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Path coefficient analysis of direct and indirect effects of yield-contributing traits on grain yield in maize (*Zea Mays* L.)

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ABSTRACT

Grain yield in maize is a complex quantitative character influenced by several interrelated morphological, phenological and biochemical traits. Correlation analysis provides information on the association between traits, whereas path coefficient analysis partitions these associations into direct and indirect effects and therefore provides a better understanding of the contribution of component characters to grain yield. The present investigation was conducted during Kharif 2025 at

R. K. Nagar Farm under the AICRP on Maize, Kasba Bawada, Kolhapur, Maharashtra, using 40 maize inbred lines along with two standard checks, Phule Umed and Bio-9462. The experiment was conducted in a randomized block design with two replications. Genotypic correlation coefficients and path coefficient analysis were estimated for grain yield per plant and twelve associated characters. Grain yield per plant showed highly significant positive genotypic associations with cob weight (0.9946), number of kernels per row (0.6486), 100-kernel weight (0.5236), cob length (0.3960) and plant height (0.3603). Path coefficient analysis revealed a high positive direct effect of cob weight (3.9924), followed by cob height (1.0617) and starch content (0.0082). Negative direct effects were recorded for number of kernels per row (-2.6051), 100-kernel weight (-1.9944), number of kernel rows per cob (-1.6223), days to 50 per cent tasseling (-0.4836), plant height (-0.2861), cob length (-0.2105), days to 50 per cent silking (-0.0920), cob diameter (-0.0794) and protein content (-0.0649). Cob weight also showed substantial positive indirect effects through number of kernels per row (2.5907), 100-kernel weight (1.9054), cob length (1.5315) and plant height (1.2401). The coefficient of determination was 0.8781, with a residual effect of 0.3491. The results demonstrated that grain yield was governed by complex interactions among yield components, with cob weight and cob height making major positive direct contributions.

Keywords: Maize, Grain yield, Path coefficient analysis, Direct effect, Indirect effect, Genotypic correlation, Cob weight, Yield components

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops and is cultivated for food, feed, fodder and industrial purposes. Grain yield is a complex quantitative character controlled by several component traits and is strongly influenced by the interaction among these traits. Consequently, selection for grain yield alone may not always provide sufficient information for effective genetic improvement.

Correlation analysis is commonly used to determine the degree and direction of association between grain yield and its component characters. However, a correlation coefficient represents the combined influence of direct and indirect relationships and does not indicate whether the association of a particular character with yield is due to its own direct influence or through other associated traits. Path coefficient analysis provides a means of partitioning correlation coefficients into direct and indirect effects.

The identification of characters having substantial direct effects on grain yield is particularly important because traits with high direct contributions can provide useful selection criteria. At the same time, traits with substantial indirect effects may contribute to yield through other component characters and should therefore be interpreted together with correlation coefficients.

Therefore, the present study was undertaken to examine the genotypic associations between grain yield and its component traits and to partition these associations into direct and indirect effects using path coefficient analysis in maize inbred lines.

Materials and Methods

Experimental material

The investigation was conducted during Kharif 2025 at R. K. Nagar Farm under the AICRP on Maize, Kasba Bawada, Kolhapur, Maharashtra. The experimental material consisted of 42 maize genotypes, comprising 40 inbred lines and two standard checks, Phule Umed and Bio-9462.

Experimental design

The genotypes were evaluated in a randomized block design (RBD) with two replications. Each genotype was grown in a single 3.0 m row. Row-to-row spacing was 60 cm and plant-to-plant spacing was 20 cm. Recommended agronomic practices were followed during crop growth.

Characters studied

Observations were recorded for 13 characters: days to 50 per cent tasseling, days to 50 per cent silking, plant height, cob height, cob length, cob diameter/circumference, number of kernel rows per cob, number of kernels per row, cob weight, 100-kernel weight, grain yield per plant, protein content and starch content.

Statistical analysis

Genotypic correlation coefficients were estimated between grain yield and its component characters. Path coefficient analysis was subsequently carried out at the genotypic level following the procedure of

Dewey *et al.* (1959) [1]. Grain yield per plant was considered the dependent variable, while the remaining component characters were treated as causal variables. The coefficient of determination and residual effect were also calculated.

