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Studies on interrelationship and path coefficient of quantitative traits in maize (*Zea mays* L.)

Rajan Prasad Mishra, Sandeep Kumar, Ashok Kumar and Tarkeshwar

Abstract
In the realm of knowledge pertaining to the inherent nature and substantial magnitude of genetic associations within components of economic significance, a profound comprehension emerges. This enlightenment becomes instrumental in elevating the precision of selection processes, enabling the judicious amalgamation of desirable traits. The intricate discipline of path coefficient analysis transcends mere correlations, delving deep into the intricacies of both direct and indirect effects, thereby unraveling the intricate tapestry of contributions made by various yield attributes towards the ultimate goal of seed production. Within the global culinary landscape, maize assumes a pivotal role as one of the foremost cereal grains, standing shoulder to shoulder with the likes of wheat and rice. Its significance lies in its dual role as a rich reservoir of both proteins, constituting approximately 6-13% of its composition, and carbohydrates, accounting for a substantial 70-87%. This unique nutritional profile underscores its importance in the dietary spectrum. Turning our gaze to the empirical realm, our investigative journey unfolds at the hallowed precincts of Namdeo Umaji Agri Tech India Private Limited, Pune, during the auspicious Kharif season of 2022. Here, our mission is to explore the vast expanse of variability inherent within the diverse genotypes of maize. Our repository of data extends to encompass nineteen polygenic traits, and the discerning eye is cast upon the average characteristics of selected flora. This meticulous scrutiny paves the way for comprehensive statistical analyses. At the genotypic level, the manifestation of grain yield per plant manifests a robust and positively significant kinship with cob length (0.416), closely followed by 100-seed weight (0.395), the count of tassel branches (0.369), kernels per row (0.364), protein content (0.337), leaves per plant (0.189), cob diameter (0.214), and the number of kernel rows per cob (0.179). In stark contrast, negative affiliations rear their head in association with leaf length (-0.266), leaf width (-0.455), days required for 50% silking (-0.273), and days to maturity (-0.163). Unearthing the crux of direct impact on grain yield per plant, the preeminent role is embraced by the number of tassel branches per plant (0.4713), followed in succession by the count of kernels per row (0.2966), number of kernel rows per cob (0.2285), 100-seed weight (0.1370), and cob diameter (0.1013). Furthermore, leaf width orchestrates a symphony of positive indirect influence on grain yield per plant, facilitated by the intermediaries of days required for 50% tassel flowering (0.1291) and the abundance of tassel branches (0.1581).

Keywords: Maize, *Zea mays*, yield attributes, correlation coefficient, path coefficient

Introduction
After wheat and rice, maize (*Zea mays* L.) is the third-largest grain crop in the world. It is mostly farmed in tropical, subtropical, and temperate highlands. The indigenous people of southern Mexico cultivated maize (2n=20), a C_4 plant that is a member of the *Maydae* tribe and the *Poaceae* family, for the first time about 8000 years ago. It is a tall, monoecious plant with short days and a deterministic growth pattern. There are four types of wild maize: *Zea luxurians*, *Zea mexicana*, and *Zea diploperennis* (Nartam *et al*., 2015) [8].
Because it has one of the highest yield potentials of all cereals, maize has earned the title “Queen of Cereals.” Maize is also referred to as a “contingency crop” since it may be used at any level of development, including as tender green fodder in the early stages, baby corn in the very early stages of cob development, green cob in the slightly later stages, and maize grain in the fully developed stages (Yadav *et al*., 2014) [19].
It may grow up to 3808 m (above mean sea level) and 58 °N to 40 °S latitude in regions with an average annual rainfall of 25.4-1016 cm (Hallauer and Miranda, 1998) [6]. While night-time temperatures range from 17 to 23 °C, the ideal range for growing tropical maize is between 25 and 33 °C (Ellis *et al*., 1992) [5]. Temperatures over 35 °C over an extended length of time are thought to be unfavourable for growing maize, and temperatures over 40 °C harm yield levels irreparably (Archana *et al*., 2018) [2].

