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Correlation, Genetic and Phenotypic Path Coefficient Analysis in Maize (*Zea mays* L.)

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ABSTRACT

Seven genotypes of maize (Naworoz, Sagunto, Jameson, Torro, Zp-Glorya, Nahrain and DKC6664) were planted on July 7, 2023 using three levels of nano chelated NPK (20-20 -20) fertilizer (0, 6 and 12 kg/ha), at Al-Sheikhan district, Jurgan village, under sprinkler irrigation, using a randomized complete block design by a split-plot system to evaluate grain yield per plant and some other traits (number of ears per plant, ear length, ear diameter, number of rows per ear, number of grains per row, number of grains per ear and 500 grains weight), and the analysis of genotypic and phenotypic path coefficient among grain yield and other traits was performed. The results showed that the nano-fertilizer level of 12 kg/ha had significant highest means for ear length, ear diameter, number of rows per ear, number of grains per row, number of grains per ear and grain yield per plant. The Torro genotype showed good mean performance for all traits, followed in importance by DKC6664, then Nahrain and Jameson, for a number of traits, reached 6, 5, and 3 for each, respectively, and these results indicate the possibility of utilizing these distinct genotypes in breeding programs. It was shown that grain yield per plant correlated positively and significantly (genetically and phenotypically) with number of ears per plant and 500 grains weight, and genetically with ear length and ear diameter. path coefficient analysis showed that number of grains per ear, followed by number of grains per row, then number of ears per plant genetically and number of grains per ear, followed by 500 grains weight then then number of ears per plant phenotypically, considered to have the strongest effects on grain yield per plant, and this is useful in the reliability of these traits as selection criteria for higher yield performance in breeding programs.

تحليل الارتباط ومعامل المسار الوراثي والمظهري في الذرة الصفراء (*Zea mays* L.)

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الخلاصة

زرعت سبعة تراكيب وراثية من الذرة الصفراء (نوروز وSagunto وJameson وTorro وZp-Glorya ونهرين وDKC6664) في 7 تموز 2023 باستخدام ثلاثة مستويات من سماد النانو NPK (20-20-20) في منطقة الشيخان، قرية جرغان (45 كم شمال الموصل)، تحت ظروف الري بالرش، باستخدام تصميم القطاعات العشوائية الكاملة بنظام القطع المنشقة لتقييم حاصل الحبوب بالنبات وبعض الصفات الأخرى (عدد العرانيص بالنبات وطول وقطر العرنوص وعدد الصفوف بالعرنوص وعدد الحبوب بالصف وبالعرنوص ووزن 500 حبة)، وتم إجراء تحليل معامل المسار الوراثي والمظهري بين حاصل الحبوب بالنبات والصفات الأخرى. أظهرت النتائج أن مستوى التسميد النانوي 12 كغم للهكتار كان له أعلى المتوسطات المعنوية لصفات طول وقطر العرنوص وعدد الصفوف بالعرنوص وعدد الحبوب بالصف، وبالعرنوص وحاصل الحبوب بالنبات. اعطى التركيب الوراثي Torro متوسطات أداء جيدة للصفات جميعها، وتلاه في الأهمية DKC6664، ثم نهرين وJameson لعدد من الصفات بلغ 6 و5 و3 لكل منها على التوالي ، وتشير هذه النتائج إلى إمكانية الاستفادة من هذه التراكيب الوراثية المتميزة في برامج التربية. تبين أن حاصل الحبوب بالنبات كان له ارتباط موجب ومعنوي (وراثياً ومظهرياً) مع صفتي عدد العرانيص بالنبات ووزن 500 حبة، ووراثياً مع طول وقطر العرنوص. وظهر من نتائج تحليل معامل المسار أن صفة عدد الحبوب بالعرنوص، تليها صفة عدد الحبوب بالصف، ثم عدد العرانيص بالنبات (وراثياً)، وصفة عدد الحبوب بالعرنوص، تليها صفة وزن 500 حبة، ثم عدد العرانيص بالنبات (مظهرياً) كان لها أقوى التأثيرات على حاصل الحبوب بالنبات، وهذا مفيد في موثوقية اعتماد هذه الصفات كأدلة انتخاب لأداء إنتاجي أعلى في برامج التربية.

