0.273
Ear weight per plant	0.220	0.086	0.360*	0.121		0.268	0.288	0.333*	0.957**
Rows ear^{-1}	0.308	0.310	-0.026	0.123	0.228		0.072	0.019	0.367*
Grains row^{-1}	-0.152	-0.207	0.465**	0.253	0.204	0.064		-0.178	0.113
100-grain weight (g)	-0.163	0.118	0.388*	0.519**	0.290	-0.038	0.081		0.224
Yield plant^{-1} (g)	0.420**	0.200	0.242	0.175	0.933**	0.263	0.094	0.203	

*, **Significant at 0.05 and 0.01 probability levels, respectively

Table 5: Direct (bold values) and indirect path coefficients between grain yield plant $^{-1}$ and other variables in 13 inbred line of corn grown under two planting dates

Character	1	2	3	4	5	6	7	8	Total effect
Sowing date⁻1st of Juue									
Days to 50% tasseling	**0.158**	-0.101	-0.004	0.093	-0.117	-0.002	0.029	-0.039	0.016
Days to 50% silking	0.008	**-0.136**	-0.004	0.123	-0.024	-0.002	0.037	-0.024	- 0.136
Ear length	-0.024	0.022	**0.026**	-0.050	0.314	0.006	-0.029	0.004	0.269
Ear diameter	-0.057	0.065	0.005	**-0.258**	0.677	0.006	-0.05	0.041	0.428
Ear weight plant^{-1}	-0.019	0.034	0.008	-0.175	**0.996**	0.010	-0.058	0.046	0.843
Rows ear^{-1}	-0.013	0.010	0.007	-0.069	0.454	**0.022**	-0.077	-0.052	0.282
Grains row^{-1}	-0.049	0.054	0.008	-0.137	0.608	0.018	**-0.094**	-0.025	0.383
100-grain weight	-0.050	0.026	0.001	-0.084	0.367	-0.009	0.019	**0.126**	0.395
Sowing date-1st of July									
Days to 50% tasseling	**0.084**	0.027	-0.020	0.092	0.259	-0.053	0.017	0.035	0.441
Days to 50% silking	0.028	**0.081**	-0.013	0.063	0.113	-0.048	0.02	-0.026	0.219
Ear length	0.006	0.004	**-0.240**	0.138	0.480	0.022	-0.038	-0.080	0.294
Ear diameter	0.028	0.019	-0.121	**0.274**	0.178	-0.029	-0.017	-0.103	0.227
Ear weight plant^{-1}	0.020	0.008	-0.105	0.045	**1.093**	-0.030	-0.023	-0.058	0.949
Rows ear^{-1}	0.036	0.032	0.044	0.065	0.272	**-0.122**	-0.006	0.001	0.321
Grains row^{-1}	-0.015	-0.017	-0.101	0.053	0.273	-0.008	**-0.092**	0.011	0.104
100-grain weight	-0.016	0.011	-0.105	0.155	0.346	0.001	0.006	**-0.182**	0.216

Residual effect: For the optimum planting: 0.483, For late planting: 0.055. 1: 50% Tasseling (d), 2: 50% Silking (d), 3: Ear length (cm), 4: Ear diameter (cm), 5: Ear weight plant^{-1} (g), 6: Rows ear^{-1}, 7: Grains row^{-1}, 8:100-grain weight (g)

weight was positively and significantly correlated with ear diameter, ear weight plant^{-1} and yield palnt^{-1} at both levels. However, low 100-grain weight was associated significantly with high row ear^{-1} and non-significantly with grains row^{-1}.

Under late sowing, the relationships among traits were different. The numbers of significant correlations were lower compared to values under normal sowing. Positive and significant genotypic correlations were existed between grain yield plant^{-1} against days to 50% tasseling, ear length, ear weight plant^{-1} and number of rows ear^{-1} at genotypic level. On the other hand, yield plant^{-1} correlated significantly and phenotypically with tasseling date and ear weight plant^{-1}. Ear diameter correlated positively and significantly at the genotypic and phenotypic level with 100-grain weight. Number of rows ear^{-1} showed positive and significant genotypic correlation with ear diameter (0.351) and grain yield (0.367), in contrast on the phenotypic level the values were positive but lower (0.123 and 0.263, respectively). Days to 50% tasseling associated positively and significantly with yield at the genotypic level, in contrast yield correlated non-significantly and positively with days to 50% silking. Days to 50% tasseling showed positive and significant genotypic correlations with ear diameter and rows ear^{-1}.