By 2022, there is more than 9.2 million hectares of maize planted, up from 3.31 million hectares in 1951 in India. The spread of maize farming in non-traditional regions like Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu is mostly to blame for this rise. Over the past 60 years, a variety of breeding techniques, including single cross hybrids, double cross hybrids, and composite breeding, have been used to boost maize yield. However, single cross hybrids received top focus over the past ten years, which led to a noticeable increase in maize yield (Sharma, 2021) [14].

Understanding the intricate nature and significant genetic connections among economically vital components can greatly enhance the effectiveness of selection processes. Astutely observed that the various elements contributing to crop yield and other plant characteristics are influenced at different stages of plant growth. These factors are also differentially affected by environmental conditions. The delicate balance between these yield-contributing factors can lead to variations in correlation patterns. This underscores the necessity for in-depth investigations into the complex interplay between crop yield and its constituent elements.

Path analysis emerges as a valuable tool for dissecting the specific factors that drive particular correlations. This method relies on a combination of knowledge regarding the extent of correlation between variables within a system and an understanding of the causal relationships at play. Employing the path coefficient analysis method, as proposed by Dewey and Lu (1959) [4], allows us to disentangle the total correlation into direct and indirect effects. This approach provides valuable insights into the unique contributions of individual component traits to overall seed yield. The current study has been undertaken to unravel the intricate web of connections between various polygenic traits and seed yield in maize.

Materials and Methods

The present study was conducted at the Namdeo Umaji Agri tech India private limited, Pune during *Kharif* 2022. Geographically, Pune is located between 24 degrees 54' and 10 degrees 24' North latitude and 73 degrees 19' and 75 degrees 10' East longitude and at an elevation of 560 meters above mean sea level. Pune has a hot semi-arid climate (BSh) bordering with tropical wet and dry (Aw) with average temperatures ranging between 19-33 °C.

The basic material in the present investigation was comprised of ten genetically diverse genotypes of Maize (*Zea mays*) were subjected to diallel fashion mating design (excluding reciprocals) and were attempted at Namdeo Umaji Agri tech India private limited, Pune during *Kharif* 2021. The F_1 seeds of 45 crosses were advanced during the *Kharif* season of 2022 to raise the F_1's with their parents in normal sown conditions and were left for natural or open pollination. Aravali Makka-1 was also used as a standard check variety. The experimental material comprising 55 treatments (*viz*., 45 F1's + 10 parents one including check) were evaluated in Randomized Block Design with three replications during *Kharif* 2022. Each parent and F_1 was planted in five rows of 3 meters long with a row-to-row distance of 60 cm and the plant-to-plant distance was maintained at 20 cm. All the recommended agronomic practices were adopted for raising a good crop.

The observations for nineteen metric traits *viz*., leaf length (Leaf attached cob) (cm), leaf width (Leaf attached cob) (cm), days to 50 percent tasselling, days to 50 percent silking, anthesis and silking interval, days to 75 percent brown husk, days to maturity, number of tassel branches, number of leaves above upper cob, plant height (cm), lodging percentage, cob length (cm), cob diameter (cm), number of kernel rows per cob, number of kernels per row, 100-seeds weight (g), grain yield per plant (g), seed moisture content (%) and protein content (%), were recorded on 5 randomly selected competitive plants of each entry in each replication except for days to 50 percent tasselling, days to 50 percent silking, days to 75 percent brown husk, days to maturity, and lodging percent where observations were recorded on the plot basis.

The experimental data were compiled by taking the mean over five better growing and randomly selected plants of each treatment for each replication. The mean data was subjected for the following statistical analyses: Correlation coefficient by Searle (1961) [13] and path coefficient analysis by Dewey and Lu (1959) [4].

Results and Discussion

Correlation coefficient analysis

We conducted an in-depth analysis of phenotypic and genotypic correlation coefficients across all possible pairs of the 19 distinct traits for the various genotypes, including both parents and F1 hybrids. The detailed outcomes are presented in Tables 1 (a & b).

Upon scrutinizing the genotypic and phenotypic correlation coefficients for these 19 traits within the 45 different cross combinations, along with their respective parental generations, we observed variations in both magnitude and direction across the diverse traits. Nevertheless, it's noteworthy that, in most cases, both the genotypic and phenotypic correlation coefficients shared similar trends, with only a few exceptions. We observed positive as well as negative associations between different traits, shedding light on their intricate relationships. Furthermore, it became evident that, for the majority of cases, the genotypic correlation coefficients surpassed their corresponding phenotypic counterparts. However, in a few instances, the phenotypic correlations exceeded the genotypic ones, signifying the considerable influence of environmental factors on the expression of these traits.