كلمات مفتاحية: الذره الصفراء، الارتباط، تحليل المسار، التراكيب الوراثية

INTRODUCTION

Maize (Zea mays L.) is one of the most important cereal crops in the world as it is cultivated over large areas, and it is the third important cereal crop after wheat and rice in terms of economic importance and productivity (Sharif and Al-Rawi, 2019). It is grown as a multi-purpose crop (which is why it is called the Queen of grains), and all parts of its plants have many benefits, including as food and fodder for animals. Its leaves are considered an essential element in paper industry, and the finest types of oils and starches are extracted from its grains. As fodder, it is concentrated because it contains several vitamins, including B_1, and B_2. , F, as well as 81% carbohydrates, 10.6% protein, 4.6% oil, and 2% ash (Al-Nasrawi, 2015). Grain yield in maize is considered the most economically important trait and is the focus of many breeding programs, as it is the final product that is attributable to a complex series of interconnected effects with different traits (Singh et al., 2005). However, it is a complex heritable quantitative trait, the inheritance of which is controlled by a large number of genetic factors and subject to significant environmental influences, so direct selection for grain yield is often ineffective. Therefore, for the purpose of improving grain yield, crop breeders resort to indirect selection for important traits from its components (Kandil et al, 2020). In this case, traits that have a significant correlation with yield are identified to have an impact on genetic accumulation after the selection process. The process of developing new varieties of the crop characterized by high production and good quality characteristics of the most important objectives sought by plant breeders. A careful look at the importance of genetic variations in crop species is of paramount importance in that it provides a fundamental basis for an effective

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Part of M. Sc. Thesis for the first researcher

selection process, and to practice that, determining the outcome of the crop is desirable. Correlations between traits are a measure of the strength of their relationship, and their knowledge between traits is important in plant breeding. If two traits are positively correlated, one can be indirectly improved by improving the other. The estimation of the correlation coefficient is necessary to develop a selection index, and in order to create a sense for correlation, (Wright, 1921) developed a path coefficient analysis method which was used to develop criteria for selecting complex traits in many crop (Dewey and Lu, 1959). The method of analyzing the path coefficient in maize was adopted by many researchers., Jakhar et al., (2017) indicated that path analysis provides an effective measure of the direct and indirect causes of association and depicts the relative importance of each factor involved in contributing to the final yield, and they found that direct and positive effect on yield was through, 100-grain weight, ear length and ear diameter. Wedwessen and Wolde (2020) concluded that grain yield showed a positive and significant genetic and phenotypic correlation with ear diameter, number of rows per ear, number of grains per row, and 1000 grains weight, and phenotypic path coefficient analysis showed that the highest positive direct effect on grain yield was through 1000 grains weight, number of rows per ear, number of grains per row, indicating that if other traits remain constant, increasing one of these traits will lead to increased grain yield. Hadi et al. (2021) obtained significant positive correlations for number of rows per ear, number of grains per row, with grain yield per plant, and that the ear length and number of grains per row, have the largest effect on grain yield. It appeared from Pranay et al. (2022) study, that there are significant positive correlations for ear length, ear diameter, number of rows per ear and 100 grains weight with grain yield per plant, and path analysis showed that the ears yield per plant had the highest direct positive effect on grain yield, followed by number of grains per row and ear diameter. Priyanto et al. (2023) concluded that traits with high heritability and wide genetic variation are ear height, ear length and 1000 grains weight, and most influence the final yield. Al-Asadi and Al-Abody (2023) indicated that 300 grains weight had the strongest direct positive genetic and phenotypic effect on grain yield according to the analysis of genetic and phenotypic path coefficients, followed by number of grains per ear. Al-Rawi et al. (2023) stated that path analysis showed that the direct effects of number of rows per ear, number of grains per row and 300 grains weight were different in their strength and direction depending on the level of potassium fertilizer, and the direct selection of number of rows per ear and number of grains per row will be greatly effective in enhance productivity. The aim of the current study is to evaluate the yield and some of other traits for seven genotypes of maize at different levels of nano NPK fertilizer, and to partition the genetic and phenotypic correlation coefficients of grain yields with other studied traits to direct and indirect effects.

