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Correlation and path coefficient analysis, for yield and yield-related traits in maize (*Zea mays* L.)

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Abstract

Maize (*Zea mays* L.) is a globally important cereal crop, notable for its adaptability across diverse environments and its role in food, feed, and industrial products. This study investigates the correlation and path coefficient analysis in maize. The crosses were made during zaid 2021. Present investigation, conducted on hybrids along with parental lines and check varieties during the Zaid season of 2022 at the Agricultural Research farm Pili Kothi, Tilak Dhari Post Graduate College, Jaunpur (U.P.). The result revealed that, grain yield per plant, a key trait in maize breeding, showed significant positive correlations with traits such as the number of grains per cob, days to silking, and seed vigor index. These associations suggest that selecting for higher grain yield may also result in improved performance for other important traits, such as the number of grains per cob and seed vigor, which are critical for early plant establishment and overall productivity. Path coefficient analysis at both phenotypic and genotypic levels identified key traits influencing yield, with seed vigor index, seedling fresh weight, and cob weight showing strong positive effects. Conversely, traits like cob length, seedling length, and plant height exhibited negative impacts on yield, emphasizing the need for balanced trait management.

Keywords: Maize (*Zea mays* L.), grain yield, correlation, path, direct effect and indirect effect

Introduction

Maize (*Zea mays* L., $2n=20$) is one of the most important cereal crops globally, belonging to the tribe Maydeae of the grass family, Poaceae. Originating from Central America, *Zea mays* is the only species within the genus *Zea* with a chromosome number of $2n=20$. It shares close genetic relationships with two American Maydeae species *Tripsacum* (gama grass) and *Teosinte* (*Euchalaena*), the latter being its closest relative. Additionally, it is related to five Asiatic Maydeae species, including *Chinonachne*, *Sclerachne*, *Coix*, *Trilobachene*, and *Polytoca* (Ramadan, *et al.*, 2022) [12]. Maize ranks third in global production, following wheat and rice, owing to its remarkable adaptability across diverse environments. From latitudes 58°N to 40°S , and at elevations ranging from sea level to more than 3000 meters, maize thrives in regions with annual rainfall between 250 to 5000 mm (Wuhaib, *et al.*, 2018) [16]. Its ability to adapt to a wide range of climates, especially in warm temperate and humid subtropical areas, has led to its extensive cultivation worldwide.

Maize is often referred to as the "queen of cereals" due to its high production potential and broad adaptability. In India, it is the fourth most important cereal crop after rice, wheat, and sorghum, with a production of 31.65 million tonnes grown across 9.89 million hectares, yielding an average productivity of 31.99 q/hectare in the 2020-2021 period (Wuhaib, *et al.*, 2018) [16]. Karnataka, a key state in India, leads in maize production, contributing significantly to the country's overall output. Over the years, the area under maize cultivation in India has expanded substantially, with a nearly 16-fold increase in production from 1.73 million tonnes in 1950-51 to 27.8 million tonnes by 2018-2019 (Ramadan, *et al.*, 2022) [12].

Maize's versatility extends beyond food and feed, as every part of the plant—grain, leaves, stalk, tassel, and cob holds economic value. The crop is used in a wide range of food and non-food products, such as starch, oil, protein, alcoholic beverages, sweeteners, and pharmaceutical products (El-Moula, *et al.*, 2004) [7]. With applications in over 1000 industrial sectors, maize serves as a vital raw material for producing biodegradable items like packaging, paper, textiles,

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and cosmetic products. Additionally, it plays a crucial role in animal feed, particularly for poultry and cattle, which accounts for around 63% of maize consumption in India (Aslam *et al.*, 2017)^[4].

The global importance of maize is underscored by its cultivation in more than 166 countries, and its role in food security, nutritional enhancement, and income generation for farmers. Maize is particularly well-suited to the Indian agricultural landscape, where it is grown in both traditional maize-growing areas (such as Bihar, Madhya Pradesh, and Uttar Pradesh) and non-traditional regions (including Karnataka and Andhra Pradesh). In recent years, the practice of growing maize during the rabi (winter) season has gained momentum, especially in Bihar, due to its advantages, including lower incidence of pests and diseases and better resource utilization (Aslam *et al.*, 2017)^[4].

Maize is a major contributor to global agricultural productivity, with significant implications for both food and industrial sectors. As a crop with diverse uses and a crucial role in global food systems, its continued development through breeding and hybridization is essential (El-Moula, *et al.*, 2004)^[7].

Materials and Methods

Experimental Site

The present study was conducted at the Agricultural Research Farm, Pili Kothi, Tilak Dhari Post Graduate College, Jaunpur (U.P.), India, during the **Zaid** season of 2022. The crosses were made during the Zaid season of 2021, and the evaluation of hybrids, parental lines, and check varieties was carried out in the Zaid season of 2022. Geographically, the experimental site is located at a latitude of 25.720°N and a longitude of 82.700°E, with an altitude of 82 meters above sea level. The area falls within the sub-tropical climatic zone, with sandy loam soil. The region experiences an annual rainfall of approximately 1270 mm, and the climate is semi-arid, characterized by hot summers and cold winters. Presents the detailed weather conditions recorded during the evaluation period of Zaid 2022.

Experimental Materials

Fifteen maize inbred lines were used in the present investigation. These lines were obtained from the Department of Genetics and Plant Breeding, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology (GBPUAT), Pantnagar (Uttarakhand), India.

Experimental Design

A line × tester mating design was used to generate 45 F₁ hybrids by crossing 15 maize inbred lines (females) with three testers (males), namely, Pant 2020 K/1004 (Pragati), Pant 2020 K/1005, and Pant 2020 K/1008. The 45 F₁ hybrids, along with their parental lines and check varieties (Pant 2020 K/1007 and Pant 2020 K/1009 (Surya)), were evaluated in a randomized complete block design (RCBD) with three replications during the Zaid season of 2022. Seeds were sown on 2nd March 2022 in separate plots of 3 meters length, with row spacing of 70 cm and plant-to-plant spacing of 25 cm. All recommended agronomic practices were followed, and fertilizers were applied at the rate of 120 kg N, 60 kg P, and 60 kg K per hectare.