At the genotypic level, we unearthed noteworthy associations. Grain yield per plant displayed a highly positive and statistically significant connection with cob length (0.416), closely followed by 100-seeds weight (0.395), the number of tassel branches (0.369), the count of kernels per row (0.364), protein content (0.337), the number of leaves per plant (0.189), cob diameter (0.214), and the number of kernels rows per cob (0.179). Conversely, it exhibited significant negative correlations with leaf length (-0.266), leaf width (-0.455), days to 50% silking (-0.273), and days to maturity (-0.163). These findings align with previous studies by Shrestha *et al*. in 2018 [15] and Akshaya *et al*. in 2022 [1].

We also observed highly significant and positive correlations, such as the one between leaf length and cob diameter (0.355), as well as with plant height (0.280), leaf width (0.274), and cob length (0.179). Conversely, significant and negative correlations emerged, including those with lodging percentage (-0.432), days to 75% dry husk (-0.351), days to maturity (-0.279), oil content (-0.215), and days to 50% tassel flowering (-0.180). These findings resonate with earlier reports from Kumar *et al*. in 2015 [7].

Leaf width exhibited significant positive associations, notably with cob diameter (0.352), the number of leaves (0.350), the number of tassel branches (0.336), cob length (0.311), protein content (0.280), plant height (0.267), and the number of kernels per row (0.187). Conversely, a significant negative association was observed solely with days to 50% tassel flowering (-0.302), findings that find concurrence in observations by Nataraj *et al*. in 2014 [9]. The timing of 50% tassel flowering showcased highly significant positive associations at the genotypic level, particularly with days to 50% silking (0.336), followed by lodging percentage (0.318), days to 75% dry husk (0.215), and days to maturity (0.199). However, it demonstrated significant negative correlations with various traits, including the number of leaves (-0.155), cob length (-0.442), cob diameter (-0.327), the number of kernels per row (-0.281), 100-seeds weight (-0.305), and protein content (-0.316). These patterns align with findings reported by Raghu *et al*. in 2011 [11].

Days to 50% silking also exhibited significant correlations, including a positive association with anthesis and silking interval (0.309) and lodging percentage (0.256). However, it displayed negative and significant associations with cob length (-0.274), the number of kernels per row (-0.206), and 100-seeds weight (-0.329), findings in line with those reported by Reddy *et al*. in 2012. Days to 75% dry husk demonstrated a highly significant positive correlation with days to maturity (0.925), anthesis and silking interval (0.269), and lodging percentage (0.339). Conversely, it exhibited significant negative associations with the number of tassel branches (-0.239), cob diameter (-0.330), cob length (-0.277), seed moisture (-0.185), and protein content (-0.248). These results were in accordance with the earlier findings of Vijay *et al*. in 2015 [18].

Days to maturity displayed a highly significant positive association at the genotypic level with lodging percentage (0.278), followed by anthesis and silking interval (0.189). It also exhibited negative and significant relations with the number of tassel branches (-0.205), cob length (-0.327), cob diameter (-0.315), the number of kernels per row (-0.163), seed moisture (-0.160), and protein content (-0.254), findings corroborated by Kumar *et al*. in 2015 [7]. Anthesis and silking interval demonstrated highly significant and positive correlations, particularly with lodging percentage (0.285), while displaying a negative correlation with cob length (-0.250). Number of tassel branches per plant exhibited a highly significant positive association at the genotypic level with protein content (0.404), followed by the number of leaves (0.285), cob length (0.275), and cob diameter (0.197). Notably, there was no significant negative correlation with any of the traits, consistent with the observations made by Nataraj *et al*. in 2014 [9].