MATERIALS AND METHODS

The experiment was carried out in the Sheikhan district, Jurgan village (45 km north of Mosul), and included seven genotypes of maize (names and sources are presented in Table 1). The planting date was on July 7, 2023 using three levels of nano chelated NPK (20-20 -20) fertilizer, 0, 6 and 12 kg/ha^{-1}, which is equivalent to 0, 18 and 36 gm for the main experimental unit, which has an area of 12 x 2.5 = 30 m^2, and was added to the soil at the sixth leaf stage. Planting was done in lines 2.5 m long and 0.75 m apart (in holes by placing three grains in each hole and then thinning to one plant), under sprinkler irrigation using a fixed irrigation system, after plowing the soil twice perpendicularly using a rotary plow, then smooth it, level it, and make the plots. Triple superphosphate fertilizer P_2O_5 was added as a source of phosphorus at a

Table 1: Genotypes of maize used in the study and their sources.

Symbol	Name of genotype	Origin	Source
G_1	Naworoz	Duhok	College of Agric. Engineering Sci.– Dohuk Univ.
G_2	Sagunto	Spain	College of Agriculture & Forestry - Mosul Univ.
G_3	Jameson	America	College of Agriculture & Forestry - Mosul Univ.
G_4	Torro	Holland	College of Agriculture & Forestry - Mosul Univ.
G_5	Zp-Glorya	Yugoslav	College of Agriculture & Forestry - Mosul Univ.
G_6	Nahrain	Iraq	College of Agriculture - Tikrit Univ.
G_7	DKC6664	America	College of Agriculture & Forestry - Mosul Univ.

rate of 200 kg per hectare at planting, and urea 200 kg per hectare in two times, half the amount at planting and second half before flowering (Yahya and Al-Zubaidy, 2022). The field soil specifications were clay loam (32.7% clay, 33.75% silt and 33.55% sand), and it contained 0.89% organic matter, 0.0058% nitrogen, 1.31 ppm phosphorus, 350 ppm potassium, its salinity was 0.5 millisiemens/cm and pH is 7.1 (Note that soil tests were conducted in the central laboratory of the

College of Agriculture and Forestry, University of Mosul). The factorial experiment was carried out using a randomized complete block design by a split-plot system with three replications, so that the three nano-fertilizer levels were distributed in each block within the main experimental units, and the seven genotypes were distributed in the secondary experimental units within each main experimental unit, so each block contained 21 secondary experimental unit (which included combinations between fertilization levels and genotypes), and each secondary experimental unit contained two lines. All crop service operations (land preparation, irrigation and weed control) were carried out according to need and recommendations during the period of crop growth and maturity. Preventive measures were taken to protect the plants from insect infections, especially the maize stalk borer, as the plants were sprayed with the pesticide Effector (10%) twice, the first after the formation of 5-6 leaves on the plant and the second a week after the first spray. At maturity, data were recorded on five randomly selected plants from each experimental unit for traits of: number of ears per plant (NEP), ear length (EL) in cm, ear diameter (ED) in cm, number of rows per ear (NRE), number of grains per row (NGR), number of grains per ear (NGE), 500 grains weight (500GW) in gm and grain yield per plant (GYP) in gm. The data of genotypes at three levels of nano-fertlizer for studied traits were analyzed according to the experimental design used, and the differences between the means of the fertilizer levels and genotypes were compared by Duncan's multiple rang test method (Al-Zubaidy and Al-Falahy, 2016), and then phenotypic and genotypic variances (σ^2_P and σ^2_G) and phenotypic and genotypic covariance's (σP_xP_y and σG_xG_y) were estimated through relationship between estimated and expected mean squares in the variance and covariance analysis table, and then phenotypic and genetic correlations (r_P and r_G respectively) were estimated between the studied traits from the following equations (Al-Zubaidy and Al-Jubory, 2016):

$$r_P = \frac{\sigma P_xP_y}{[\sqrt{(\sigma^2 P_x)(\sigma^2 P_y)}]} \quad ; \quad r_G = \frac{\sigma G_xG_y}{[\sqrt{(\sigma^2 G_x)(\sigma^2 G_y)}]}$$

Path coefficient analysis established by Wright (1921) was approved as an average of nano-fertilization levels to partition the coefficients of correlation (genetic and phenotypic) between GYP and other studied traits to direct and indirect effects, in the manner described by Dewey and Lu (1959) and then explained by Al-Zubaidy and Al-Jubory (2016) in detail, to test the model which included seven independent variables: NEP (x_1), EL (x_2), ED (x_3), NRE (x_4), NGR (x_5), NGE (x_6), and 500 GW (x_7), as illustrated in Figure (1). The direct effects (phenotypic and genetic) were estimated using correlation matrices as follows:

