Jordan Journal of Agricultural Sciences, Volume **9**, No.**2** 2013

Potence Ratio and Path Analysis for Yield and Quality Traits in Single Crosses of Maize (*Zea mays* L.) Produced in Syria

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ABSTRACT

The present study was carried out at the Maize Researches Department in General Commission for Science agriculture Research (G-C-S-A-R) Damascus, Syria. This study aimed at estimating the potence ratio and phenotypic correlations and path analysis coefficient analysis for protein, oil, and starch content in grain, grain yield per plant and 100-kernel weight. Twenty eight single cross hybrids were produced using a half diallel cross in 2008 cropping season and consequently evaluated during 2009 cropping season. Potence ratio results indicated that partial and over-dominance gene effects played a major role in inheritance of protein, oil, and starch content in grain while, over-dominance gene effects were the most dominant in the inheritance grain yield per plant and 100-kernel weight. Positive and high significantly correlations were observed between protein and oil content in grain (0.366) and between grain yield and100-kernel weight (0.386). Potence ratio estimates indicating partial and over-dominance towards the higher starch, oil, protein, for 100 grain yield per plant over-dominance gene effects played a major role in inheritance of this trait. Path analysis results showed the contribution of oil content in grain, 100-kernel weight and grain yield per plant for protein content in grain variation account 15.55%, and the relative important of oil content in grain reach to 13.40%. So, it can be considered as selection criteria which may lead to improve protein content in maize grain.

Keywords: Maize, Potence Ratio, Phenotypic Correlation, Path Analysis Coefficient.

INTRODUCTION

Maize (*Zea mays* L.) is one of Syria's principal cereal crops. Much effort are devoted to increase its productivity. Thus, to carry out a successful breeding program, the breeder should have enough knowledge about the inheritance and type of gene action of yield and quality traits. Studies on the inheritance of quantitative traits in maize were started by East in 1906 in Connecticut, and later by Emerson in Nebraska (Smith, 1955). Grain yield and quality traits (i. e. protein, oil and starch content of grains) are polygenic traits; and these traits are considerably affected by the environmental factors especially. Those affect grain filling. Types of the gene action in the breeding materials are essential for planning various breeding system component of genetic variance can be estimated by different mating designs. Comostock and Robinson (1952) suggested average degree of dominance also; Mather (1949) and Smith (1952) calculated potence ratio. Inheritance of protein content has been studied by Hayes and Garber (1919), East and Jones (1920) and Hayes (1922). They found that crosses between low and high protein inbred lines show phenotypic dominance of low protein in F_1 generation. It seems probable that

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Received on 21/7/2010 and Accepted for Publication on 8/8/2012.

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many genes are responsible for the inheritance of protein content. Frey (1949) studied the inheritance of protein in individual ear samples of Illions high and Illions low-protein and in F_1, F_2, BC_1 and BC_2 populations and found that low protein percentage were completely dominant. He also concluded that the general nature of the interaction of genes determining protein percentages was found to be arithmetic in the high × low protein cross. Cockerham (1961) discussed the relation between type of gene action and the efficient breeding schemes; he concluded that all systems of selection are fruitful if gene action is entirely additive. El Hosary and Abd El Sattar (1998), Khalil (1999), Edward and Lamky (2002) found that over-dominance was involved in the inheritance of 100-kernel weight and grain yield per plant where potence ratio values were larger than (+1). Srdić *et al*., (2008) and Haq *et al*., (2010) reported that additive and non-additive gene effects were involved in determining the performance of genotypes, however additive gene effects were more predominant for the inheritance of grain yield and oil content. Amit and Joshi, (2007) concluded that non-additive gene action was controlled the inheritance of oil, starch and protein contents in grain. Selvaraj *et al*., (2006) derived that additive gene action was more important than non-additive gene action in controlling grain yield and oil content, while non-additive was controlled the inheritance of protein contents. Tabassum *et al*., (2007) revealed that dominance absence and over dominance were controlled the inheritance of 100- kernel weight. Protein and oil content in cereal generally show strong negative correlations with yield, consequently progression breeding for improved protein and oil content without reducing yield, has been generally slow or disappointing. Hayes (1922) showed a very direct association between the number of kernels on an ear and the average protein content of the kernels of that ear. Sumathi *et al*., (2005) mentioned that oil content had consistent negative and significant correlation with grain yield. On the other hand, Mittelmann *et al*., (2003) found positive and significant correlation between grain yield and oil content, but this correlation was negative with protein content, however protein content exhibited significant and positive correlation with oil content. Positive and significant correlation between 100-kernel weight and grain yield was reported by Shamim *et al*., (2010) Efforts made to determine the relative contribution of yield related traits to grain yield variation, revealed that the most sources of variation in plant yield were the direct effects of 100-kernel weight (Abd El Sattar and Motawea 1999, Amin *et al* 2003 and Rafiq *et al*., 2010), Abirami *et al*., (2007) indicated that grain yield showed positive association with oil content and protein content. Saleem *et al*., 2007 reported that negative and significant correlation were between yield and protein content in grains (-0.393), while positive and significant correlation were between yield and starch content in grains (0.217). The results of (Parimala *et al*., 2011) showed that an increase in protein contents may decrease grain yield ultimately. Highest positive indirect effects were exhibited by plant height and starch content with grain yield (Shinde *et al.* 2009).