Path coefficient analysis: The results of path coefficient analysis at each sowing date are presented in Table 5. At optimum planting date, ear weight plant^{-1}, days to 50% tasseling, 100 grain weight and ear length were key to increasing grain yield under the mentioned conditions since they exhibited positive direct effects on yield. Ear weight plant^{-1} wielded the highest positive direct influence (0.996) on grain yield followed by days to 50% tasseling (0.158) and 100-grain weight (0.126). On the other hand, ear diameter and days to 50% silking exerted high negative direct effect (-0.258 and -0.136, respectively) on grain yield. Most of the traits exhibited indirect influence on grain yield plant^{-1} through ear weight plant^{-1}, ear length, days to

50% silking and number of rows ear^{-1}. It was observed that days to 50% silking had a positive indirect effect via ear diameter and grain number row^{-1}. Although the moderate negative direct effect of grain number row^{-1} on yield, its indirect effects through ear weight plant^{-1}, ear length, rows ear^{-1} and days to 50% silking were positive.

At late sowing, the results revealed that, ear weight plant^{-1} (1.093) and ear diameter (0.274) recorded the highest positive direct effect on grain yield. A moderate and positive influence of flowering traits was observed. In contrast ear length, 100 kernel weight, rows ear^{-1} and grains row^{-1} exhibited high and negative direct effects. Grains number row^{-1} (-0.092) recorded negative direct effect on yield and recorded positive and indirect effects through ear weight plant^{-1}, ear diameter and 100-grain weight. On the other hand, all measured traits showed positive and high indirect effects on grain yield through ear weight plant^{-1}. All studied traits recorded medium to low indirect positive effect via days to 50% silking on yield (except grains row^{-1}) and ear diameter.

DISCUSSION

Genetic variability: The study of inter-relationship among various characters in the form of correlation is one of very important aspects in selection programme for the breeder to make an effective selection based on the correlated and uncorrelated response. Nature and magnitude of associations among plant characteristics are important when desirable characters have low heritability measure (Mohammadi and Pourdad, 2009) and if the efficiency of indirect selection is measured as a correlated response (Falconer, 1981). Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters. There is scarce information on the correlation studies, genetic variability and path analysis in the literature in corn under different sowing dates. So estimation of the genetic parameters, the relationships between yield and its components and their contribution in grain yield were of prime importance.

Although the values of PCV at both sowing dates were higher than the corresponding GCV values for all characters, the differences between them were low for the most of studied traits. The low differences between PCV and GCV values for grain yield plant^{-1} followed by ear weight plant^{-1} under optimal sowing compared to late sowing is an indication for the large role of genetic differences in variability existence. However, the higher values of PCV than GCV are indication that almost all of the characters are more influenced by the environment. Similar conclusions have been achieved by Mohammadi and Pourdad (2009) on soybean. Also, Tyagi and Khan (2010) reported that, high GCV estimates are an indicative of less amenability of these traits to environmental fluctuations and hence, greater emphasis should be given to these characters, while breeding cultivars from the present material. Johnson *et al.* (1955) suggested that the estimates of heritability and expected genetic advance should always be considered jointly. The high heritability estimates coupled with high genetic gain for yield plant^{-1}, ear weight plant^{-1}, grains row^{-1} and 100-grain weight at optimal sowing and for yield plant^{-1}, 100-grain weight and ear weight plant^{-1} at late sowing suggesting that these characters can be considered as favorable attributes for improvement through selection under the mentioned environmental conditions in the studied genetic materials and this may due to additive gene action (Panse, 1957). Also, in contrast, traits with low heritability and genetic gain (number of rows ear^{-1} at optimal sowing) are limited for genetic improvement through selection. On the other hand, traits with high heritability values and moderate genetic gain (days to 50% teaseling and silking and ear length) at optimum sowing and flowering traits at late planting are considered not suitable for genetic improvement through selection under such conditions.

