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EFFECT OF MINERAL AND ORGANIC FERTILIZER COMBINATIONS ON THE YIELD-RELATED TRAITS OF MAIZE THROUGH PATH COEFFICIENT ANALYSIS

F.K.J. BLEBISH and M.A.I. AL-ANBARI*

Department of Field Crops, College of Agriculture, University of Kerbala, Kerbala, Iraq
Corresponding author's emails: sabraoassociateeditors@gmail.com, falakad1974@gmail.com
Email address of co-author: dr.mohammed.ibraihim@uokerbala.edu.iq

SUMMARY

The latest study aimed to analyze the path coefficient for synthetic cultivars of maize (*Zea mays* L.) to determine the selection criterion for improved grain yield. In achieving this goal, a field experiment commenced in 2022 at the Ibn-Al-Bitar Preparatory Vocational School, Kerbala Governorate, Iraq. The study set up in a randomized complete block design (RCBD) used a split-plot arrangement and three replications. The main plots comprised six combinations of mineral and organic fertilizers, while sub-plots were the six synthetic corn cultivars, Fajr1, Maha, 5018, Sumer, Sarah, and Baghdad-3. The genotypic path coefficient analysis showed that grains per ear in the first and second fertilizer levels could benefit as a selection index, achieving the highest total effect (genotypic correlation) of 0.9459 and 0.9957, respectively, obtained through an indirect influence of the biological yield. The third level of fertilizer combination gave a harvest index that can also be a selection index because it showed the highest total result of 0.9825, obtained from a direct consequence of the grain yield (0.8745). In the fourth fertilizer combination, the biological yield can become a selection index because it gained the highest total outcome of 0.9898 from the direct effect of the grain yield (6.7848). In the fifth and sixth fertilizer combinations, the total uptake of nitrogen may be the basis for the selection index reaching the maximum total effects of 0.9806 and 0.9834, respectively, acquired through indirect effects of the biological yield in the fifth and total uptake of phosphorus in the sixth fertilizer combination.

Keywords: Maize (*Zea mays* L.), mineral fertilizers, organic manures, path coefficient, selection criteria, nitrogen uptake, growth and yield traits

Key findings: The grains per ear at the first and second fertilizer levels, the harvest index at the third level, the biological yield at the fourth level, and the total nitrogen uptake at the fifth and sixth fertilizer levels can be effective selection indicators for improving the maize grain yield.

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INTRODUCTION

Maize (*Zea mays* L.) belongs to the family Poaceae and is one of the family's most valuable cereal crops, as it follows wheat and rice in terms of economic importance. Maize is a triple-purpose crop, as its cultivation is for obtaining grains, fodder, and oil. It is also one of the strategic crops with enhanced magnitude in the food industries because it provides the basics of human food security on the one side and feed for livestock on the other (FICCI, 2022).

Maize is a vital food source and a provider of raw materials for various industries. Its grains' uses include cornmeal, corn flour, oil, syrup, and other food ingredients. Additionally, corn is a component in producing biofuels and animal feeds and manufacturing various products like ethanol, starch, and plastic (Majeed *et al*., 2022). Cultivating yellow corn requires suitable soil conditions, adequate sunlight, and sufficient irrigation water sources. It grows in various regions worldwide, with major producers including the United States, China, Brazil, and Mexico. Overall, the yellow corn is significant in the global agriculture and food security. Its nutritional value, versatility, and wide range of uses make it a valuable crop in many regions globally (Erenstein *et al.,* 2022).

Genotypic and phenotypic variations in various maize traits are important factors in determining the best breeding method to improve grain yield. Therefore, it is necessary to have a good knowledge of these traits that have a significant positive correlation with grain yield for use in their direct selection or as an indicator to identify the productivity of the various genotypes. Genetic and phenotypic correlation coefficients enunciated the relationship among the assorted studied traits, which provide possible improvement in grain yield and its related traits in maize (Dias *et al.,* 2018).