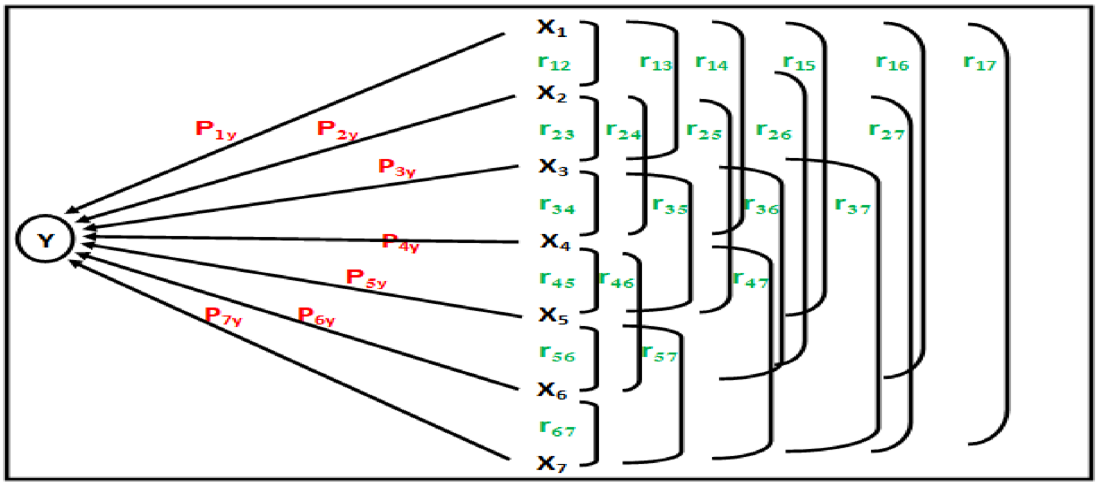

Figure (1): Path relationship of the independent variables of yield components (X_1, X_2, X_3, X_4, X_6, and X_7) affecting grain yield.

P_{iy}= R^{-1} r, where, P_{iy} = the direct effects vector, R^{-1} = the inverse matrix of correlation coefficients between all possible pairs of traits and r = correlation coefficient vector between grain yield and other traits. Following path way shown in Figure 1, the direct and indirect effects (genetic and phenotypic) were estimated. The significance of direct and indirect effects was determined according to the grading mentioned by Al-Zubaidy and Al-Jubory (2016) as follows (from 0,00 - 0.09 neglected), (from 0.10 - 0.19 few), (from 0.20 - 0.29) moderate, (from 0,30 - 0,99) high and (more than 1,00) very high.

The available programs SAS (statistical Analysis System) and Microsoft Excel 2003 were used to implement various statistical procedures.

RESULTS AND DISCUSSION

Table (2) shows the analysis of variance results from the data of genotypes grown at three levels of nano fertilizer for yield and its components traits in maize. It is noted that the mean square of fertilizer levels was highly significant for all traits except NEP, while that related to genotypes and their interaction with fertilizer levels were highly significant for all traits except NRE in case of interaction interaction. The results regarding the significant mean square of the genotypes for all traits were similar to what found by Babatope et al. (2021), Ige et al. (2021), Amegbore et al. (2022) and Al-Shakarchy et al. (2023), who got highly significant variations among genotypes for all studied traits, which indicated the existence of genetic variability that can be exploited in breeding programs. The means of nano-fertilizer levels as average of genotypes are shown in Table (3), and it is noted that the fertilizer level of 12 kg/ha had significant highest means for EL, ED, NRE, NGR, NGE and GYP. The highest mean of 500GW was 141.39 gm in case of not using nano-fertilizer, with a non-significant difference from the average of 6 kg/ha, as for NEP, no significant differences appeared between the three levels. The

Table 2: Analysis of variance results for grain yield and its components.

source	df	Mean square for traits:			
		NEP	EL	ED	NRE
Reps.	2	0.013	4.092	0.244	2.665
Nano fertilizer levels	2	0.012	46.544**	0.462**	16.636**
Error (a)	4	0.021	1.646	0.031	1.914
Genotypes	6	0.249**	27.752**	0.221**	5.324*
Fertilizer x Genotypes	12	0.177**	10.517**	0.151**	1.536
Error (b)	36	0.023	0.692	0.024	1.965
		NGR	NGE	500GW	GYP
Reps.	2	6.265	1054.902	74.015	83.067
Nano fertilizer levels	2	228.359**	149928.476**	1971.853**	1512.945**
Error (a)	4	0.909	1510.2485	9.068	266.078
Genotypes	6	129.302**	37489.911**	3366.784**	10767.247**
Fertilizer x Genotypes	12	43.993**	13353.457**	1293.281**	5696.437**
Error (b)	36	1.272	852.049	31.823	215.345

(**) and (*) significant at 1% and 5% probability levels respectively.