Statistical analyses

The experimental data collected on all the characters in respect of two experiments of the present study were compiled by taking the mean values over five randomly selected plants in each plot in each replication. It was then subjected to various statistical

analyses. Estimation of correlation coefficients (Searle, 1961)^[14]. Path-coefficient analysis (Dewey and Lu, 1959)^[6].

Estimation of correlations

The simple correlation coefficient between different characters was estimated according to Searle (1961)^[14] as follows:

Results

Analysis of the correlation coefficients

The analysis of the correlation coefficients among the 19 agronomic traits in maize revealed both positive and negative associations at both phenotypic and genotypic levels across the 45 F₁ crosses and their 18 parents. Overall, the genotypic correlation coefficients were higher than the corresponding phenotypic values, indicating stronger genetic relationships for most traits (Table 1).

Grain yield per plant exhibited significant positive correlations with the number of grains per cob (0.4112), days to silking (0.3927), and seed vigor index (0.3784). It was also positively correlated with the number of leaves at 60 DAS (0.3201), cob weight (0.2363), and 100 kernel weight (0.2571). Days to 50% tasseling showed a strong positive correlation with days to silking (0.5275), number of leaves at 60 DAS (0.3769), shelling percentage (0.3767), and seedling length (0.3273), with significant associations with the number of cobs per plant (0.3018).

Days to silking demonstrated highly significant positive correlations with the number of leaves at 60 DAS (0.5662), days to tasseling (0.5275), shelling percentage (0.4844), seed vigor index (0.4810), cob diameter (0.4584), cob weight (0.4073), and other traits such as seedling length (0.2907), days to maturity (0.2893), 100 kernel weight (0.2756), and leaf area at maturity (0.2587). Plant height at 60 DAS had a positive significant correlation with cob length (0.3183), cob weight (0.2954), and cob diameter (0.2716), while a negative correlation with the number of cobs per plant (-0.2636). The number of leaves at 60 DAS showed highly significant correlations with days to silking (0.5662), shelling percentage (0.5642), cob diameter (0.4568), and days to 50% tasseling (0.3779), while also being positively correlated with the number of cobs per plant (0.2512) and 100 kernel weight (0.2424).

Leaf area at maturity exhibited highly significant positive correlations with seed vigor index (0.5700), days to maturity (0.4322), 100 kernel weight (0.3691), and the number of grains per cob (0.3369), while also showing significant associations with germination percentage (0.3095), cob weight (0.3067), and days to silking (0.2587). Days to maturity was positively correlated with cob weight (0.4659), leaf area at maturity (0.4332), cob diameter (0.3239), and number of grains per cob (0.3147), seed vigor index (0.2869), and 100 kernel weight (0.2555). The number of cobs per plant had a significant positive association with seedling fresh weight (0.3689), shelling percentage (0.3300), and a positive but weaker correlation with 100 kernel weight (0.3018), days to 50% tasseling (0.3018), and number of leaves at 60 DAS (0.2512). Cob length showed highly significant positive correlations with cob diameter (0.6061), seed vigor index (0.5067), and cob weight (0.4573), while also having a positive significant association with plant height at 60 DAS.

Cob diameter had highly significant positive correlations with cob length (0.6061), shelling percentage (0.5072), days to silking (0.4584), number of leaves at 60 DAS (0.4568), and cob weight (0.3488), along with significant associations with days to maturity (0.3239), plant height at 60 DAS (0.2716), and seedling

dry weight (0.2626). Cob weight was positively and highly significantly correlated with days to maturity (0.4659), cob length (0.4573), days to silking (0.4073), cob diameter (0.3488), seed vigor index (0.3429), and several other traits such as leaf area at maturity (0.3067), plant height at 60 DAS (0.2954), 100 kernel weight (0.2936), and grain yield per plant (0.2363). The number of grains per cob had strong positive correlations with seed vigor index (0.4269), grain yield per plant (0.4112), and 100 kernel weight (0.3827), while also being positively correlated with leaf area at maturity (0.3369) and days to maturity (0.3147). 100 kernel weight demonstrated significant positive correlations with the number of grains per cob (0.3827), leaf area at maturity (0.3691), number of cobs per plant (0.3219), cob weight (0.2936), days to silking (0.2756), and number of leaves at 60 DAS (0.2624), seed vigor index (0.2596), and grain yield per plant (0.2571).

Shelling percentage showed highly significant positive correlations with the number of leaves at 60 DAS (0.5642), cob diameter (0.5072), days to maturity (0.4844), days to 50% tasseling (0.3767), and number of cobs per plant (0.3300). Seedling length had a highly significant positive correlation with seed vigor index (0.3847), while also showing positive but weaker associations with seedling dry weight (0.2969) and days to maturity (0.2907). Seedling fresh weight demonstrated a significant positive correlation with the number of cobs per plant (0.3689) and seed vigor index (0.2872), though a negative correlation was observed with seedling dry weight (-0.2705). Seedling dry weight had a positive and significant correlation with seedling length (0.2669) and cob diameter (0.2626), but showed a significant negative correlation with seedling fresh weight (-0.2705).

Finally, the seed vigor index exhibited highly significant positive correlations with leaf area at maturity (0.5700), cob length (0.5067), days to silking (0.4810), number of grains per cob (0.4269), days to 50% silking (0.3943), grain yield per plant (0.3784), cob weight (0.3429), and other traits such as cob diameter (0.3061), seedling fresh weight (0.2872), days to maturity (0.2869), and 100 kernel weight (0.2596). Germination percentage showed a significant positive correlation with leaf area at maturity (0.3095). These correlations provide a comprehensive understanding of the interrelationships among traits, offering valuable insights into the genetic and phenotypic associations within the maize breeding material.