By studying the genotypic correlations, one will understand the degree of association among different characteristics at the genetic level. Path coefficient analysis allows the identification of various causes and measuring their relative effects and importance, as the probe provides the exact picture of the correlation among the different characteristics (Kole *et al*., 2010). It also helps the breeders determine the diverse parameters' relative value and evaluate their direct and indirect effects on the grain yield and its components. By understanding the path coefficient analysis, breeders can identify the chief characteristics critically affecting the target trait and arrange them on a priority basis in the selection process (Alnuaimi *et al.,* 2019). Based on the above discussion, the presented study sought to determine the viable traits most related to grain yield to improve the maize grain yield.

MATERIALS AND METHODS

The maize experiment with a randomized complete block design (RCBD) and a split-plot arrangement had two factors and three replications. The main plots comprised six combinations of mineral and organic fertilizers: a) 160N + $100P_2O_5$ + $40K_2O$ kg ha^{-1}, b) 160N + $00P_2O_5$ + $40K_2O$ kg ha^{-1} + 4 t ha^{-1} of organic fertilizer, c) 160N + $100P_20_5$ + $40K_2O$ kg ha^{-1} + 8 t ha^{-1} of organic fertilizer, d) 320N + $200P_2O_5$ + $80K_2O$ kg ha^{-1}, e) 320N + $200P_2O_5$ + $80K_2O$ kg ha^{-1} + 4 t ha^{-1} of organic fertilizer, and f) 320N + $200P_2O_5$ + $80K_2O$ kg ha^{-1} + 8 t ha^{-1} organic fertilizer. The study grew six synthetic corn cultivars in the subplots, i.e., Fajr1, Maha, 5018, Sumer, Sarah, and Baghdad-3. The cultivation transpired in experimental units with an area of 3 m^2 × 3 m^2 for each experimental unit. The distance was 75 cm apart and 25 cm between hills, with a distance of 1.5 m between main plots. The organic fertilizer used contained cow and poultry waste in a ratio of 3:1.

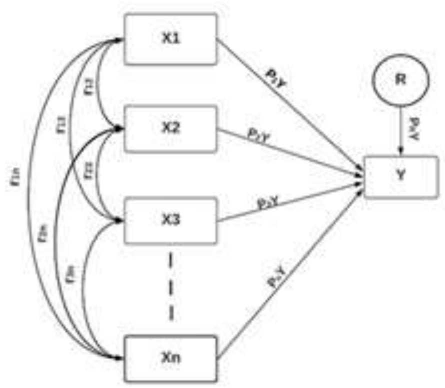
Statistical analysis

Genotypic variances and covariances calculations determined the values of genotypic correlation (Robinson *et al*., 1951; Falconer, 1970; Singh and Chaudhary, 1985).

$$rGxy = \frac{cov.G\ xy}{\sqrt{(\sigma^2 Gx)(\sigma^2 Gy)}}$$

Where:
x and y = studied traits,
σ^2G = Genotypic variation,
cov.G = Genotypic covariance, and
rGxy = Genotypic correlation.

After confirming the presence of genotypic correlation between the studied characteristics, path coefficient analyses continued, with the foundations laid by Wright (1921) and described by Turner and Stevens (1959). The following diagram shows the causal relationship between the variables:



Calculating the matrix first led to calculating the values of the path coefficient:

$$\underset{C}{\begin{bmatrix} px1y \\ px2y \\ . \\ . \\ . \\ px15y \end{bmatrix}} = \underset{B^{-1}}{\begin{bmatrix} 1 \quad rx1x2 \ldots\ldots\ldots rx1x15 \\ rx2x1 \quad 1 \ldots\ldots\ldots rx2x15 \\ . \\ . \\ . \\ rx15x1rx15x2 \ldots\ldots\ldots\ldots 1 \end{bmatrix}} \times \underset{A}{\begin{bmatrix} rx1y \\ rx2y \\ . \\ . \\ . \\ rx15y \end{bmatrix}}$$

By solving this matrix using a computer, the path coefficient estimations followed the method developed by Li (1956) and explained by Dewey and Lu (1959). The study also adopted the scale presented by Lenka and Misra (1973) to determine the importance of direct and indirect effects, which are 0 – 0.09 is negligible, 0.10 – 0.19 is low, 0.20 – 0.29 is moderate, 0.30 – 0.99 is high, and one and above is highest.