The aim of this investigation was to estimate the potence ratio and phenotypic correlations and path analysis coefficient analysis for protein, oil, and starch content in grain, grain yield per plant and 100-kernel weight.

Materials and Methods

Eight inbred lines of maize i. e IL.375-06 (P_1), IL.363-06 (P_2), IL.260-06 (P_3), IL.459-06 (P_4), IL.275-06 (P_5), IL.792-06 (P_6), IL.256-06 (P_7) and IL.362-06 (P_8) were crossed in a half diallel fashion in 2008 and evaluated in 2009 season in experiment designed in randomized complete blocks design (R.C.B.D) with three replication. Each, plot consisted of four ridges, 6m long and 70 cm width. Plants were spaced at 25 cm within ridge and thinned at one plant per hill after about 21 days of planting. Other recommended cultural practices for maize production were applied during the growing season.

Observations and measurements were recorded on 10 guarded plants chosen at random from each plot for the following characteristics: grain yield/plant, 100- kernel weight, protein, oil and starch content of grain. Mather (1949) and Smith (1952) approaches used to estimate potence ratio (P) as follows:

$P = (F_1 - MP) / [0.5 \times (P_2 - P_1)]$

Where:

F_1 = the first generation mean; P_1 = the mean of the smaller parent; P_2 = the mean of the larger parent; MP = mid parents value.

Complete dominance is indicated when potence ratio is equal to (+1) or (-1). Partial dominance is the case when ratio between (+1) and (-1). Over-dominance indicated if ratio exceeds (± 1).

The phenotypic correlation coefficients calculated as described by Snedecor and Cochran, (1981): $R\text{-}_{xy} = cov_{(x,y)}/[(v_x)(v_y)]^{1/2}$

Where: $R\text{-}_{xy}$ = the combined variance of x, y traits ; v_x = variance of x trait;

v_y= variance of y trait.

For all possible pairs of the studied characters including grain yield. To obtain more information about the relative contribution of specific characters to protein content in grain.

The path coefficient analysis performed for all crosses. Partitioning correlation coefficients into direct and indirect effects at phenotypic level made by determining path coefficients "where: the protein content in grains is the dependent variable while Starch, oil content in grains, 100-kernel weight and Grain yield per plant are the independent factors" using the method proposed by Wright (1934) and utilized by Dewey and Lu (1959):

$$1 = a^2 + b^2 + c^2 + h^2$$
$$+2r\,(x_1x_2)ab + 2r\,(x_1x_3)ac + 2r\,(x_2x_3)\,bc$$
$$a^2 = \sigma^2 x_1 / \sigma^2 y$$
$$b^2 = \sigma^2 x_2 \,/\, \sigma^2\, y$$
$$c^2 = \sigma^2 x_3 \,/\, \sigma^2\, y$$
$$h^2 = \sigma^2\, R \,/\, \sigma^2\, y$$

Where: x_1,x_2,x_3 = the traits which are considered as the most important sources of grain yield variation; a, b, c = path coefficient of these traits; h: path coefficient of no considered factors which name R.