Path coefficient analysis

The path coefficient analysis at both the phenotypic and genotypic levels assessed the direct and indirect effects of eighteen traits on grain yield per plant in F1 hybrids (Table 3). Phenotypic level for direct effects, the highest positive direct effects on grain yield were observed for the seed vigor index (0.3546), seedling fresh weight (0.2583), and cob weight (0.2553). Other significant positive effects included the number of grains per cob (0.2039), days to silking (0.1724), and number of leaves at 60 DAS (0.1548). In contrast, negative direct effects were noted for traits such as cob length (-0.3342), seedling length (-0.2234), number of cobs per plant (-0.1376), and plant height at 60 DAS (-0.1354).

Indirect effects revealed the high positive indirect effects on grain yield were exerted by the seed vigor index via leaf area at maturity (0.2022) and cob length (0.1797). Seedling fresh weight had significant indirect effects through cob length and seed vigor index. Additionally, cob weight exhibited notable positive indirect effects via cob length and days to maturity. Conversely, negative indirect effects were observed for cob length, seedling length, and the number of cobs per plant, mainly

affecting grain yield via cob diameter and seed vigor index. Residual factors at the phenotypic level was 0.1217, indicating a relatively low unexplained variance. Genotypic level for direct effects recorded the highest positive direct effects on grain yield were exerted by the number of leaves at 60 DAS (0.5398), followed by the number of grains per cob (0.5075) and seedling fresh weight (0.4320). Cob weight also had a strong direct effect (0.3983). In contrast, the highest negative direct effects were seen for cob diameter (-0.2833), cob length (-0.2544), and plant height at 60 DAS (-0.1815).

Indirect effects at the genotypic level, the number of leaves at 60 DAS had the highest positive indirect effects on grain yield via days to silking (0.4052) and cob diameter (0.4271). The number of grains per cob had significant indirect effects through days to maturity and seed vigor index. Seedling fresh weight exerted substantial indirect effects via cob length and seed vigor index. Cob weight had important indirect effects through germination percentage and plant height. Negative indirect effects for cob diameter exerted negative indirect effects on grain yield through traits such as plant height, number of leaves at 60 DAS, and cob length. Similarly, cob length and plant height also had negative indirect effects on grain yield via other traits like cob diameter and leaf area at maturity.

Residual factors at the genotypic level was low (0.0300), indicating a well-explained model with minimal unexplained variance. Conclusively, both phenotypic and genotypic path coefficient analyses highlighted key traits influencing grain yield. Positive direct effects were largely attributed to seed vigor index, seedling fresh weight, and cob weight, while negative effects were notably due to cob length, seedling length, and plant height. Indirect effects, both positive and negative, through various traits such as cob diameter, days to maturity, and seed vigor index, further emphasized the complexity of trait interactions in influencing grain yield.

Discussion

Correlation coefficients

The analysis of correlation coefficients revealed important insights into the relationships among the various agronomic traits. The genotypic correlation coefficients were generally higher than the corresponding phenotypic values, indicating stronger genetic control over the traits in question. This is a positive sign for maize breeding, as it suggests that selecting for one trait will likely result in improvements in associated traits (Raut., *et al.*, 2017) ^[13].

Grain yield per plant, a key trait in maize breeding, showed significant positive correlations with traits such as the number of grains per cob, days to silking, and seed vigor index. These associations suggest that selecting for higher grain yield may also result in improved performance for other important traits, such as the number of grains per cob and seed vigor, which are critical for early plant establishment and overall productivity (Rajwade *et al.*, 2018) ^[11]. Additionally, grain yield was positively correlated with cob weight, 100 kernel weight, and the number of leaves at 60 days after sowing, further emphasizing the importance of selecting for multiple traits in tandem to improve overall yield (Rajwade *et al.*, 2018) ^[11].

Days to 50% tasseling and days to silking showed strong positive correlations with several traits, including the number of leaves at 60 DAS, shelling percentage, and seedling length. This suggests that the timing of flowering stages in maize is closely linked to other important agronomic traits, and modifying the flowering time could have a cascading effect on the overall performance of the crop (Alam *et al.*, 2008) ^[3]. For example,

earlier flowering may lead to improved seedling vigor and enhanced grain fill, ultimately contributing to higher yield potential.

Cob characteristics, such as cob length, cob diameter, and cob weight, exhibited highly significant positive correlations with several other traits, including plant height, seed vigor index, and days to silking. These associations highlight the importance of cob characteristics in determining the overall productivity of maize and suggest that breeding for larger cobs could be beneficial for improving yield (Alam *et al.*, 2008)^[3]. Moreover, cob diameter and weight showed strong correlations with days to maturity and seedling vigor index, indicating that these traits are also linked to the plant's ability to thrive under varying environmental conditions (Fayyad, *et al.*, 2021)^[8].

The number of cobs per plant was positively correlated with traits such as seedling fresh weight and shelling percentage, suggesting that increasing the number of cobs per plant could also result in better overall plant health and higher grain yield (Fayyad, *et al.*, 2021)^[8]. Cob weight and the number of grains per cob were strongly positively correlated with each other and with seed vigor index, reinforcing the importance of these traits in breeding for high-yielding maize varieties (Aslam *et al.*, 2017)^[4].

The seed vigor index itself was highly positively correlated with traits such as leaf area at maturity, cob length, and days to silking, highlighting its potential as an important selection criterion for improving maize performance. Seed vigor is a critical determinant of early growth and establishment, and improving seed vigor could lead to better plant establishment, healthier plants, and ultimately higher yields (Aslam *et al.*, 2017)^[4].