RESULTS AND DISCUSSION

The genotypic correlations among various characteristics of maize underwent direct and indirect effects' division on the grain yield to identify the traits with the superior influence for selection index and to obtain the highest possible productivity from the maize cultivars with the best fertilizer levels. Separate genotypic path coefficient analysis at each fertilizer level showed the number of days until silking had a direct positive effect at the third, fourth, and fifth fertilizer combinations, while negative at the first, second, and sixth fertilizer levels. Notably, the sum of direct and indirect effects negatively affected the grain yield for all fertilizer levels. It means that early flowering is inversely proportional to the maize grain yield. These results were consistent with the findings of Huda *et al*. (2016) for the outcomes on genotypic variability, character association, and path analysis of yield and its component traits in maize (*Zea mays* L.).

The results also revealed that the number of days from planting to physiological maturity had a direct and high positive effect at the fourth fertilizer combination (0.9709), low positive at the first (0.0194) and fifth (0.0339) fertilizer levels, and negative at the rest of the fertilizer levels (Unpubished data). It is also noticeable that the sum of the direct and indirect effects negatively influenced the maize grain yield for all fertilizer levels except the first and fourth levels.

The trait plant height has a high direct positive effect on grain yield at the fourth fertilizer level (5.5303) and negative at the rest of the fertilizer combinations (Unpubished data). Outcomes also indicated that the fourth fertilizer level contains a double combination of phosphorus, nitrogen, and potassium, indicating more nutrients affect this trait, directly affecting the maize grain yield. The sum of direct and indirect effects markedly affected the grain yield positively for all the combinations of organic and mineral fertilizers. These results also agreed with past findings on the correlation and path-coefficient analysis for agronomic traits and grain yield in maize genotypes (Yahaya *et al*., 2021).

In maize, the leaf area had a direct negative effect at the first, fourth, fifth, and sixth fertilizer combinations and a direct positive influence at the second (0.0467) and third (0.1992) fertilizer levels (Unpubished data). It was also evident that the sum of the direct and indirect effects had a straight and positive impression on the maize grain yield and all fertilizer levels. Adesoji *et al*. (2015) also recorded similar values in studying the character association and path coefficient analysis of maize grown under incorporated legumes and nitrogen.

The total nitrogen uptake had a direct high effect at the first and second fertilizer levels, medium at the sixth, and negative at the rest of the levels. However, the highest total effects were at the fifth and sixth fertilizer levels (0.9806 and 0.9834, respectively). The highest indirect effect was through the biological yield for the fifth fertilizer level and the phosphorus uptake for the sixth level (0.4014 high). These two levels contained an addition to the recommended amount of nitrogen, phosphorus, and potassium in the organic fertilizer (Table 1). It means that this fertilizer combination has a definite positive effect on the maize grain yield, and these results were consistent with past findings by studying the growth and nitrogen use efficiency in irrigated maize genotypes (Valero *et al*., 2005).

The results further showed that the total uptake of phosphorus had a direct negative impact at the first, second, and fourth fertilizer combinations and was positive at the third level negligibly (0.369), and fifth and sixth levels were high (0.5292 and 0.3693, respectively) (Table 2). All the combinations with organic and mineral fertilizers emerged with a distinct positive effect, and the highest was at the second fertilizer level (0.9091). The study concludes that increased fertilizer level did not considerably affect the correlation between the said trait and the outcome; however, the relationship remained strong at all the fertilizer levels.

The potassium uptake had an explicit negative and direct effect at all the fertilizer levels except the second fertilizer combination, which was negligible (0.0331). It explains that the direct impact of the total potassium uptake was negative; however, the total effects were also affirmative due to indirect positivity through other characteristics contributing to the exact positive effect (Unpubished data).