Table 3: Means of nano fertilizer levels for grain yield and its components.

Fertilizer levels	Traits							
	NEP	EL	ED	NRE	NGR	NGE	500GW	GYP
0 kg/ha	1.505 a	17.729 b	3.734 b	15.848 b	33.981 c	546.86 c	141.39 a	192.50 b
6 kg/ha	1.519 a	18.657 b	3.813 b	17.205 a	37.795 b	657.70 b	139.17 a	193.36 b
12 kg/ha	1.471 a	20.643 a	4.021 a	17.524 a	40.548 a	712.75 a	123.61 b	207.61 a
Mean	1.498	19.009	3.856	16.859	37.441	639.104	134.721	197.822

- Means followed by the same letter for each trait did not significantly different.

effectiveness of nano-fertilization in increasing yield may be due to the effective role of nitrogen, phosphorus, and potassium in the synthesis, distribution, and accumulation of important substances responsible for growth, which reflects positively on yield and some of its components. Nourain (2019) and Abdullah (2023) concluded from their studies that nano-fertilizer compared to any other fertilizers increased the productivity of most traits in various field crops, and a suitable choice of nano-fertilizer can be considered the most critical factor in crops farm management. The means of genotypes for the different traits (as an average of the nano-fertilizer levels) are presented in Table (4), and the results of Duncan's Multiple Range Test show that there are significant differences between them for all traits. The highest mean values for EL, NGR, NGE, GYP, were 21.844 cm, 42.967 grains, 733.60 grains and 262.08 gm respectively in Torro genotype, with a significant difference from all other genotypes, achieving an increase in GYP by 32.483% compared to the general mean and 20.997% compared to Nahrain genotype, which came in second place in GYP, with a mean of 216.60 gm. Likewise, the Torro genotype gave the highest mean of NEP, reaching 1.733 ear, with a non-significant difference from the Sagunto genotype only, while the lowest number was 1.267 ear in Zp-Glorya genotype. The Jameson genotype was distinguished by having the highest mean of ED (4.048 cm), with a non-significant difference over the Torro, Nahrain, and DKC6664 genotypes. For NRE trait, the highest mean was 17.489 row in Torro genotype, with a significant difference from Nahrain genotype only, while for 500GW trait, the highest mean was 171.69 gm in Nahrain

Table 4: Means of genotypes for grain yield and its components.

genotypes	Traits							
	NEP	EL	ED	NRE	NGR	NGE	500GW	GYP
Naworoz	1.478cd	17.767d	3.781bc	17.456 a	34.956d	613.86d	112.93f	171.22de
Sagunto	1.667ab	18.967c	3.718cd	17.389 a	34.522d	623.27d	127.01d	190.29c
Jameson	1.567bc	17.578d	4.048 a	16.60ab	33.233e	554.84e	137.52c	207.59b
Torro	1.733 a	21.844a	3.924ab	17.489a	42.967a	733.60a	143.14b	262.08a
Zp-Glorya	1.267 e	19.389c	3.611 d	17.044a	39.244c	664.86c	118.70e	160.89e
Nahrain	1.400de	16.944d	3.978 a	15.311b	35.633d	580.82e	171.69a	216.60b
DKC6664	1.378de	20.578b	3.933ab	16.722a	41.533b	702.47b	131.94d	176.08d
Mean	1.498	19.009	3.856	16.859	37.441	639.104	134.721	197.822

- Means followed by the same letter for each trait did not significantly different.