In conclusion, the correlation analysis offers a comprehensive understanding of the interrelationships among various agronomic traits in maize, providing valuable insights for breeders. The positive associations among traits like grain yield, seed vigor index, cob characteristics, and seedling weight suggest that focusing on these traits could lead to substantial improvements in maize productivity ((Abdolhamid *et al.*, 2004)^[2]. Additionally, the moderate to high heritability and genetic advance observed for several traits indicate that selection for these traits in breeding programs is likely to be effective, further supporting the potential for genetic improvement in maize (Abdolhamid *et al.*, 2004)^[2]. Overall, the results highlight the importance of considering multiple traits simultaneously in maize breeding programs to achieve optimal yield potential and improve the overall performance of maize varieties (Abdel-Hady, *et al.*, 2004)^[1].

Path coefficient analysis

The path coefficient analysis conducted at both the phenotypic and genotypic levels provides valuable insights into the complex relationships between various agronomic traits and grain yield per plant in F1 maize hybrids (Table 3 and 4). By examining both direct and indirect effects of key traits, this analysis helps identify critical factors that breeders can target to improve yield potential. Similar studies have highlighted the usefulness of path coefficient analysis in understanding these complex trait relationships in maize (Abdel-Hady, *et al.*, 2004)^[1].

Phenotypic path coefficient analysis

At the phenotypic level, several traits showed strong positive direct effects on grain yield (Table 3). The seed vigor index,

seedling fresh weight, and cob weight emerged as the most influential traits, highlighting the importance of early plant development and strong cob formation in determining yield. Seed vigor is particularly important, as it affects the initial growth of the plant, which then translates into better overall performance and higher yield potential. This is consistent with findings by (Chaurasia, *et al.*, 2020)^[5], who found that seed vigor plays a significant role in enhancing the early establishment of maize and boosting yield. Similarly, seedling fresh weight and cob weight, both of which are directly related to early growth and cob development, play key roles in determining the final grain yield (Chaurasia, *et al.*, 2020)^[5].

However, some traits showed negative direct effects on grain yield. Traits such as cob length, seedling length, number of cobs per plant, and plant height at 60 days after sowing exhibited negative direct effects. Excessive cob length, for instance, may reduce space for grain filling or make the plant more susceptible to environmental stress. Similar findings were reported by (Fayyad, *et al.*, 2021)^[8], who suggested that excessive cob length and plant height could limit the optimal grain filling process, potentially reducing overall yield. Similarly, excessive plant height or multiple cobs per plant could lead to reduced resource allocation for grain production, limiting overall yield potential (Yousaf, *et al.*, 2017)^[17].

Indirect effects also played a significant role in influencing grain yield. The seed vigor index had a particularly strong positive indirect effect on yield through its impact on leaf area at maturity and cob length. This suggests that improving seed vigor not only boosts early seedling growth but also enhances the development of other critical traits such as leaf area and cob characteristics. This is consistent with the findings of (Fayyad, *et al.*, 2021)^[8], who observed that traits such as seed vigor indirectly improve yield by promoting better leaf development and overall plant health. Similarly, seedling fresh weight and cob weight exerted positive indirect effects, further supporting the idea that traits related to early growth and cob formation contribute significantly to grain yield (Yousaf, *et al.*, 2017)^[17].

On the flip side, several traits like cob length, seedling length, and number of cobs per plant showed negative indirect effects on grain yield. These negative effects typically manifested through their influence on traits such as cob diameter and seed vigor index, demonstrating the complex interactions between different traits and their cumulative impact on grain yield. This is in line with research by (Fayyad, *et al.*, 2021)^[8], who found that negative indirect effects through interactions between traits like cob diameter and seedling length often hindered the genetic improvement of yield in maize.

Genotypic path coefficient analysis

At the genotypic level, the analysis revealed even stronger associations between key traits and grain yield (Table 4). Number of leaves at 60 days after sowing, number of grains per cob, and seedling fresh weight had the highest positive direct effects on grain yield. The number of leaves plays a crucial role in enhancing photosynthesis and overall plant health, leading to better yield. The number of grains per cob is another critical factor that directly increases the total grain count, while seedling fresh weight reflects early vigor, which positively influences later stages of crop development. Cob weight also showed a significant positive direct effect, further underscoring the importance of cob size and weight in determining final yield (Chaurasia, *et al.*, 2020)^[5].

Table 1: Estimates of phenotypic correlation coefficients (F₁s) between 19 characters in maize.