Table 1. Path coefficient analysis and the effect of total nitrogen uptake on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	P 5 Y	0.7424	-0.0832	0.9652	-2.3200	-0.0858	0.2693
B. Indirect effect							
Days to 75% silking	r1 5 p1y	0.1012	0.0052	-0.1522	-0.2305	0.0044	0.0346
Days to physiol. maturity	r2 5p2y	-0.0016	0.0003	0.0695	0.4719	-0.0086	0.0660
Plant height	r3 5p3y	-0.2604	0.0340	-0.7830	5.4062	-0.0270	-0.1583
Leaf area	r4 5p4y	-0.4704	0.0336	0.1102	-0.6576	-0.0647	-0.2361
P uptake	r5 6p6y	-0.8495	-0.0063	0.0913	-2.8120	0.0863	0.4014
K uptake	r5 7p7y	-0.8495 -	0.0177	-0.0497	-2.1544	-0.0582	-0.0460
Seed oil (%)	r5 8p8y	0.3187	0.0138	0.0029	-0.0271	-0.0009	-0.0480
Ears per plant	r5 9p9y	0.0210	-0.0061	0.0363	0.3269	0.0314	-0.0062
Rows per ear	r5 10p10y	-0.4819	0.0609	0.0335	-0.2688	0.0589	0.2156
Grains per row	r5 11p11y	0.3795	-0.0670	-0.0004	-2.0159	0.0607	0.0148
Grains per ear	r5 12p12y	-0.1802	0.0009	-0.2848	-5.9791	0.1293	0.1217
500-grain weight	r5 13p13y	-0.1162	-0.0203	0.1520	2.4369	-0.1630	0.1747
Biological yield	r5 14p14y	2.6379	0.6405	0.0544	6.3054	0.7968	0.1221
Harvest index	r5 15p15y	-0.1301	0.4086	0.4189	2.4485	0.2210	0.0757
The total effect	r5y	0.8606	0.9647	0.6640	0.9304	0.9806	0.9834

Table 2. Path coefficient analysis and the effect of total phosphorus uptake on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	p 6y	-0.9358	-0.0071	0.0936	-3.4353	0.5292	0.3693
B. Indirect effect							
Days to 75% silking	r 1 6 p1y	0.2147	0.0057	-0.1313	-0.1675	-0.0431	0.0438
Days to physiol. maturity	r 2 6p2y	0.0034	0.0047	0.1233	0.1394	-0.0264	0.0770
Plant height	r 3 6p3y	-0.2293	-0.0280	-0.9208	3.8996	-0.2328	-0.1570
Leaf area	r 4 6p4y	-0.5466	0.0455	0.1710	-0.7059	-0.0007	-0.2277
N uptake	r 5 6 p5y	0.6740	-0.0740	0.9413	-1.8991	-0.0140	0.2927
K uptake	r 6 7 p7y	-0.7486	0.0318	-0.0645	-1.7678	-0.0202	-0.0558
Seed oil (%)	r 6 8p8y	0.2524	-0.0097	-0.0014	0.0276	-0.0002	-0.0474
Ears per plant	r6 9 p9y	0.0159	-0.0040	0.0726	0.3883	-0.0164	0.0045
Rows per ear	r 6 10p10y	-0.3551	0.0803	0.0153	-0.4940	-0.0033	0.1340
Grains per row	r 6 11p11y	0.3221	-0.0875	-0.0013	-1.2546	0.0111	-0.0154
Grains per ear	r6 12 p12y	-0.1416	0.0010	-0.4553	-4.4331	0.0549	0.1251
500-grain weight	r 6 13p13y	-0.1286	-0.0281	0.1705	2.5051	-0.1842	0.1714
Biological yield	r 6 14p14y	2.4485	0.4740	0.2310	5.2302	0.2328	0.1163
Harvest index	r6 15p15y	0.0247	0.5045	0.4855	2.8231	0.2779	0.0639
The total effect	r6y	0.8701	0.9091	0.7295	0.8559	0.5645	0.8856

The genotypic path coefficient analysis revealed that the effect of the oil percentage in the maize seeds is directly negative at the fourth, fifth, and sixth fertilizer levels and positive at the rest of the fertilizer levels with the grain yield (Unpubished data). This trait had a progressive indirect effect at the first (2.4729 very high) and second (0.4103 high) fertilizer levels through the biological yield. At the third fertilizer level, it was through the total nitrogen uptake (0.3984 high), and at the fourth level, it was very high through the number of days to physiological maturity and plant height in maize (Zarei *et al.,* 2012).