Results and Discussion

Genotypic correlation of grain yield with component characters

Grain yield per plant exhibited highly significant and positive genotypic associations with cob weight (0.9946), number of kernels per row (0.6486), 100-kernel weight (0.5236), cob length (0.3960) and plant height (0.3603). Positive associations were also observed with number of kernel rows per cob, cob height, days to 50 per cent tasseling, cob circumference and days to 50 per cent silking. Protein content (−0.0876) and starch content (−0.1370) showed negative genotypic associations with grain yield.

The particularly strong positive association between grain yield and cob weight indicated that variation in cob weight was closely associated with variation in grain yield in the evaluated material. Positive relationships of grain yield with kernels per row and 100-kernel weight further indicated the contribution of kernel number and kernel size to yield expression.

Table 1. Direct (diagonal) and Indirect (above and below diagonal) path effects of different characters towards grain yield

	Days to 50 per cent tasseling	Days to 50 per cent silking	Plant height (cm)	Ear height (cm)	Cob Weight (gm)	Cob length(cm)	Cob circumference (cm)	No. of Kernel Rows / Ear	No. of kernel / Row	100 Kernel weight (gm)	Starch %	Protein %
Days to 50 per cent tasseling	-0.4836	-0.4767	0.0065	-0.1773	-0.0514	0.0998	-0.0564	-0.0418	-0.0371	0.0439	0.0510	-0.0306
Days to 50 per cent silking	-0.0907	-0.0920	-0.0054	-0.0263	-0.0079	0.0173	0.0001	0.0053	-0.0092	0.0061	0.0064	-0.0053
Plant height (cm)	0.0038	-0.0167	-0.2861	-0.2117	-0.0889	-0.1094	-0.0532	-0.0329	-0.0621	-0.0799	-0.0649	0.0964
Ear height (cm)	0.3892	0.3033	0.7855	1.0617	0.1186	0.2046	0.2816	0.1920	0.2925	-0.0699	0.1752	-0.2667
Cob Weight (g)	0.4246	0.3440	1.2401	0.4458	3.9924	1.5315	0.3325	0.5903	2.5907	1.9054	-0.5577	-0.1535
Cob length(cm)	0.0434	0.0396	-0.0805	-0.0406	-0.0808	-0.2105	-0.0178	0.0134	-0.0652	-0.0467	0.0272	0.0520
Cob circumference	-0.0093	0.0001	-0.0148	-0.0211	-0.0066	-0.0067	-0.0794	-0.0208	0.0116	-0.0113	0.0086	0.0104
No. of Kernel/ Rows	-0.1404	0.0927	-0.1865	-0.2933	-0.2399	0.1032	-0.444	-1.6223	0.3175	0.4864	-0.0077	-0.2353
No. of kernel/ Row	-0.2001	-0.2598	-0.5651	-0.7176	-1.6904	-0.8066	0.3814	0.5098	-2.6051	0.2745	0.2861	0.2311
100 Kernel weight	0.1811	0.1314	-0.5571	0.1313	-0.9518	-0.4421	-0.2849	0.5980	0.2101	-1.9944	-0.0795	0.2801
Starch %	-0.0009	-0.0006	0.0019	0.0014	-0.0011	-0.0011	-0.0009	0.0000	-0.0009	0.0003	0.0082	-0.0013
Protein %	-0.0041	-0.0038	0.0219	0.0163	0.0025	0.0160	0.0085	-0.0094	0.0058	0.0091	0.0101	-0.0649
Yield per plant (g)	0.1132	0.0615	0.3603	0.1686	0.9946	0.3960	0.0872	0.1815	0.6486	0.5236	-0.1370	-0.0876

$R^2 = 0.8781$; Residual effect = 0.349

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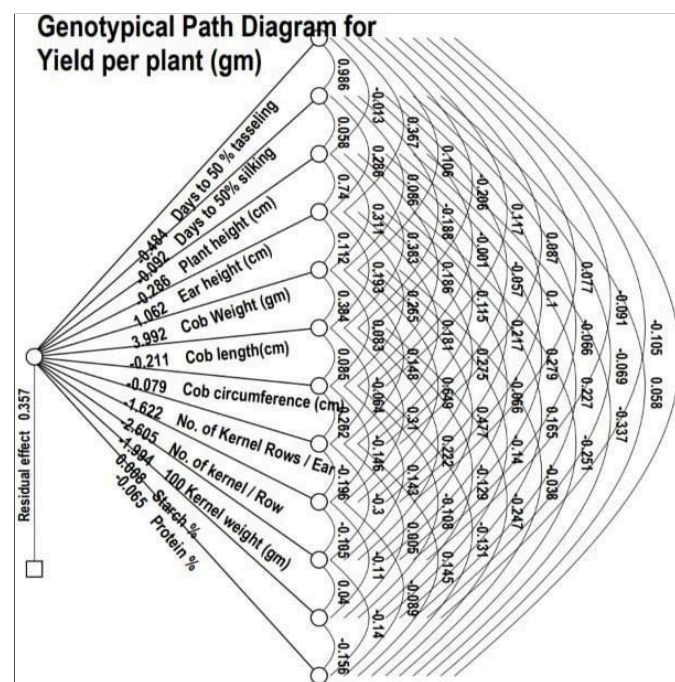