Results and Discussion

Potence Ratio Estimates

Starch content in grains showed that potence ratios ranged from -5.7 in hybrid ($P_2 \times P_8$) to 19.0 in hybrid ($P_5 \times P_7$), they were between ±1 in ten crosses and they were more than unity for remaining crosses indicating partial and over-dominance towards the higher starch content in grains, with exception of hybrid ($P_6 \times P_8$) shows dominance absence, that may be attributed to genetic diversity among its parents, these results are in harmony with those obtained by Shanthi *et al*., (2002) while it is disagree with literature data (Alika and Ojomo, 1996) which concluded that additive action more important than non additive in heredity of Starch content in grains . Potence ratios of protein content in grains ranged from -31.0 in hybrid ($P_2 \times P_7$) to 0.4 in hybrid ($P_5 \times P_8$), they were more than unity in fifteen crosses and between ±1 in six crosses. However, over-dominance and partial dominance gene effects played a major role in inheritance of protein content in grains; these results are in agreement with that reported by Selvaraj *et al.*, (2006). different results were also reported by (Tabassum, 2004) who obtained that additive gene effects played a major role in inheritance of protein content in grains. On the other hand, hybrids ($P_5 \times P_6$),

($P_5 \times P_7$) and ($P_6 \times P_8$) showed dominance absence, while ($P_2 \times P_3$) had complete dominance. Similar findings were obtained by Selvaraj *et al*., (2006). Regarding oil content in grains, potence ratios ranged from -0.9 in hybrid ($P_1 \times P_7$) to 9.9 in hybrid ($P_2 \times P_8$). They were between ±1 in twenty-one crosses and more than unity in six crosses indicating, that partial and over-dominance played a major role in inheritance of oil content in grains, with exception of hybrid ($P_6 \times P_8$) which shows complete dominance, Amit and Joshi, (2007) using diallel cross analysis revealed that dominance controlled the behavior of oil content in grains and this results intersected with above result, Concerning 100-kernel weight, values of potence ratio ranged from -0.1 in hybrid ($P_4 \times P_8$) to 74.1 in hybrid ($P_1 \times P_3$). They were larger than unity for the most crosses indicating over-dominance towards the heavy kernel weight with exception of hybrids ($P_4 \times P_8$) and ($P_5 \times P_7$) show partial dominance and ($P_4 \times P_6$) had complete dominance, our findings supported by the results of (Tabassum *et al*., 2007) On the other hand (Sedhom, 1994) reported that additive action controlled 100-kernel weight. Grain yield per plant showed that potence ratios ranged from 3.9 in hybrid ($P_5 \times P_6$) to 42.3 in hybrid ($P_3 \times P_7$). They more than unity in all crosses indicating, over-dominance gene effects which played a major role in inheritance of this trait; this result is in agreement with that reported by Srdić *et al*., (2008).

Table (1). Potence ratio of traits studied for 28 F_1 crosses.

Crosses	starch	protein	oil	100-kernel	GYP
$P_1 \times P_2$	0.4	-1.5	-0.2	2.9	9.6
$P_1 \times P_3$	0.6	-2.3	-0.2	74.1	35.2
$P_1 \times P_4$	2.7	-1.3	-0.5	13.4	30.2
$P_1 \times P_5$	0.9	-0.7	-0.6	2.5	6.9
$P_1 \times P_6$	1.1	-0.9	0.4	2.9	15.1
$P_1 \times P_7$	1.4	-1.7	-0.9	1.9	24.9
$P_1 \times P_8$	0.5	-1.5	1.8	2.9	8.9
$P_2 \times P_3$	-1.2	-1.0	0.6	2.5	10.4
$P_2 \times P_4$	13.1	-2.4	0.2	2.1	7.6
$P_2 \times P_5$	0.1	-1.3	0.3	1.5	24.7
$P_2 \times P_6$	4.9	-15.2	-0.1	9.0	4.6
$P_2 \times P_7$	1.3	-31.0	0.6	3.8	11.3
$P_2 \times P_8$	-5.7	-0.2	9.9	5.5	2.8
$P_3 \times P_4$	5.7	-7.7	0.4	10.0	12.0
$P_3 \times P_5$	0.2	-0.9	2.7	2.7	4.3
$P_3 \times P_6$	-0.9	0.4	0.1	2.2	10.3
$P_3 \times P_7$	-0.4	-1.5	1.6	1.1	42.3
$P_3 \times P_8$	1.5	-5.0	0.8	5.5	8.9
$P_4 \times P_5$	3.6	-1.7	-0.6	3.6	5.6
$P_4 \times P_6$	7.7	-3.4	-0.1	1.0	28.8
$P_4 \times P_7$	1.9	-2.2	0.6	1.7	13.4