The genotypic path coefficient analysis separately at each fertilizer level revealed that the trait number of ears per plant had a negative direct outcome at the second and sixth fertilizer levels (-0.0126 and -0.0304, respectively), while this trait had a positive direct effect at all other fertilizer levels (Unpubished data). The maximum positive and direct influences occurred at the fourth fertilizer level (0.5731), while the total effects were constructive at all the fertilizer combinations (Yahaya *et al.,* 2021).

The separate analysis of the genotypic path coefficient at each fertilizer level indicated a direct negative effect of the number of rows per ear on the grain yield at the first (-0.6916) and fourth (-0.5284) fertilizer levels. It was positive and negligible at the second and fifth fertilizer levels and low at the third level (Unpubished data). It was moderate at the sixth level, and the biological yield characteristic appeared with utmost indirect effects at all fertilizer levels except the sixth fertilizer level, with the highest at the fourth level (4.7102). Notably, the overall effect was positive at all fertilizer levels, reaching the maximum at the sixth fertilizer level (0.9215) with a double dose of nitrogen, phosphorus, potassium, and organic fertilizer (Jilo and Tulu, 2019).

The genotypic path coefficient analysis revealed that the number of grains per row in a cob affects the grain yield directly and negatively at all the fertilizer levels except the first two levels, which were high (0.8240), and the fifth fertilizer level was negligible (0.0802), which had a progressive effect (Unpubished data). The biological yield was notable for the highest indirect impacts on the grain yield at all the fertilizer levels except the sixth level, and the maximum was at the fourth level (6.1767). Significantly, the total effect was positive at all the fertilizer combinations, and these results aligned with past findings in the maize genotypes (Bello *et al*., 2010).

The genotypic path coefficient analysis further signified a direct positive effect of the number of grains per ear on the maize grain yield with the second fertilizer combinations of mineral and organic fertilizer (0.0012), which was negligible. The fifth fertilizer level was low (0.1593), and the sixth fertilizer level was medium (0.2886) (Table 3). The utmost indirect influence was visible through the biological yield at the first and second fertilizer levels (2.5046 and 0.7193, respectively), and these findings were consistent with the results obtained by Zarei *et al*. (2012) in different maize populations under diverse fertilizer levels.

The effect of 500-grain weight on the maize grain yield has a direct positive impact at the fourth fertilizer level, which was very high (2.7724), followed by the third (0.1846), and the sixth fertilizer level (0.1836); however, it revealed the negative effects on other fertilizer levels (Table 4). It was also prominent that the said trait indirectly and positively influenced grain yield through most characteristics. The distinct effect was positive at all levels, reaching its highest at the sixth fertilizer level (0.9230). It means adding the combination of mineral and organic fertilizers contributed to creating an environment for gene expression that strengthened the genotypic associations of this trait with grain yield. Teodoro *et al*. (2014) also reported the same findings through path analysis and correlation of two genetic classes of maize (*Z. mays* L.).

The trait biological yield directly affected positively the grain yield at all fertilizer levels, with the highest effects recorded at the fourth fertilizer level (6.7848) (Table 5). It was also noteworthy that the maximum indirect impact of this trait at the fourth fertilizer level succeeded through the plant height, 500-seed weight, and the harvest index in maize. Winnows *et al.* (2010) observed the same genetic variances, heritability, and correlation coefficient through path coefficient analysis in yellow maize crosses.