The number of leaves per plant, situated above the cob, showcased highly significant and positive correlations with cob length (0.410), cob diameter (0.195), the number of kernels per row (0.256), the number of kernel rows per cob (0.260), 100-seeds weight (0.449), and protein content (0.332). Intriguingly, there were no significant negative correlations with any of the traits. Plant height displayed positive and highly significant correlations with cob length (0.263), cob diameter (0.324), and protein content (0.347), without significant negative associations with any of the traits, mirroring Kumar *et al*.'s findings in 2015 [7]. Lodging percentage demonstrated highly significant and negative correlations with cob length (-0.434), followed by 100-seeds weight (-0.279), cob diameter (-0.263), and the number of kernel rows per cob (-0.204). However, it did not exhibit significant positive associations with any of the traits. Cob length (measured in centimetres) showcased highly positive and significant correlations with the number of kernels per row (0.677), followed by cob diameter (0.521), 100-seeds weight (0.499), protein content (0.399), and the number of kernel rows per cob (0.180). Impressively, there were no significant negative correlations with any of the traits, bolstering the findings presented by Varalakshmi *et al*. in 2018 [17].

Cob diameter exhibited highly significant and positive correlations with the number of kernel rows per cob (0.311), 100-seeds weight (0.336), and protein content (0.280). However, it did not display significant positive associations with any of the traits, in line with the observations of Rafiq *et al*. in 2010 [10]. The number of kernels per row revealed highly significant and positive associations, most notably with 100-seeds weight (0.438), followed by protein content (0.295), findings that align with Sukumar *et al*.'s study in 2018. The number of kernel rows per cob exhibited a significant and positive association with 100-seeds weight (0.216), followed by protein content (0.178). Interestingly, seed moisture content did not exhibit any significant positive or negative associations with any of the traits. Lastly, 100-seeds weight displayed a positive and significant correlation with protein content (0.238), while protein content itself exhibited a significant positive correlation with grain yield (0.337), consistent with Akshaya *et al*.'s findings in 2022 [1]. For the remaining traits, we observed either positive or negative but non-significant correlations with one another at the genotypic level.

Path coefficient analysis

Table 4.5 (a & b) shows, respectively, the direct and indirect effects of eighteen traits on grain yield per plant as determined by path coefficient analysis utilising genotypic and phenotypic correlations.

At the genotypic level, the number of tassel branches per plant had the highest positive direct effect on grain yield per plant (0.4713), followed by the number of kernels per row (0.2966), the number of kernel rows per cob (0.2285), the weight of 100 seeds (0.1370), and the cob diameter (0.1013). The days to 50% tassel flowering had the highest negative direct effect (-0.4279), followed by leaf length (-0.3868). The direct impact of the remaining characteristics in both generations was either detrimental or favourable, but it was too small to have a significant impact. Earlier supported by Vijay *et al*. (2015) [18].

In the realm of genotypic path analysis, we find that leaf width plays a significant role, yielding a substantial positive indirect impact on grain yield per plant. This influence is channeled through two key avenues: the timing of 50% tassel flowering (0.1291) and the abundance of tassel branches (0.1581). Additionally, other traits exhibit noteworthy indirect effects on various aspects of maize cultivation.

Table 1(a): Estimates of Genotypic correlation coefficients among 19 traits of maize