Characters	Days to 50% tasselling	Days to silking	Plant height at 60 DAS (cm)	Number of Leaves at 60 DAS	Leaf area at maturity(cm) ²	Days to maturity	Number of Cobs/Plant	Cob length (cm)	Cob Diameter (cm)	Cob Weight (g)	Number of grain/cob	100 kernel weight (g)	Shelling Percent	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Seed vigour index	Germination Percentage	Grain yield/plant (g)
Days to 50% tassling	1.0000	0.5275**	0.0148	0.3779**	0.1431	0.0439	0.3018*	0.0486	0.1427	0.1135	-0.0428	0.1269	0.3767**	0.3273**	-0.0846	0.0711	0.3943**	0.0384	0.1584
Days to silking		1.0000	0.0359	0.5662**	0.2587*	0.2893*	0.1503	0.2334	0.4584**	0.4073**	0.2329	0.2756*	0.4844**	0.2907*	-0.0368	0.1719	0.4810**	0.1270	0.3927**
Plant height at 60 DAS (cm)			1.0000	-0.1205	0.0527	0.1197	-0.2636*	0.3183*	0.2716*	0.2954*	-0.0436	-0.0765	-0.1685	0.0657	0.0122	0.0588	0.0183	0.0349	-0.2032
Number of Leaves at 60 DAS				1.0000	0.0475	0.1661	0.2512*	0.1586	0.4568**	0.1997	0.0147	0.2624*	0.5642**	0.1090	0.0528	0.0673	0.2431	0.1250	0.3201*
Leaf area at maturity(cm) ²					1.0000	0.4332**	0.2033	0.1222	0.1668	0.3067*	0.3369**	0.3691**	-0.0933	0.2451	-0.0625	-0.0385	0.5700**	0.3095*	0.1794
Days to maturity						1.0000	-0.0486	0.2419	0.3239*	0.4659**	0.3147*	0.2555*	0.0009	0.1130	0.0565	0.1034	0.2869*	0.1529	0.2284
Number of Cobs/Plant							1.0000	0.0388	0.1774	-0.0557	-0.0387	0.3219*	0.3300**	-0.0063	0.3689**	-0.0460	0.1882	0.0531	0.0094
Cob length (cm)								1.0000	0.6061**	0.4573**	0.1688	0.1404	0.1674	0.2165	0.1020	0.1499	0.5067**	0.1252	0.0160
Cob Diameter (cm)									1.0000	0.3488**	-0.0579	0.2435	0.5072**	0.2365	-0.0207	0.2626*	0.3061*	0.0398	0.0014
Cob Weight (gram)										1.0000	0.0520	0.2936*	0.1462	0.1788	0.1314	0.1916	0.3429**	0.2473	0.2363*
Number of grain/cob											1.0000	0.3827**	-0.1025	-0.0331	0.0081	-0.1791	0.4269**	0.1057	0.4112**
100 kernel weight (g)												1.0000	0.1939	0.1358	0.0364	0.0696	0.2596*	0.1797	0.2571*
Shelling Percent													1.0000	0.1465	-0.0892	0.2216	0.2134	-0.0568	0.2124
Seedling length (cm)														1.0000	-0.0892	0.2969*	0.3847**	0.0056	-0.1091
Seedling fresh weight (g)															1.0000	-0.2705*	0.2872*	0.0987	0.2443
Seedling dry weight (g)																1.0000	0.0517	0-0.1208	-0.0957
Seed vigor index																	1.0000	0.2419	0.3784**
Germination Percentage																		1.0000	0.0897

***&* Significant at 5% and 1% probability levels, respectively

Table 2: Estimates of genotypic correlation coefficients (F₁s) between 19 characters in maize

Characters	Days to 50% tassling	Days to silking	Plant height at 60 DAS (cm)	Number of Leaves at 60 DAS	Leaf area at maturity (cm) ²	Days to maturity	Number of Cobs/Plant	Cob length (cm)	Cob Diameter (cm)	Cob Weight (gram)	Number of grain/cob	100 kernel weight (g)	Shelling Percent	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Seed vigour index	Germination Percentage	Grain yield/plant (g)
Days to 50% tassling	1.0000	0.5493**	0.0643	0.4946**	0.1524	0.0983	-0.4093**	0.0534	0.1633	0.1164	-0.0436	0.1300	0.3871**	0.8762**	-0.0903	0.0880	0.4120**	-0.1550	0.1613
Days to silking		1.0000	0.1138	0.7506**	0.2640*	0.5133**	-0.1754	0.2769*	0.5419**	0.4132**	0.2364	0.2949*	0.4923**	0.7736**	-0.0349	0.1915	0.4972**	0.4695**	0.3969**
Plant height at 60 DAS (cm)			1.0000	-0.6241**	0.1312	0.4329**	0.9332**	1.1224	0.8861**	0.7970**	-0.2156	-0.2068	-0.4720**	0.5198**	0.0158	0.1712	-0.0061	0.4570**	-0.5616**
Number of Leaves at 60 DAS				1.0000	0.0726	0.4523**	-0.4896**	0.3241*	0.7912**	0.2599*	0.0071	0.3588**	0.7672**	0.4237**	0.0625	0.0530	0.3614**	0.6678**	0.4205**
Leaf area at maturity (cm) ²					1.0000	0.7322**	-0.2885*	0.1580	0.2054	0.3086*	0.3401	0.3893**	-0.0950	0.6275**	0.0535	-0.0442	0.5869**	0.9288**	0.1806
Days to maturity						1.0000	0.0149	0.4129**	0.6368**	0.7796**	0.5289**	0.4956**	-0.0194	0.4305**	-0.1153	0.1978	0.4958**	0.9254**	0.3728**
Number of Cobs/Plant							1.0000	-0.1803	-0.3784**	0.0743	0.0622	-0.4264**	-0.4480**	-0.3009*	-0.1023	0.0721	-0.2560	0.7738**	-0.0079
Cob length (cm)								1.0000	0.7096**	0.5458**	0.2038	0.1867	0.2067	0.5473**	0.4465**	0.1805	0.6071**	0.5009**	0.0191
Cob Diameter (cm)									1.0000	0.4072**	-0.0631	0.3236*	0.5937**	0.6240**	0.1172	0.3333**	0.3782**	0.5071**	-0.0003
Cob Weight (gram)										1.0000	0.0518	0.3149*	0.1486	0.4648**	-0.0120	0.2048	0.3553**	0.9166**	0.2368*
Number of grain/cob											1.0000	0.4099**	-0.1034	-0.0774	0.1321	-0.1978	0.4382**	0.4317**	0.4131**
100 kernel weight (g)												1.0000	0.2034	0.2598*	0.0060	0.0678	0.2777*	0.9546**	0.2746*
Shelling Percent													1.0000	0.3758**	0.0364	0.2383*	0.2220	-0.2365*	0.2136
Seedling length (cm)														1.0000	-0.2374*	0.8325**	0.9616**	0.0441	-0.2734*
Seedling fresh weight (g)															1.0000	-0.2962*	0.2971*	0.4189**	0.2454*
Seedling dry weight (g)																1.0000	0.0666	-0.8383**	-0.1053
Seed vigor index																	1.0000	0.8487**	0.3901**
Germination Percentage																		1.0000	0.3827**