Table 3. Path coefficient analysis and the effect of the grains number in the ear on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	p 12 y	-0.1940	0.0012	-0.5346	-6.2243	0.1593	0.2886
B. Indirect effect							
Days to 75% silking	r 1 12p1y	0.0125	0.0025	-0.0915	-0.2357	-0.0017	0.0066
Days to physiol. maturity	r 2 12p2y	0.0003	0.0057	0.1551	0.4813	-0.0251	0.0704
Plant height	r 3 12p3y	-0.2578	-0.0424	-0.9990	5.2573	-0.1294	-0.1118
Leaf area	r 4 12p4y	-0.5634	0.0471	0.1548	-0.6365	-0.0334	-0.0403
N uptake	r 5 12p5y	0.6896	-0.0659	0.5141	-2.2286	-0.0696	0.1135
P uptake	r 6 12p6y	-0.6832	-0.0061	0.0797	-2.4467	0.1824	0.1600
K uptake	r 7 12p7y	-0.7238	0.0226	-0.0603	-2.2018	-0.0249	-0.0669
Seed oil (%)	r 8 12p8y	0.2989	0.0205	-0.0014	-0.0044	-0.0007	-0.0373
Ears per plant	r 9 12p9y	0.0290	-0.0183	0.0826	0.3671	0.0237	-0.0334
Rows per ear	r 10 12p10y	-0.5847	0.0617	0.0729	-0.1666	0.0118	0.2073
Grains per row	r 11 12p11y	0.5678	0.0012	-0.0025	-1.9501	0.0750	-0.0861
500-grain weight	r 12 13p13y	-0.2647	-0.0282	0.1402	2.1268	-0.1776	0.1181
Biological yield	r12 14p14y	2.5046	0.7193	0.6058	6.5198	0.7368	0.1344
Harvest index	r 12 15p15y	0.1149	0.3534	0.7835	2.2842	0.1324	0.0330
The total effect	r 12 y	0.9459	0.9957	0.8994	0.9416	0.8589	0.7532

Table 4. Path coefficient analysis and the effect of 500-grain weight trait on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	p 13 y	-0.5060	-0.0311	0.1846	2.7724	-0.2276	0.1836
B. Indirect effect							
Days to 75% silking	r 1 13p1y	-0.1935	0.0021	-0.1115	-0.1186	- 0.0315	0.0451
Days to physiol. maturity	r 2 13p2y	0.0151	0.0121	0.1379	-0.0209	-0.0306	0.0914
Plant height	r 3 13p3y	-0.1009	0.0023	-1.0978	4.1717	-0.2038	-0.1589
Leaf area	r 4 13p4y	-0.6311	0.0482	0.0738	-0.8041	-0.0261	-0.2027
N uptake	r 5 13p5y	0.1705	-0.0542	0.7949	-2.0393	-0.0615	0.2562
P uptake	r 6 13p6y	-0.2377	-0.0064	0.0864	-3.1041	0.4285	0.3448
K uptake	r 7 13p7y	-0.1756	0.0352	-0.0860	-1.8781	-0.0366	-0.0707
Percentage of oil in seeds	r 8 13 p8y	0.0385	-0.0288	0.0042	0.0840	-0.0005	-0.0360
Ears per plant	r 9 13p9y	0.0334	-0.0029	0.0847	0.4267	0.0115	-0.0177
Rows per ear	r 10 13 p10y	-0.0140	0.0812	0.0364	-0.5042	0.0150	0.1514
Grains per row	r 11 13 p11y	0.9179	-0.1065	-0.0019	-1.3865	0.0558	-0.0423
Grains per ear	r 12 13p12y	-0.1015	0.0011	-0.4060	-4.7749	0.1243	0.1857
Biological yield	r 13 14p14y	0.9735	0.2368	0.5264	5.6825	0.5969	0.1348
Harvest index	r 13 15p15y	0.3144	0.4422	0.5704	2.3464	0.2272	0.0583
The total effect	r 13 y	0.5031	0.6315	0.7965	0.8528	0.8411	0.9230

Table 5. Path coefficient analysis and the effect of biological yield trait on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	p 14 y	2.8181	0.7095	1.0119	6.7848	0.7731	0.1490
B. Indirect effect							
Days to 75% silking	r 1 14p1y	0.0996	0.0031	0.0065	-0.1586	0.0030	0.0303
Days to physiol. maturity	r 2 14 p2y	-0.0019	0.0021	0.1231	0.2409	-0.0191	0.0865
Plant height	r 3 14p3y	-0.1433	-0.0378	-1.0505	4.7048	-0.0998	-0.1536
Leaf area	r 4 14 p4y	-0.5644	0.0312	0.0063	-0.8332	-0.0446	-0.1485
N uptake	r 5 14 p5y	0.6949	-0.0751	0.0519	-2.1561	-0.0885	0.2207
P uptake	r 6 14p6y	-0.8130	-0.0047	0.0214	-2.6482	0.1594	0.2884
K uptake	r 7 14 p7y	-0.7992	0.0126	-0.0458	-2.0717	-0.0314	-0.0764
Percentage of oil in seeds	r 8 14 p8y	0.2813	0.0265	0.0012	0.0228	-0.0010	-0.0420
Ears per plant	r 9 14p9y	0.0289	-0.0154	0.0661	0.5407	0.0298	-0.0255
Rows per ear	r 10 14 p10y	-0.5498	0.0491	0.0559	-0.3668	0.0266	0.1929
Grains per row	r 11 14 p11y	0.4520	-0.0588	-0.0039	-1.8048	0.0736	-0.0672
Grains per ear	r 12 14 p12y	-0.1724	0.0012	-0.3201	-5.9811	0.1518	0.2604
500-grain weight	r 13 14 p13y	-0.1748	-0.0104	0.0960	2.3220	-0.1757	0.1662
Harvest index	r 14 15p15y	-0.2996	0.2863	0.4788	2.3942	0.1697	0.0514
The total effect	r 14y	0.8562	0.9196	0.4988	0.9898	0.9270	0.9327