Crosses	starch	protein	oil	100-kernel	GYP
$P_4 \times P_8$	10.8	-3.4	0.2	-0.1	7.3
$P_5 \times P_6$	0.0	0.0	-0.2	1.1	3.9
$P_5 \times P_7$	19.0	0.0	-0.1	0.7	5.2
$P_5 \times P_8$	-0.7	0.4	2.0	1.8	36.2
$P_6 \times P_7$	0.7	-26.1	0.1	11.3	8.7
$P_6 \times P_8$	1.3	0.0	1.0	5.2	5.2

GYP= grain yield/plant: 100-KW= 100- kernel weight.

Phenotypic Correlation

Correlation studies allow for the verification of indirect selection viability in providing genetic gains faster than in direct selection (de Carvalho *et al*., 2001), Phenotypic correlation coefficients estimated between all pairs of studied characters including grain yield, obtained results are presented in Table (2). The data showed that positive and high significantly correlation coefficients were found between protein and oil content in grain (0.366^{**}), protein content of grain significantly and negatively correlated with starch content (-0.673^{**}). However, non-significant correlations were observed between protein content in grain and all the other recorded characters. Starch content in grain showed significant and negative correlation with oil content of grain (-0.701^{**}). were found between oil grain content with 100-kernel weight and grain yield per plant. while the association was positive and significant between grain yield per plant and 100-kernel weight (0.386^{**}). These results indicate that selection for high oil content may be accompanied by increasing kernels protein content. On the other hand, selection 100-kernel weight may accompanied by increasing grain yield per plant of maize in this contexture. Fabijianac *et al*, (2006) found that positive and high significantly correlation between 100-kernel weight and grain yield per plant (0.63), Starch content in grains (0.35), while there were negative and high significantly correlation between grain yield per plant and oil (-0.30), protein content in grains (-0.23), these results agreed with those obtained by Rafiq *et al*., (2010), and these are in coincidence with those mentioned by Okporie and Oselebe, (2007).

Table (2). Phenotypic correlation between all studied traits.

Traits	Protein	Starch	Oil	100-KW
Starch	-0.673^{**}			
Oil	0.366^{**}	-0.701^{**}		
100-KW	-0.057	0.009	-0.075	
GYP	-0.149	-0.060	-0.012	0.386^{**}

GYP= grain yield/plant: 100-KW= 100- kernel weight. * and ** significant at P= 0.05 and P= 0.01 respectively.

Path coefficient analysis

Path coefficient analysis was estimated to study the direct and indirect effects of traits studied protein content in grain as well as the relative importance of these traits as selection criteria. so path coefficient analysis performed for all crosses, "where: the protein content in grains is the dependent variable while Starch, oil content in grains, 100-kernel weight and Grain yield per plant are the independent factors, The data showed that the direct effect of oil content of grain on protein content of grain was 0.366 The indirect effects of this trait through both 100- kernel weight and grain yield per plant were-0.002 and 0.002 (Table 3). These results indicated that the relative importance of oil content of grain on protein content of grain was 13.40% (Table 4). 100- Kernel weight proved to have negligible direct 0.031, and in direct effect on protein content of grain via oil content in grain -0.027 and in direct effect on protein content of grain via grain yield -0.061 (Table 3). However, the relative importance of direct and joint effects for 100- kernel weight may be negligible (Table 4). Also the direct and indirect influence of grain yield per plant on protein content of grain was negligible value (Table 3). However, relative importance of grain yield per plant was 2.47%. Our results support the conclusion of (Hou Jian-hua *et al*., 2001.; Parimala *et al*., 2011) who are sure that breeding for high protein genotypes require moderate balance between grain yield and protein content in grains, and the results indicated that any increase in oil content in grains would correspond to a positive increase in protein content in grains.