In general, the higher magnitude of genotypic correlation than their corresponding phenotypic correlation coefficients in most of the characters suggesting a strong inherent association exists for the traits studied and phenotypic selection may be rewarding. Higher magnitude of genotypic correlation helps in selection for genetically controlled characters and gives a better response for seed yield improvement than that would be expected on the basis of phenotypic association alone (Robinson *et al.*, 1951). Under optimum and late planting, the significant genotypic correlations among the number of rows ear^{-1}, ear length, days to 50% tasseling and the positive and non-significant genotypic correlations between grains row^{-1} with ear weight $plant^{-1}$ suggest depending on those traits as selection criteria for high grain yield when selection in the present materials. Under late sown, number of days to reach flowering are increasing to enable the corn plant to accumulate more photosynthatase and this does not affect the yield at the genotypic level (the positive correlation between flowering traits and yield). However, 100 grain weight recorded positive genotypic correlation under normal and late plantings. Significant and positive associations of ear length, number of grains row^{-1}, number of grains ear^{-1} and 100- grain weight with grain yield were recorded by Selvaraj and Nagarajan (2011) while days to tasseling and silking showed positive and non-significant association. Also, Khalily *et al.* (2010) reported a significant and positive correlation between grain yield against 300 kernel weight, number of kernels row^{-1}, green cover percentage and ear length. In contrast, days to silk emergence and anthesi-silking interval recorded positive and significant correlation with grain yield in non-stressed corn and negative and significant associations in water-stress corn at both vegetative and reproductive stages. In contrast to their findings, days to silk emergence associated positively with grain yield under late planting conditions. Kashiani *et al.* (2010) suggested that kernel rows ear^{-1} and ear length are selection criteria for yield improvement among the tested inbred lines as they were highly correlated with grain yield (0.71 and 0.67, respectively). The present results were in consistency with those obtained by Oktem (2008) who recorded a significant and positive association between sweet corn yield and ear length, ear diameter and kernels ear^{-1} and a positive correlation between ear length and ear diameter, between ear length and kernels ear^{-1}.

Path coefficient analysis: Path coefficient analysis permits separation of correlation coefficients into components of direct and indirect effects which provide actual information on contribution of characters and thus form the basis for selection to improve the yield.

Path coefficient analysis for grain yield confirm the direct positive contributions of ear weight $plant^{-1}$, days to 50% tasseling, 100 grain weight and ear length (at early sowing); and ear diameter, days to 50% tasseling and silking (at late sowing) towards grain yield. Thus these traits could be explored more confidently as selection criteria for yield improvement in the studied materials and a slight increase in one of the above traits may directly contributes to seed yield. Similar findings which support the present results were reported by many scientists. Khayatnezhad *et al.* (2010) recorded a positive and direct effect of 500 kernel weight and ear length on grain yield in corn genotypes grown under dry conditions, with the more importance of 500 kernel weight in selecting different traits in corn. In contrast, kernels row^{-1} showed the lowest direct effect on yield (-0.091). Khazaei *et al.* (2010) reported that 1000 grain weight and grain number m^{-2} had the highest direct effect on grain yield, furthermore their indirect effects via other traits were scarcely. On the other hand, Khan and Dar (2010) recorded a positive indirect contribution of 100-grain weight in wheat on grain yield via days to 75% spike emergence. The study carried out by Selvaraj and Nagarajan (2011) on interrelationship and path-coefficient in corn revealed that direct selection for ear length and number of rows per ear are effective for yield improvement since they revealed positive and significant relationship with grain yield. The results obtained by Khalily *et al.* (2010) affirmed the importance of kernels row^{-1}, ear length and rows ear^{-1} and concluded that those traits should be used as target traits for tailoring an ideal corn plant for high yield. The same authors stated that, the positive direct and indirect effects of a trait on grain yield make it possible for its exploitation in selection under specific conditions. Mohan *et al.* (2002) studied path analysis on corn cultivars (169, cultivars) for grain yield and oil content and reported that, number of grain per row, 100-grain weight and ear length had direct effect on grain yield, whereas ear height, plant height and number of days to 50% tasseling had most minimum direct effect. Oktem (2008) found that ear length and single ear weight had high positive effects on grain yield, further those traits contributed the highest to grain yield (42.3 and 31.3%, respectively). The previous result agrees with the present study under optimum conditions. Whereas, under late sowing, ear weight $plant^{-1}$, days to 50% tasseling and silking, ear diameter had the major effects. Furthermore, all traits had indirect positive effects through ear weight $plant^{-1}$. In their study on path analysis in wheat, Akanda and Mundt (1996) stated that yield components that showing the highest correlations with yield also had the largest direct effect on yield. In contrast, for the present results some traits which recorded positive and significant coefficients with yield revealed negative direct effect on grain yield. These results are supported by that reported by Bekavac *et al.* (2007) who mentioned that correlation identifies mutual associations between the various parameters irrespective of causation. While, path coefficient analysis, on the other hand, specifies the causes and measures their relative importance (Dewey and Lu, 1959) and therefore, should be applied in addition to correlation analysis as the more powerful tool (Bhatt, 1973). They also added in some instances, path coefficient analysis gives a somewhat different picture of net effects than does correlation analysis. That was the case here-the negative direct effects of number of grains row^{-1} on grain yield, although the significant and positive genetic correlations between them at both sowing dates.