**&* Significant at 5% and 1% probability levels, respectively

Table 3: Estimates of phenotypic direct and indirect (F_{1S}) effect of 19 characters on grain yield per plant in maize

Characters	Days to 50 percent tasselling	Days to silking	Plant height at 60 DAS (cm)	Number of leaves at 60 DAS	Leaf area at maturity (cm) ²	Days to maturity	Number of cob /plant	Cob length(cm)	Cob diameter ((cm)	Cob weight (g)	Number of grain/cob	100 kernel weight (g)	Shelling percentage	Seedling length(cm)	Seedling fresh weight (g)	Seedling dry weight(g)	Seed vigor index	Germination percentage	Grain yield/plant (g)
Days to 50 percent tasselling	-0.0097	-0.0051	-0.0001	-0.0037	-0.0014	-0.0004	-0.0029	-0.0005	-0.0014	-0.0011	0.0004	-0.0012	-0.0037	-0.0032	0.0008	-0.0007	-0.0038	0.0004	0.1585
Days to silking	0.0909	0.1724	0.0062	0.0976	0.0446	0.0499	0.0259	0.0402	0.0790	0.0702	0.0401	0.0475	0.0835	0.0501	-0.0063	0.0296	0.0829	0.0219	0.3927
Plant height at 60 DAS (cm)	-0.0020	-0.0049	-0.1354	0.0163	-0.0071	-0.0162	0.0357	-0.0431	-0.0368	-0.0400	0.0059	0.0104	0.0228	-0.0089	-0.0017	-0.0080	-0.0025	-0.0047	-0.2032
Number of leaves at 60 DAS	0.0585	0.0876	-0.0187	0.1548	0.0074	0.0257	0.0389	0.0246	0.0707	0.0309	0.0023	0.0406	0.0873	0.0169	0.0075	0.0104	0.0376	0.0193	0.3201
Leaf area at maturity (cm)	-0.0168	-0.0303	-0.0062	-0.0056	-0.1172	0.0508	-0.0238	-0.0143	-0.0195	-0.0359	-0.0395	-0.0433	0.0109	-0.0287	-0.0062	0.0045	-0.0668	-0.0363	0.1794
Days to maturity	0.0031	0.0201	0.0083	0.0116	0.0301	0.0695	-0.0034	-0.0168	0.0225	0.0324	0.0219	0.0178	0.0001	0.0079	-0.0043	0.0072	0.0200	0.0106	0.2248
Number of cob /plant	-0.0415	-0.0207	0.0363	-0.0345	-0.0280	0.0067	-0.1376	-0.0053	-0.0224	0.0077	0.0053	-0.0443	-0.0454	0.0009	-0.0078	0.0063	-0.0259	-0.0073	0.0094
Cob length(cm)	-0.0162	-0.0780	-0.1064	-0.0530	-0.0408	-0.0808	-0.0130	-0.3342	-0.2026	-0.1528	-0.0564	-0.0469	-0.0560	-0.0724	-0.1233	-0.0501	-0.1693	-0.0418	0.0160
Cob diameter ((cm)	-0.0146	-0.0468	-0.0277	-0.0466	-0.0170	-0.0331	-0.0181	-0.0618	-0.1020	-0.0356	0.0059	-0.0248	-0.0517	-0.0241	-0.0104	-0.0268	-0.0312	-0.0041	0.0014
Cob weight (g)	0.0290	0.1040	0.0754	0.0510	0.0783	0.1189	-0.0142	0.1167	0.0891	0.2553	0.0133	0.0750	0.0373	0.0456	-0.0053	0.0489	0.0875	0.0631	0.2363
Number of grain/cob	-0.0087	0.0475	-0.0089	0.0030	0.0687	0.0642	-0.0079	0.0344	-0.0118	0.0106	0.2039	0.0780	-0.0209	-0.0067	0.0268	-0.0365	0.0871	0.0216	0.4112
100 kernel weight (g)	0.0105	0.0228	-0.0063	0.0217	0.0306	0.0212	0.0267	0.0116	0.0202	0.0243	0.0317	0.0828	0.0161	0.0112	0.0007	0.0058	0.0215	0.0149	0.2571
Shelling percentage	0.0280	0.0359	-0.0125	0.0419	-0.0069	0.0001	0.0245	0.0124	0.0376	0.0108	-0.0076	0.0144	0.0742	0.0109	0.0027	0.0164	0.0158	-0.0042	0.2124
Seedling length(cm)	-0.0731	-0.0649	-0.0147	-0.0244	-0.0547	-0.0252	0.0014	-0.0484	-0.0528	-0.0399	0.0074	-0.0303	-0.0327	-0.2234	0.0199	-0.0663	-0.0859	-0.0013	-0.1091
Seedling fresh weight (g)	-0.0219	-0.0095	0.0032	0.0125	0.0136	-0.0161	0.0146	0.0953	0.0263	-0.0054	0.0339	0.0021	0.0093	-0.0230	0.2583	-0.0699	0.0742	0.0255	0.2443
Seedling dry weight(g)	0.0004	0.0011	0.0004	0.0004	-0.0002	0.0006	-0.0003	0.0009	0.0016	0.0012	-0.0011	0.0004	0.0014	0.0018	-0.0017	0.0062	0.0003	-0.0008	-0.0957
Seed vigor index	0.1398	0.1706	0.0065	0.0862	0.2022	0.1018	0.0667	0.1797	0.1086	0.1216	0.1514	0.0921	0.0757	0.1364	0.1019	0.0183	0.3546	0.0858	0.3784
Germination percentage	0.0028	-0.0093	-0.0026	-0.0091	-0.0226	-0.0112	-0.0039	-0.0091	-0.0029	-0.0181	-0.0077	-0.0131	0.0041	-0.0004	-0.0072	0.0088	-0.0177	-0.0730	0.0897