Table (3). Direct and indirect effects of Oil content of grain, 100- kernel weight vs and grain yield/plant in protein content of grain.

	Source of variation	Effects
1-	Oil vs. protein content in grain	
	Direct effect	0.366
	Indirect effect via 100-kernel weight	-0.002
	Indirect effect via grain yield	0.002
	Total	0.366
2-	100-kernel weight vs. protein content in grain	
	Direct effect	0.031
	Indirect effect via Oil content in grain	-0.027
	Indirect effect via grain yield	-0.061
	Total	-0.057
3-	grain yield vs. protein content in grain	
	Direct effect	-0.157
	Indirect effect via Oil content in grain	-0.004
	Indirect effect via 100-kernel weight	0.012
	Total	-0.149

Table (4): Relative importance (direct and joint effects) in percent of protein content in grain

	Source of variation	CD	RI%
1	Oil content in grain (X_1)	0.1340	13.40
2	100-kernel weight (X_2)	0.0009	0.09
3	grain yield per plant (X_3)	0.0247	2.47
4	(X_1) × (X_2)	-0.0017	-0.17
5	(X_1) × (X_3)	0.0014	0.14
6	(X_2) × (X_3)	-0.0038	0.38
	Residual	0.8445	84.45
	Total relative importance		15.55

CD denote coefficient of determination. RI% denotes relative Importance.

Conclusion

Potence ratio indicated that partial and over-dominance ruled the gene action of starch, oil, protein, content in grains, over-dominance controlled inheritance of 100-kernel weight, with exception of hybrids ($P_4 \times P_8$) and ($P_5 \times P_7$) show partial dominance and ($P_4 \times P_6$) had complete dominance in other hand over-dominance overruled the inheritance of Grain yield per plant.

Phenotypic correlation concluded that Positive and high significantly correlations were observed between protein and oil content in grain and between protein content in grain and100-kernel weight.

Path coefficient analysis results revealed that oil content in grain can be considered as selection criteria may be lead to important of protein content in maize grain. However, effectiveness of selection in moderate and late segregation generation of the studied hybrids may be lead to improvement of protein and oil content in grain, the low relative important (15.55)%, probably due to other factors not included in this study especially amino acids.

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درجة السيادة وتحليل المسار لصفات الغلة والنوعية في هجن فردية من الذرة مستنبطة في سورية

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ملخـص

أجريت هذه الدراسة في قسم بحوث الذرة التابع للهيئة العامة للبحوث العلمية الزراعية في دمشق، سورية بهدف تقدير درجة السيادة Potence Ratio، وتحليل المسار Path Analysis Coefficient لصفات: محتوى الحبوب من البروتين والزيت والنشاء وغلة النبات الفردي ووزن 100 حبة. كونت الهجن الثمانية والعشرون من خلال التهجين نصف التبادلي بين ثمان سلالات من الذرة الصفراء في الموسم الزارعي 2008، ثم قيمت في الموسم 2009. بينت نتائج درجة السيادة سيطرة السيادة الوراثية الجزئية والفائقة على سلوك معظم الهجن المستنبطة في صفات: محتوى الحبوب من البروتين والزيت والنشاء، في حين سيطرت السيادة الفائقة على السلوك الوراثي لمعظم الهجن المدروسة لصفتي وراثة صفة ووزن 100 حبة والغلة الحبية. أظهر محتوى الحبوب من البروتين ارتباطاً موجباً ومعنوياً بمحتوى الحبوب من الزيت (0.366) وارتبطت إنتاجية النبات الفردي ارتباطاً موجباً ومعنوياً بصفة وزن 100 حبة (0.386). أشارت نتائج تحليل المسار إلى أن الأهمية النسبية لصفات محتوى الحبوب من الزيت ووزن100 حبة وغلة النبات الفردي في صفة محتوى الحبوب من البروتين تبلغ 15.55%، وان الانتخاب لصفة محتوى الحبوب من الزيت يمكن أن يكون مؤشرا على تحسين محتوى الحبوب من البروتين في حبوب الذرة الصفراء.

الكلمات الدالة: الذرة ودرجة السيادة والارتباط المظهري وتحليل المسار.

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تاريخ استلام البحث 2012/7/21 وتاريخ قبوله 2012/8/8.