genotype, with a significant difference from all other genotypes. It is noted that Torro genotype showed good mean performance for all traits, followed in importance by DKC6664, then Nahrain and Jameson, and these results indicate the possibility of utilizing these distinct genotypes in breeding programs. From previous studies, other researchers got a significant differences between the means of genotypes for GYP and other traits of its components in maize, including (Al-Falahy et al, 2020; Tesfaye and Mengistu, 2021; Gokulakrishnan et al., 2021; Yahya, and Al-Zubaidy, 2022 and Al-Shakarchy et al., 2023). Table (5) shows values of genetic and phenotypic correlation coefficients between pairs of studied traits in maize. It is noted that both genetic and phenotypic correlations were similar in strength and direction for most cases, and that the genetic correlations values exceeded most of what they are phenotypically between most pairs of traits. It seems that GYP correlated positively and significantly (genetically and phenotypically) with NEP and 500GW, and genetically with EL and ED, indicating that all these four traits are genetically associated with GYP. while the genetic and phenotypic correlation with other traits (positive or negative) did not reach the significant level. On the other hand, EL had positive and significant correlations (genetic and phenotypic) with NRE, NGR and NGE, but its correlations with the ED and 500GW did not reach the significant levels. The genetic correlation of ED trait was highly significant (negative) with NRE and positive with 500GW, while its other genetic and phenotypic correlations were non-significant. The NRE trait was highly significantly correlated genetically with NGE and phenotypically with NGR and NGE traits, while its negative correlation with 500GW was significant at 1% probability level genetically and not

Table (5): Genetic correlations (above) and phenotypic (below) between maize grain yield and its components.

Traits	GYP	NEP	EL	ED	NRE	NGR	NGE	500GW
GYP	1	0.738**	0.321*	0.618**	-0.128	0.271	0.182	0.638**
NEP	0.643**	1	0.302	0.314	0.537**	-0.044	0.0949	0.098
EL	0.295	0.127	1	-0.1224	0.667**	0.905**	0.978**	-0.198
ED	0.187	0.031	0.038	1	-0.599**	-0.047	-0.247	0.703**
NRE	0.029	0.159	0.345*	0.069	1	0.291	0.6061**	-1.040**
NGR	0.234	0.021	0.739**	0.112	0.336*	1	0.962**	0.009
NGE	0.278	0.079	0.723**	0.105	0.452**	0.919**	1	-0.209
500GW	0.395*	0.030	-0.246	0.164	-0.314	-0.382*	-0.416**	1

(**) and (*) significant at 1% and 5% probability levels.

significant phenotypically. The genetic and phenotypic correlation of NGR with NGE was positive and highly significant, while its correlation with 500GW was genetically positive, insignificant, and phenotypically negative, significant at 5% probability level. Finally, the correlation between NGE and 500GW traits was negative, not significant genetically, and highly significant phenotypically. This independent association of yield components traits with GYP is generally beneficial to crop breeders, because if any of these traits are heavily selected in early generations, there is less possibility of excluding offspring that yielded well, if they are negatively correlated. From previous studies references, Wedwessen and Wolde (2020) and Pranay et al. (2022) found significant positive correlations between grain yield and some of its components and between components. The simple correlation coefficients between pairs of different traits vary between positive and negative, or significant and non-significant, in proportion to the strength of the relationship between them. Knowing this relationship between the different traits is considered necessary and of great importance in plant breeding, as it is possible in the presence of a positive and significant correlation between two traits, improving one indirectly by improving the other. Likewise, estimating the correlations between different traits is considered necessary and useful in arriving at an appropriate selection index that contributes to improving yield. In order to achieve greater benefits from the correlations of yield in any crop with other traits of its components, the concept of path coefficient analysis was developed by Wright (1921) because the correlation coefficient value between yield and any of its component traits does not express the true relationship between them in many cases. Many researchers have used this concept for the purpose of identifying a suitable criterion to indirect selection for yield trait in maize (Hadi et al., 2021 ; Pranay et al., 2022 ; Al-Asadi and Al-Abody, 2023 ; Al-Rawi et al., 2023). Path coefficient analysis diagram between the studied variables, in other words, this system is used to partition the correlation coefficients (genetic or phenotypic) between a group of independent variables and a dependent variable into direct and indirect effects, through which the independent variables with the greatest effects on the independent variable are identified. For the purpose of determining the yield components traits that most influence GYP to benefit from them in selection breeding programs, the simple correlation coefficients (genetic and phenotypic) of GYP with other traits were partitioned into direct and indirect effects through the use of this analysis technique. It is noted from the results of the genetic path analysis (Table 6), that the direct effect on GYP was positive very high for NEP, NGR, and NGE (1.857, 2.378, and 2.787, respectively), high for ED and NRE (0.303 and 0.411, respectively), and slight for 500GW (0.178), while it was negative, very high for EL trait. It is noted that the indirect effects for NEP were positive, high through EL, ED, and NRE, slight through NGE and 500GW, and for NGR trait positive very high through EL and NGE, high