Table 6. Path coefficient analysis and the effect of harvest index trait on grain yield.

Effect types		Coefficient values					
		First fertilizer level	Second fertilizer level	Third fertilizer level	Fourth fertilizer level	Fifth fertilizer level	Sixth fertilizer level
A. Direct Effect	p 15 y	1.0748	0.5040	0.8745	2.8117	0.3503	0.0730
B. Indirect effect							
Days to 75% silking	r 1 15p1y	0.1104	0.0074	-0.0959	-0.1954	-0.0152	0.0090
Days to physiol. maturity	r 2 15p2y	0.0130	-0.0021	0.1364	0.3407	-0.0129	0.0611
Plant height	r 3 15p3y	-0.2643	-0.0334	-0.9211	4.2275	-0.1688	-0.1259
Leaf area	r 4 15p4y	-0.0176	0.0428	0.1289	-0.7170	-0.0217	-0.1551
N uptake	r 5 15p5y	-0.0899	-0.0675	0.4623	-2.0204	-0.0541	0.2793
P uptake	r 6 15p6y	-0.0215	-0.0071	0.0520	-3.4493	0.4198	0.3232
K uptake	r 7 15p7y	0.2348	0.0313	-0.0468	-1.9692	-0.0107	-0.0564
Seed oil (%)	r 8 15p8y	-0.0983	-0.0041	0.0017	0.0140	-0.0009	-0.0453
Ears per plant	r 9 15p9y	-0.0071	-0.0003	0.0721	0.4652	-0.0146	-0.0103
Rows per ear	r 10 15p10y	0.1469	0.0684	0.1253	-0.4086	0.0090	0.1989
Grains per row	r 11 15p11y	0.1424	-0.0709	-0.0021	-1.2136	0.0095	-0.0190
500-grain weight	r 12 15p12y	-0.0207	0.0008	-0.4790	-5.0566	0.0602	0.1305
Biological yield	r13 15p13y	-0.1480	-0.0273	0.1204	2.3136	-0.1476	0.1466
Biological yield	r 14 15p14y	-0.7856	0.4030	0.5540	5.7774	0.3746	0.1049
The total effect	r 15 y	0.2691	0.8451	0.9825	0.9200	0.7768	0.9144
Residual		0.0420	0.0159	0.0000	0.0477	0.0151	0.0141
For all traits under study							

The genotypic path coefficient analysis showed that the trait of harvest index had a direct and positive effect on maize grain yield with all the fertilizer levels (Table 6). However, the said effect was very high in the first and fourth fertilizer levels, high in the second, third, and fifth levels, and negligible at the sixth level, with the maximum overall impact achieved at the third combination of mineral and organic fertilizers (0.9825). Reports on similar results also surfaced through the correlation and path coefficient analysis in advanced wheat genotypes (Ayer *et al.*, 2017).

CONCLUSIONS

The genotypic path coefficient analysis revealed promising results. It indicated the number of grains per ear at the first and second combination of mineral and organic fertilizers, the harvest index at the third fertilizer level, the biological yield at the fourth fertilizer level, and the total uptake of nitrogen at the fifth and sixth fertilizer levels can be better selection indices for improving the maize grain yield.

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