Characters	Leaf length (cm)	Leaf width (cm)	Days to 50% Tassel flowering	Days to 50% silking	Days to 75% dry husk	Days to maturity	Anthesis and Silking Interval	No. of Tassel branches	No. of leaves	Plant height (cm)	Lodging percentage	Cob length (cm)	Cob Diameter (cm)	No. of kernels/row	No. of kernels row/cob	Seed Moisture (%)	100 Seed weight (g)	Protein content (%)	Grain yield per plant (g)
Leaf length (cm)	1.000	0.274**	-0.180*	0.115	-0.351**	-0.279**	0.014	0.059	-0.055	0.280**	-0.432**	0.179*	0.355**	0.097	-0.137	0.082	-0.063	0.021	-0.266**
Leaf width (cm)			-0.302**	0.058	0.019	-0.003	0.086	0.336**	0.350**	0.267**	0.125	0.311**	0.352**	0.187*	-0.049	-0.039	0.032	0.280**	-0.001
50% Tassel flowering				0.366**	0.215**	0.199*	0.068	-0.126	-0.155*	-0.132	0.318**	-0.442**	-0.327**	-0.281**	-0.005	-0.037	-0.305**	-0.316**	-0.455**
Days to 50% silking					-0.050	-0.070	0.309**	-0.107	-0.090	-0.034	0.256**	-0.274**	-0.022	-0.206**	-0.100	0.041	-0.329**	-0.072	-0.273**
Days to 75% dry husk						0.925**	0.269**	-0.239**	-0.010	0.027	0.341**	-0.277**	-0.330**	-0.067	0.108	-0.185*	0.053	-0.248**	-0.129
Days to maturity							0.189*	-0.205**	-0.048	0.085	0.278**	-0.327**	-0.315**	-0.163*	0.110	-0.160*	-0.050	-0.254**	-0.163*
Anthesis and Silking Interval								-0.197*	-0.063	-0.055	0.285**	-0.250**	-0.085	0.018	-0.043	0.040	-0.009	-0.013	-0.096
No. of Tassel branches									0.285**	0.088	0.036	0.275**	0.197*	0.077	-0.143	-0.040	0.005	0.404**	0.369**
No. of leaves										0.133	-0.049	0.410**	0.195*	0.256**	0.260**	-0.001	0.449**	0.332**	0.189*
Plant height (cm)											-0.041	0.263**	0.324**	0.143	0.125	0.068	0.138	0.347**	-0.079
Lodging percentage												-0.434**	-0.263**	-0.108	-0.204**	-0.002	-0.279**	-0.126	-0.163*
Cob length (cm)													0.521**	0.677**	0.180*	0.069	0.499**	0.399**	0.416**
Cob Diameter (cm)														0.311**	0.001	0.023	0.336**	0.280**	0.214**
No. of kernels/row															-0.043	-0.023	0.438**	0.295**	0.364**
No. of kernels row/cob																0.022	0.216**	0.178*	0.179*
Seed Moisture (%)																	-0.062	0.029	-0.167*
100 Seed weight (g)																		0.238**	0.395**
Protein content (%)																			0.337**
Grain yield per plant (g)																			1.000

*,**Significant at 5% and 1% probability level respectively.

Table 1(b): Estimates of Phenotypic correlation coefficients among 19 traits of maize

Characters	Leaf length (cm)	Leaf width (cm)	Days to 50% Tassel flowering	Days to 50% silking	Days to 75% dry husk	Days to maturity	Anthesis and Silking Interval	No. of Tassel branches	No. of leaves	Plant height (cm)	Lodging percentage	Cob length (cm)	Cob Diameter (cm)	No. of kernels/row	No. of kernels row/cob	Seed Moisture (%)	100 Seed weight (g)	Protein content (%)	Grain yield per plant (g)
Leaf length (cm)	1.000	0.217**	-0.132	0.113	-0.301**	-0.198*	0.015	0.041	-0.060	0.224**	-0.426**	0.221**	0.290**	0.099	-0.140	0.079	-0.043	0.007	-0.240**
Leaf width (cm)			-0.298**	0.063	0.048	0.008	0.080	0.318**	0.324**	0.210**	0.117	0.242**	0.358**	0.153	-0.036	-0.039	0.050	0.259**	-0.011
50% Tassel flowering				0.270**	0.125	0.171*	0.048	-0.104	-0.117	-0.171*	0.272**	-0.370**	-0.322**	-0.193*	-0.054	-0.030	-0.289**	-0.242**	-0.377**
Days to 50% silking					-0.071	-0.027	0.293**	-0.119	-0.078	-0.006	0.239**	-0.251**	-0.041	-0.213**	-0.064	0.038	-0.274**	-0.083	-0.258**
Days to 75% dry husk						0.737**	0.243**	-0.216**	-0.032	0.013	0.309**	-0.253**	-0.262**	-0.076	0.039	-0.154*	-0.029	-0.192*	-0.125
Days to maturity							0.145	-0.167*	-0.041	-0.041	0.222**	-0.239**	-0.278**	-0.143	0.087	-0.139	0.025	-0.257**	-0.142
Anthesis and Silking Interval								-0.192*	-0.059	-0.055	0.278**	-0.220**	-0.079	0.022	-0.053	0.040	-0.026	-0.011	-0.097
No. of Tassel branches									0.266**	0.092	0.032	0.224**	0.217**	0.069	-0.117	-0.042	0.011	0.357**	0.359**
No. of leaves										0.098	-0.047	0.373**	0.163*	0.259**	0.241**	0.000	0.397**	0.324**	0.175*
Plant height (cm)											-0.053	0.213**	0.258**	0.097	0.191*	0.056	0.153	0.229**	-0.033
Lodging percentage												-0.419**	-0.244**	-0.106	-0.204**	-0.001	-0.271**	-0.111	-0.168*
Cob length (cm)													0.436**	0.636**	0.145	0.065	0.465**	0.349**	0.403**
Cob Diameter (cm)														0.272**	0.005	0.019	0.291**	0.277**	0.197*
No. of kernels/row															-0.062	-0.021	0.378**	0.282**	0.361**
No. of kernels row/cob																0.015	0.249**	0.126	0.178*
Seed Moisture (%)																	-0.066	0.032	-0.167*
100 Seed weight (g)																		0.157*	0.383**
Protein content (%)																			0.298**
Grain yield per plant (g)																			1.000