Table (6): Genetic path analysis for traits affecting maize grain yield

Traits	NEP	EL	ED	NRE	NGR	NGE	500GW	Correlation with GYP
NEP	**1.857**	-1.609	0.095	0.221	-0.104	0.261	0.018	0.738**
EL	0.562	**-5.319**	-0.037	0.274	2.152	2.726	-0.035	0.321*

ED	0.583	0.651	**0.303**	-0.246	-0.112	-0.687	0.125	0.618**
NRE	0.998	-3.549	-0.182	**0.411**	0.692	1.688	-0.185	-0.128
NGR	-0.081	-4.814	-0.014	0.119	**2.378**	2.682	0.002	0.271
NGE	0.174	-5.204	-0.075	0.249	2.288	**2.787**	-0.037	0.182
500GW	0.183	1.053	0.213	-0.427	0.022	-0.583	**0.178**	0.638**

(**) and (*) significant at 1% and 5% probability levels. - Values in bold indicate direct effects

through NRE, and not important through 500GW, and for NGE trait is very high through EL, NRE, and NGR, and moderate through NEP. These results indicate that the correlation coefficient of these traits with GYP does not express the true relationship among them, because there are indirect effects through other traits that are part of this correlation coefficient, so the direct effect of the trait in addition to its indirect effects through other traits is the true expression of its relationship with GYP. According to these results, NGE, followed by NGR, then NEP are considered to have the strongest effects on GYP genetically. Phenotypically, it is observed from the results shown in Table (7) that the direct effects of NEP, NGE and 500GW traits on GYP were high (0.601, 0.509, and 0.537, respectively), while for the other traits (negative or positive) were small or not important. The indirect effects of NGE trait were high through EL and NGR traits (0.368 and 0.468, respectively) and moderate through NRE. Likewise, the indirect effects of 500GW on GYP were moderately negative through NGR and NGE, small through EL and NRE, and positive not important through NEP and ED. As for the NEP trait, the indirect effects

Table (7): Phenotypic path analysis for traits affecting maize grain yield

Traits	NEP	EL	ED	NRE	NGR	NGE	500GW	Correlation with GYP
NEP	**0.601**	0.008	0.001	-0.022	-0.001	0.040	0.016	0.643**
EL	0.076	**0.061**	0.002	-0.047	-0.033	0.368	-0.132	0.294
ED	0.018	0.002	**0.039**	-0.009	-0.005	0.053	0.088	0.187
NRE	0.096	0.021	0.003	**-0.137**	-0.0149	0.230	-0.169	0.029
NGR	0.012	0.045	0.004	-0.046	**-0.044**	0.468	-0.205	0.234
NGE	0.047	0.044	0.004	-0.062	-0.041	**0.509**	-0.223	0.278
500GW	0.018	-0.015	0.006	0.043	0.017	-0.212	**0.537**	0.395*

(**) and (*) significant at 1% and 5% probability levels. - Values in bold indicate direct effects

were positive and not important through all other traits. These results indicate however, that the greatest effect on GYP was for NGE, followed by 500GW, then NEP. These three traits, according to their important sequence, are considered selection indices for high GYP trait phenotypically. From previous studies in this field, Hadi et al. (2021) found that ear length and number of grains per row have the largest effect on grain yield, and Pranay et al. (2022) arrived that ears yield per plant had the highest direct positive effect on grain yield, followed by number of grains per row and ear diameter, while Al-Asadi and Al-Abody (2023) indicated that 300 grains weight had the strongest direct positive genetic and phenotypic effect on grain yield followed by number of grains per ear.

CONCLUSIONS

It was concluded that 12 kg/ha of nano-fertilizer level and Torro genotype had significant highest means for most studied traits, and that the grain yield per plant correlated positively and significantly (genetically and phenotypically) with number of ears per plant and 500 grains weight, and genetically with ear length and ear diameter. The path coefficient analysis revealed that number of grains per ear (genetically and phenotypically), considered to have the strongest effects on grain yield per plant, and this is useful in the reliability of this trait as a selection criteria for higher yield performance in breeding programs.

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