Residual factors = 0.1217, Bold figures indicate direct effects

Table 4: Estimates of genotypic direct and indirect (F₁s) effect of 19 characters on grain yield per plant in maize

Characters	Days to 50 percent tasselling	Days to silking	Plant height at 60 DAS	Number of leaves at 60 DAS	Leaf area at maturity (cm)	Days to maturity	Number of cob/pant	Cob length (cm)	Cob diameter (cm)	Cob weight (g)	Number of grain /cob	100 kernel weight (g)	Shelling percent	Seedling length(cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Seed vigour index	Germination percentage	Grain yield /plant (g)
Days to 50 percent tasselling	-0.0233	-0.0128	-0.0015	-0.0115	-0.0036	-0.0023	0.0096	-0.0012	-0.0038	-0.0027	0.0010	-0.0030	0.0090	-0.0204	0.0021	-0.0021	-0.0096	0.0036	0.1613
Days to silking	-0.0554	-0.1009	-0.0115	-0.0757	-0.0266	-0.0518	0.0177	-0.0279	-0.0547	-0.0417	-0.0239	-0.0298	-0.0497	-0.0780	0.0035	-0.0193	-0.0502	-0.0474	0.3969
Plant height at 60 DAS	-0.0117	-0.0206	-0.1815	0.1133	-0.0238	-0.0786	-0.1694	-0.2037	-0.1608	-0.1447	0.0391	0.0375	0.0857	-0.0943	-0.0029	-0.0311	0.0011	-0.0829	-0.5616
Number of leaves at 60 DAS	0.2670	0.4052	-0.3369	0.5398	0.0392	0.2442	-0.2643	0.1750	0.4271	0.1403	0.0038	0.1937	0.4142	0.2287	0.0338	0.0286	0.1951	0.3605	0.4205
Leaf area at maturity (cm)	-0.0269	-0.0466	-0.0232	-0.0128	-0.1765	-0.1292	0.0509	-0.0279	-0.0362	-0.0544	-0.0600	-0.0687	0.0168	-0.1107	-0.0094	0.0078	-0.1036	-0.2168	0.1806
Days to maturity	0.0120	0.0628	0.0529	0.0553	0.0896	0.1223	0.0018	0.0505	0.0779	0.0954	0.0647	0.0606	-0.0024	0.0527	-0.0141	0.0242	0.0606	0.1376	0.3728
Number of cob/pant	-0.0079	-0.0034	0.0179	-0.0094	-0.0055	0.0003	0.0192	-0.0035	-0.0073	0.0014	0.0012	-0.0082	-0.0086	-0.0058	-0.0020	0.0147	-0.0049	0.0149	-0.0079
Cob length (cm)	-0.0136	-0.0704	-0.2855	-0.0824	-0.0402	-0.1050	0.0459	-0.2544	-0.2011	-0.1388	-0.0518	-0.0475	-0.0526	-0.1392	-0.1136	-0.0459	-0.1544	-0.1274	0.0191
Cob diameter (cm)	-0.0462	-0.1535	-0.2510	-0.2241	-0.0582	-0.1804	0.1072	-0.2240	-0.2833	-0.1153	0.0179	-0.0917	-0.1682	-0.1768	-0.0332	-0.0944	-0.1071	-0.1437	-0.0003
Cob weight (g)	0.0464	0.1646	0.3175	0.1035	0.1229	0.3105	0.0296	0.2174	0.1622	0.3983	0.0206	0.1254	0.0592	0.1852	-0.0083	0.0816	0.1415	0.4050	0.2368
Number of grain /cob	-0.0221	0.1200	-0.1094	0.0036	0.1726	0.2684	0.0316	0.1034	-0.0320	0.0263	0.5075	0.2080	-0.0525	-0.0393	0.0670	-0.1004	0.2224	0.2191	0.4131
100 kernel weight (g)	-0.0253	-0.0574	0.0402	-0.0698	-0.0757	-0.0964	0.0829	-0.0363	-0.0630	-0.0613	-0.0797	-0.1945	-0.0396	-0.0505	-0.0012	-0.0131	-0.0540	-0.1857	0.2746
Shelling percent	-0.0149	-0.0190	0.0182	-0.0296	0.0037	0.0007	0.0173	-0.0080	-0.0229	-0.0057	0.0040	-0.0079	-0.0386	-0.0145	-0.0014	-0.0092	-0.0086	0.0091	0.2136
Seedling length(cm)	0.2168	0.1915	0.1286	0.1049	0.1553	0.1065	-0.0745	0.1355	0.1544	-0.1150	-0.0192	0.0643	0.0930	0.2475	-0.0587	0.2060	0.2627	0.0109	-0.2734
Seedling fresh weight (g)	-0.0390	-0.0151	0.0068	0.0270	0.0231	-0.0498	-0.0442	0.1929	0.0506	-0.0091	0.0571	0.0026	0.0157	-0.1025	0.4320	-0.1280	0.1284	0.1810	0.2454
Seedling dry weight (g)	0.0070	0.0152	0.0136	0.0042	-0.0035	0.0157	0.0057	0.0143	0.0264	0.0162	-0.0157	0.0053	0.0189	0.0659	-0.0235	0.0792	0.0053	-0.0664	-0.1053
Seed vigor index	-0.0874	-0.1055	0.0013	-0.0767	-0.1245	-0.1052	0.0543	-0.1288	-0.0802	-0.0754	-0.0930	-0.0589	-0.0471	-0.2252	-0.0630	-0.0141	0.2122	-0.1801	0.3901
Germination percentage	-0.0142	0.0429	0.0418	0.0610	0.1123	0.1029	0.0707	0.0458	0.0464	0.0929	0.0395	0.0873	-0.0216	0.0040	0.0383	-0.0766	0.0776	0.0914	0.3827

Residual factors =0.03, Bold figures indicate direct effects

However, some traits had negative direct effects on grain yield, particularly cob diameter, cob length, and plant height at 60 days after sowing. These traits, when excessively large, may interfere with optimal grain filling or divert resources away from reproductive growth, thus limiting yield potential. Similar results were observed by (Chaurasia, *et al.*, 2020) ^[5], who reported negative correlations between these traits and yield due to resource allocation issues.