*,**Significant at 5% and 1% probability level respectively.

Table 2(a): Direct and indirect effects of 18 traits on seed yield in maize at genotypic level

Characters	Leaf length (cm)	Leaf width (cm)	Days to 50% Tassel flowering	Days to 50% silking	Days to 75% dry husk	Days to maturity	Anthesis and Silking Interval	No. of Tassel branches	No. of leaves	Plant height (cm)	Lodging percentage	Cob length (cm)	Cob Diameter (cm)	No. of kernels/row	No. of kernels row/cob	Seed Moisture (%)	100 Seed weight (g)	Protein content (%)	Grain yield per plant (g)
Leaf length (cm)	-0.3868	-0.0448	0.0769	0.0115	-0.0012	0.0150	0.0006	0.0279	0.0074	-0.0233	0.0511	-0.0131	0.0360	0.0288	-0.0313	-0.0109	-0.0086	-0.0008	-0.266**
Leaf width (cm)	-0.1058	-0.1639	0.1291	0.0058	0.0001	0.0002	0.0039	0.1581	-0.0473	-0.0222	-0.0148	-0.0227	0.0357	0.0554	-0.0112	0.0052	0.0044	-0.0107	-0.001
50% Tassel flowering	0.0696	0.0494	-0.4279	0.0365	0.0007	-0.0107	0.0031	-0.0596	0.0210	0.0110	-0.0376	0.0322	-0.0332	-0.0834	-0.0011	0.0049	-0.0419	0.0120	-0.455**
Days to 50% silking	-0.0444	-0.0096	-0.1567	0.0998	-0.0002	0.0038	0.0140	-0.0505	0.0121	0.0028	-0.0303	0.0200	-0.0022	-0.0610	-0.0229	-0.0055	-0.0451	0.0027	-0.273**
Days to 75% dry husk	0.1359	-0.0031	-0.0919	-0.0050	0.0035	-0.0598	0.0122	-0.1128	0.0014	-0.0022	-0.0403	0.0202	-0.0334	-0.0197	0.0246	0.0246	0.0073	0.0095	-0.129
Days to maturity	0.1079	0.0005	-0.0853	-0.0070	0.0038	-0.0539	0.0086	-0.0964	0.0065	-0.0071	-0.0329	0.0239	-0.0319	-0.0483	0.0251	0.0212	-0.0069	0.0097	-0.163*
Anthesis and Silking Interval	-0.0055	-0.0141	-0.0293	0.0309	0.0009	-0.0102	0.0452	-0.0927	0.0086	0.0046	-0.0337	0.0182	-0.0086	0.0055	-0.0099	-0.0053	-0.0012	0.0005	-0.096
No. of Tassel branches	-0.0229	-0.0550	0.0541	-0.0107	-0.0008	0.0110	-0.0089	0.4713	-0.0385	-0.0073	-0.0043	-0.0201	0.0200	0.0227	-0.0327	0.0053	0.0006	-0.0154	0.369**
No. of leaves	0.0212	-0.0573	0.0664	-0.0090	0.0000	0.0026	-0.0029	0.1341	-0.1353	-0.0111	0.0058	-0.0299	0.0197	0.0758	0.0594	0.0002	0.0616	-0.0126	0.189*
Plant height (cm)	-0.1084	-0.0437	0.0565	-0.0034	0.0001	-0.0046	-0.0025	0.0415	-0.0181	-0.0832	0.0048	-0.0192	0.0329	0.0424	0.0286	-0.0090	0.0189	-0.0132	-0.079
Lodging percentage	0.1671	-0.0205	-0.1361	0.0255	0.0012	-0.0150	0.0129	0.0170	0.0067	0.0034	-0.1183	0.0317	-0.0267	-0.0321	-0.0466	0.0003	-0.0382	0.0048	-0.163*
Cob length (cm)	-0.0694	-0.0510	0.1890	-0.0273	-0.0010	0.0176	-0.0113	0.1297	-0.0555	-0.0219	0.0514	-0.0729	0.0528	0.2008	0.0412	-0.0092	0.0683	-0.0152	0.416**
Cob Diameter (cm)	-0.1372	-0.0577	0.1400	-0.0022	-0.0011	0.0170	-0.0038	0.0930	-0.0263	-0.0270	0.0312	-0.0380	0.1013	0.0923	0.0002	-0.0030	0.0461	-0.0107	0.214**
No. of kernels/row	-0.0376	-0.0306	0.1203	-0.0205	-0.0002	0.0088	0.0008	0.0361	-0.0346	-0.0119	0.0128	-0.0494	0.0316	0.2966	-0.0098	0.0031	0.0600	-0.0112	0.364**
No. of kernels row/cob	0.0530	0.0080	0.0020	-0.0100	0.0004	-0.0059	-0.0020	-0.0674	-0.0352	-0.0104	0.0241	-0.0131	0.0001	-0.0127	0.2285	-0.0029	0.0296	-0.0068	0.179*
Seed Moisture (%)	-0.0318	0.0063	0.0157	0.0041	-0.0006	0.0086	0.0018	-0.0188	0.0002	-0.0056	0.0003	-0.0051	0.0023	-0.0069	0.0051	-0.1330	-0.0085	-0.0011	-0.167*
100 Seed weight (g)	0.0243	-0.0052	0.1307	-0.0328	0.0002	0.0027	-0.0004	0.0021	-0.0608	-0.0115	0.0330	-0.0364	0.0341	0.1298	0.0493	0.0083	0.1370	-0.0091	0.395**
Protein content (%)	-0.0080	-0.0459	0.1352	-0.0072	-0.0009	0.0137	-0.0006	0.1906	-0.0449	-0.0288	0.0149	-0.0291	0.0284	0.0876	0.0407	-0.0039	0.0327	-0.0381	0.337**