It can be conclude that ear weight $plant^{-1}$, 100 grain weight and ear length, revealed the highest genotypic correlation with grain yield and recorded the largest direct path coefficients under optimum sowing. Whereas, at late sown, ear weight $plant^{-1}$, flowering traits (direct effects), ear length (its indirect effects) showed positive and significant correlations. Grains row^{-1} showed negative indirect effects at both planting dates and positive indirect effects through ear weight $plant^{-1}$, ear length, days to 50% silking and rows number and 100 grain weight, ear weight $plant^{-1}$ and ear diameter at optimum and late planting, respectively. Ear weight $plant^{-1}$ (at both planting dates), ear diameter and flowering traits (at late planting), ear length and rows ear^{-1} (at optimum planting) as a primary; 100 grain weight and kernels row^{-1} as a secondary could be used as the main criteria for yield improvement when selecting in the studied materials.

REFERENCES

Akanda, S.I. and C.C. Mundt, 1996. Path coefficient analysis of the effects of stripe rust and cultivar mixtures on yield and yield components of winter wheat. Theor. Applied Genet., 92: 666-672.

Bekavac, G., B. Purar, M. Stojakovic, D.J. Jockovic, M. Ivanovic and A. Nastasic, 2007. Genetic analysis of stay-green trait in broad-based maize populations. Cereal Res. Commun., 35: 31-41.

Bhatt, G.M., 1973. Significance of path coefficient analysis in determining the nature of character association. Euphtica, 22: 338-343.

Bidgoli, A.M., G.A. Akbari, M.J. Mirhadi, E. Zand and S. Soufizadeh, 2006. Path analysis of the relationships between seed yield and some morphological and phenological traits in safflower (*Carthamus tinctorius* L.). Euphytica, 148: 261-268.

Burton, G.W. and E.M. Devane, 1953. Estimating heritability in fall fescue (*Festuca circunclinaceae*) from replicated clonal-material. Agron. J., 45: 478-481.

Dewey, D.R. and K.H. Lu, 1959. A correlation and path coefficient analysis of component of crested wheatgrass seed production. Agron. J., 51: 515-518.

El-Shouny, K.A., O.H. El-Bagoury, K.I.M. Ibrahim and S.A. Al-Ahmad, 2005. Correlation and path coefficient analysis in four yellow maize crosses under two planting dates. Arab Univ. J. Agric. Sci., 13: 327-339.

Esan, E.B. and S.S. Omolaja, 2002. Genotypic association, path analysis and pluck quality value in tea (*Camellia sinensis* (L.) O. Kuntze). Trop. Agric., 79: 100-104.

Falconer, D.S., 1981. Introduction to Quantitative Genetics. 2nd Edn., Oliver and Boyd, Edinburg, London, pp: 316.

Hanson, C.H., H.F. Robinson and R.E. Comstock, 1956. Biometrical studies of yield in segregating populations of Korean Lespedeza. Agron. J., 48: 268-272.

Hefny, M., 2010. Genetic control of flowering traits, yield and its components in maize (*Zea mays* L.) at different sowing dates. Asian J. Crop Sci., 2: 236-249.