Indirect effects at the genotypic level revealed how various traits influence each other. The number of leaves at 60 days after sowing exerted strong positive indirect effects through its influence on days to silking and cob diameter, suggesting that early leaf development not only supports early growth but also positively affects the timing of reproductive stages and cob formation (Ramadan, *et al.*, 2022) ^[12]. Similarly, number of grains per cob had positive indirect effects via traits such as days to maturity and seed vigor index, indicating that improving early growth traits can indirectly enhance reproductive success and yield (Ramadan, *et al.*, 2022) ^[12].

Conversely, some traits, like cob diameter and plant height, had negative indirect effects on grain yield. For example, cob diameter negatively influenced yield through traits such as plant height and number of leaves, indicating that an imbalance in plant morphology could reduce overall productivity. Similarly, cob length and plant height showed negative indirect effects through their interactions with other traits like cob diameter and leaf area at maturity, emphasizing the need to manage these traits carefully to avoid compromising yield (Taiwo, *et al.*, 2020) ^[15].

Conclusion

The analysis of correlation coefficients and path coefficient analysis provided valuable insights into the interrelationships and genetic influences on grain yield per plant in maize. Strong positive correlations were observed between grain yield and traits such as the number of grains per cob, seed vigor index, and cob weight, highlighting their potential as key indicators for improving yield. Path coefficient analysis revealed that both phenotypic and genotypic direct effects were primarily driven by the seed vigor index, seedling fresh weight, and cob weight, while negative direct effects were linked to traits like cob length and plant height. Indirect effects, particularly through traits like cob diameter and days to maturity, further emphasized the complexity of trait interactions. The low residual variance at both phenotypic and genotypic levels indicated a well-explained model, reinforcing the importance of these traits in maize breeding for higher grain yield.

References

1. Abdel-Hady MS, Abdel-Sattar AA, Mahmoud IM. Prediction of heterosis and combining ability in maize using tissue cultures.
2. Abdolhamid Rezaei AR, Yazdisamadi BY, Zali AZ, Tallei AT, Zeinali HZ, Rezaei AR. Estimate of heterosis and combining ability in maize (*Zea mays* L.) using diallel crossing method.
3. Alam AKMM, Ahmed S, Begum M, Sultan M. Heterosis and combining ability for grain yield and its contributing characters in maize. *Bangladesh J Agric Res*. 2008;33(3):375-379.
4. Aslam M, Sohail Q, Maqbool MA, Ahmad S, Shahzad R. Combining ability analysis for yield traits in diallel crosses of maize. *JAPS: J Anim Plant Sci*. 2017;27(1).
5. Chaurasia NK, Nirala RBP, Singh B, Mandal SS. Trait association and path coefficient analysis in maize (*Zea mays* L.) for grain yield and its attributes. *J Pharm Phytochem*. 2020;9(6):527-531.
6. Dewey DR, Lu KH. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. *Agron J*. 1959;51(9):515-518.
7. El-Moula MAA, Barakat AA, Ahmed AA. Combining ability and type of gene action for grain yield and other attributes in maize (*Zea mays* L.).
8. Fayyad HF, Hammadi HJ. Estimation of combining ability and gene action for yield and yield components in maize (*Zea mays* L.). *IOP Conf Ser Earth Environ Sci*. 2021 May;761(1):012079.
9. Panse VG, Sukhatme PV. Statistical methods for agricultural workers. 2nd ed. ICAR, New Delhi; 1967. p. 152-157.
10. Prakash R, Ravikesavan R, Vinodhana NK, Senthil A. Genetic variability, character association, and path analysis for yield and yield component traits in maize (*Zea mays* L.). *Electron J Plant Breed*. 2019;10(2):518-524.
11. Rajwade JK, Jagadev PN, Lenka D, Gupta S. Correlation and path coefficient studies on elite genotypes of maize inbred lines. *J Pharm Phytochem*. 2018;7(2):2765-2771.
12. Ramadan ASA, Mukhlif FH, Najm BF. Evaluation of performance, combining ability and gene action of inbred lines and its single hybrids in maize (*Zea mays* L.). *Int J Agric Stat Sci*. 2022;18(1):1117-1125.
13. Raut SK, Ghimire SK, Kharel R, Kuwar CB, Sapkota M, Kushwaha UKS. Study of yield and yield attributing traits of maize. *Am J Food Sci Health*. 2017;3(6):123-129.
14. Searle SR. Phenotypic, genetic, and environmental correlation. *Biometrics*. 1961;17(3):474-480.
15. Taiwo OP, Nwonuala AI, Isaiah BF, Olawamide DO, Aghbugba IK. Correlation and path coefficient analysis studies on grain yield and its contributing characters in maize (*Zea mays* L.). *Int J Plant Soil Sci*. 2020;32(7):7-13.
16. Wuhaib KM. Genotypic and phenotypic correlation in maize and path coefficient I-Agronomic traits. *Iraqi J Agric Sci*. 2018;49(2).
17. Yousaf MI, Hussain K, Hussain S, Shahzad R, Ghani A, Arshad M, Akhter N. Morphometric and phenological characterization of maize (*Zea mays* L.) germplasm under heat stress. *Int J Biol Biotech*. 2017;14(2):271-278.