Figure 01. Genotypical path diagram for grain yield per plant

Direct effects of component traits on grain yield

Path coefficient analysis revealed considerable differences among the component characters in their direct contribution to grain yield.

Character	Direct effect
Days to 50% tasseling	-0.4836
Days to 50% silking	-0.0920
Plant height	-0.2861
Cob height	1.0617
Cob length	-0.2105
Cob diameter	-0.0794
No. of kernel rows/cob	-1.6223
No. of kernels/row	-2.6051
Cob weight	3.9924
100-kernel weight	-1.9944
Starch content	0.0082
Protein content	-0.0649
Residual effect	0.3491
R ²	0.8781

Cob weight recorded the highest positive direct effect (3.9924) on grain yield, followed by cob height (1.0617) and starch content (0.0082). The strong direct contribution of cob weight is particularly important because cob weight also had a very high positive genotypic correlation with grain yield.

In contrast, number of kernels per row, 100-kernel weight and number of kernel rows per cob recorded negative direct effects. The negative direct effects of number of kernels per row and 100-kernel weight, despite their positive genotypic correlations with grain yield, indicate the presence of substantial compensating indirect effects through other component characters.

Indirect effects of days to 50 per cent tasseling

Days to 50 per cent tasseling showed positive indirect effects through cob length (0.0998), starch content (0.0510), 100-kernel weight (0.0439) and plant height (0.0065). Negative indirect effects were observed through days to 50 per cent silking (-0.4767), cob height (-0.1773), cob

diameter (-0.0564), cob weight (-0.0514), number of kernel rows per cob (-0.0418), number of kernels per row (-0.0371) and protein content (-0.0306).

Indirect effects of days to 50 per cent silking

Days to 50 per cent silking exhibited small positive indirect contributions through cob length, cob diameter, number of kernel rows per cob, 100-kernel weight and starch content. Negative indirect effects were observed through days to 50 per cent tasseling, plant height, cob height, cob weight, number of kernels per row and protein content.

Indirect effects of plant height

Plant height recorded positive indirect effects through protein content (0.0964) and days to

50 per cent tasseling (0.0038). Negative indirect effects were recorded through cob height (-0.2117), cob length (-0.1094), cob weight (-0.0889), 100-kernel weight (-0.0799), number of kernels per row (-0.0621), cob diameter (-0.0532), number of kernel rows per cob (-0.0329), days to 50 per cent silking (-0.0167) and starch content (-0.0064).

Indirect effects of cob height

Cob height recorded positive indirect contributions through plant height (0.7855), days to 50 per cent tasseling (0.3892), days to 50 per cent silking (0.3033), number of kernels per row (0.2925), cob diameter (0.2816), cob length (0.2046), number of kernel rows per cob (0.1920), starch content (0.1752) and cob weight (0.1186). Negative indirect effects were observed through protein content (-0.2667) and 100-kernel weight (-0.0699).

Indirect effects of cob length

Cob length exhibited positive indirect effects through number of kernel rows per cob (0.0134), starch content (0.0272) and protein content (0.0520). Negative indirect effects were observed through cob diameter (-0.0178), number of kernels per row (-0.0652), cob weight (-0.0808), cob height (-0.0406), plant height (-0.0805) and 100-kernel weight (-0.0467).

Indirect effects of cob diameter

Cob diameter showed positive indirect effects through number of kernels per row (0.0116), starch content (0.0086), protein content (0.0104) and days to 50 per cent silking (0.0001). Negative indirect effects were observed through cob length (-0.0067), number of kernel rows per cob (-0.0208), cob weight (-0.0066), cob height (-0.0211), plant height (-0.0148), 100-kernel weight (-0.0113) and days to 50 per cent tasseling (-0.0930).