Jayakumar, J., T. Sunderam, A. Ranguramarajan and S. Kannan, 2007. Studies on path analysis in maize (*Zea mays* L.) for grain yield and other yield attributes. Plant Arch., 7: 279-282.

Johnson, H.W., H.F. Robinson and R.E. Comstock, 1955. Estimation of genetic and environmental variability in soybeans. Agron. J., 47: 314-318.

Kashiani, P., G. Saleh, N.A.P. Abdullah and S.N. Abdullah, 2010. Variation and genetic studies on selected sweet corn inbred lines. Asian J. Crop Sci., 2: 78-84.

Khalily, M., M. Moghaddam, H. Kanouni and E. Asheri, 2010. Dissection of drought stress as a grain production constraint of maize in Iran. Asian J. Crop Sci., 2: 60-69.

Khan, M.H. and A.N. Dar, 2010. Correlation and path coefficient analysis of some quantitative traits in wheat. Afr. Crop Sci. J., 18: 9-14.

Khayatnezhad, M., R. Gholamin, S. Jamaati-e-Somarin and R. Zabihi-e-Mahmoodabad, 2010. Study of genetic diversity and path analysis for yield in corn (*Zea mays* L.) genotypes under water and dry conditions. World Applied Sci. J., 11: 96-99.

Khazaei, F., M.A. Alikhani, L. Yari and A. Khandan, 2010. Study the correlation, regression and path coefficient analysis in sweet corn (*Zea mays* var. saccharata) under different levels of plant density and nitrogen rate. ARPN J. Agric. Biol. Sci., 5: 14-19.

Mohammadi, R. and S.S. Pourdad, 2009. Estimation, interrelationships and repeatability of genetic variability parameters in spring safflower using multi-environment trial data. Euphytica, 165: 313-324.

Mohan, Y.C., D.K. Singh and N.V. Rao, 2002. Path coefficient analysis for oil and grain yield in maize (*Zea mays* L.) genotypes. Natl. J. Plant Improvement, 4: 75-76.

Oktem, A., 2008. Determination of selection criterions for sweet corn using path coefficient analyses. Cereal Res. Commun., 36: 561-570.

Panse, V.G., 1957. Genetic of quantitative characters in relation to plant breeding. Ind. J. Genet., 17: 318-328.

Robinson, H.F., R.E. Comstock and P.H. Harvery, 1951. Genotypic and phenotypic correlations in corn and their implication in selection. Agron. J., 43: 282-287.

Saleem, M., M. Ahsan, M. Aslam and A. Majeed, 2008. Comparative evaluation and correlation estimates for grain yield and quality attributes in maize. Pak. J. Bot., 40: 2361-2367.

Sarawgi, A.K., N.K. Rastogi and D.K. Soni, 1997. Correlation and path analysis in rice accessions from Madhya Pradesh. Field Crops Res., 52: 161-167.

Selvaraj, C.I. and P. Nagarajan, 2011. Interrelationship and path-coefficient studies for qualitative traits, grain yield and other yield attributes among maize (*Zea mays* L.). Int. J. Plant Breed. Genet., (In Press). 10.3923/ijpbg.2011

Shah, W.A., J. Bakht, T. Ullah, A. Khan, M. Zubair and A. Khakwani, 2006. Effect of sowing dates on the yield and yield components of different wheat varieties. J. Agron., 5: 106-110.

Singh, R.K. and S.S. Narayanan, 2000. Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi.

Sivasubranian, S. and M. Menon, 1973. Heterosis and inbreeding depression in rice. Madras Agric. J., 60: 1139-1144.

Snedecor, G.W. and W.G. Cochran, 1967. Statistical Methods. 6th Edn., Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, India, pp: 593.

Sofi, P.A. and A.G. Rather, 2007. Studies on genetic variability, correlation and path analysis in maize (*Zea mays* L.). Maize Newslett. Note, 81: 26-27.

Tyagi, S.D. and M.H. Khan, 2010. Studies on genetic variability and interrelationship among the different traits in *Microsperma lentil* (*Lens culinaris* Medik). J. Agric. Biotechnol. Sustain. Dev., 2: 15-20.

Wright, S., 1929. Path coefficients and path regressions: Alternative complementary concepts. Biometric, 16: 189-202.