Indirect effects of number of kernel rows per cob

Number of kernel rows per cob exhibited positive indirect effects through 100-kernel weight (0.4864), number of kernels per row (0.3175), cob length (0.1032) and days to 50 per cent silking (0.0927). Negative indirect effects were observed through cob diameter (-0.4244), cob weight (-0.2399), cob height (-0.2399), protein content (-0.2353), plant height (-0.1865), days to 50 per cent tasseling (-0.1404) and starch content (-0.0077).

Indirect effects of number of kernels per row

Number of kernels per row showed positive indirect effects through number of kernel rows per cob (0.5098), cob diameter (0.3814), starch content (0.2861), 100-kernel weight (0.2745) and protein content (0.2311). However, negative indirect effects were observed through cob weight (-1.6904), cob length (-0.8066), cob height (-0.7176), plant height (-0.5651), days to 50 per cent silking (-0.2598) and days to 50 per cent tasseling (-0.2001).

Indirect effects of cob weight

Cob weight exhibited extensive positive indirect effects on grain yield. The largest positive indirect effects were recorded through number of kernels per row (2.5907), 100-kernel weight (1.9054), cob length (1.5315), plant height (1.2401), number of kernel rows per cob

(0.5903), cob height (0.4458), days to 50 per cent tasseling (0.4246), days to 50 per cent silking (0.3440) and cob diameter (0.3325). Negative indirect effects were observed through starch content (−0.5577) and protein content (−0.1535).

Indirect effects of 100-kernel weight

The 100-kernel weight exhibited positive indirect effects through number of kernel rows per cob (0.5980), protein content (0.2801), number of kernels per row (0.2101), days to 50 per cent tasseling (0.1811), days to 50 per cent silking (0.1314) and cob height (0.1313). Negative indirect effects were observed through cob weight (−0.9518), plant height (−0.5571), cob length (−0.4421), cob diameter (−0.2849) and starch content (−0.0795).

Indirect effects of protein content

Protein content showed positive indirect contributions through several morphological and yield-component traits, including plant height, cob height, cob weight, cob length, cob circumference, number of kernels per row, 100-kernel weight and starch content. Negative indirect contributions were observed through days to 50 per cent tasseling, days to 50 per cent silking and number of kernel rows per cob. The direct effect of protein content on grain yield was negative (−0.0649), and its genotypic association with grain yield was also negative (−0.0876).

Indirect effects of starch content

Starch content exhibited positive indirect effects through plant height (0.0019), cob height (0.0014) and 100-kernel weight (0.0003). Negative indirect effects were observed through protein content (−0.0013), cob length (−0.0011), cob weight (−0.0011), cob diameter (−0.0009), number of kernels per row (−0.0009), days to 50 per cent tasseling (−0.0009) and days to 50 per cent silking (−0.0006).

Overall interpretation of path coefficient analysis

The path analysis demonstrated that the relationship between component characters and grain yield was complex. A positive correlation between a character and grain yield did not necessarily correspond to a positive direct effect. Number of kernels per row had a highly significant positive genotypic correlation with grain yield (0.6486) but a negative direct effect (−2.6051). Similarly, 100-kernel weight had a positive genotypic correlation of 0.5236 but a negative direct effect of −1.9944. These results emphasize that correlation coefficients alone cannot fully explain the contribution of individual characters to grain yield.

The coefficient of determination ($R^2 = 0.8781$) indicated that the characters included in the path analysis accounted for a substantial proportion of the variation associated with grain yield. The residual effect was 0.3491, indicating that additional factors not included in the analysis also contributed to variation in grain yield.

Conclusion

The present investigation demonstrated substantial interrelationships among grain yield and its component characters in the evaluated maize inbred lines. Grain yield per plant showed highly significant positive genotypic associations with cob weight, number of kernels per row, 100-kernel weight, cob length and plant height.

Path coefficient analysis provided a clearer interpretation of these associations. Cob weight recorded the highest positive direct effect on grain yield, followed by cob height and starch content. Cob weight also showed several substantial positive indirect effects, particularly through number of kernels per row, 100-kernel weight, cob length and plant height.

Several traits, including number of kernels per row, 100-kernel weight and number of kernel rows per cob, recorded negative direct effects despite positive associations with grain yield. This indicates that their relationships with yield were strongly influenced by indirect pathways through other component characters. Overall, combining genotypic correlation analysis with path coefficient analysis provides useful information for understanding the contribution of yield-related traits in maize.

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