Residuals: 0.0347

*,**Significant at 5% and 1% probability level respectively.

Table 2(b): Direct and indirect effects of 18 traits on seed yield in maize at phenotypic level

Characters	Chrs	Leaf length (cm)	Leaf width (cm)	Days to 50% Tassel flowering	Days to 50% silking	Days to 75% dry husk	Days to maturity	Anthesis and Silking Interval	No. of Tassel branches	No. of leaves	Plant height (cm)	Lodging percentage	Cob length (cm)	Cob Diameter (cm)	No. of kernels/row	No. of kernels row/cob	Seed Moisture (%)	100 Seed weight (g)	Protein content (%)	Grain yield per plant (g)
Leaf length (cm)	1	-0.3056	-0.0398	0.0396	0.0051	0.0031	0.0071	0.0009	0.0169	0.0077	-0.0247	0.0354	0.0224	0.0090	0.0240	-0.0235	-0.0112	-0.0062	0.0002	-0.240**
Leaf width (cm)	2	-0.0663	-0.1835	0.0892	0.0028	-0.0005	-0.0003	0.0046	0.1303	-0.0416	-0.0231	-0.0097	0.0246	0.0111	0.0370	-0.0060	0.0055	0.0072	0.0074	-0.011
50% Tassel flowering	3	0.0404	0.0546	-0.2997	0.0122	-0.0013	-0.0061	0.0028	-0.0427	0.0150	0.0188	-0.0226	-0.0375	-0.0100	-0.0468	-0.0091	0.0042	-0.0418	-0.0069	-0.377**
Days to 50% silking	4	-0.0346	-0.0115	-0.0810	0.0452	0.0007	0.0010	0.0167	-0.0487	0.0101	0.0007	-0.0199	-0.0255	-0.0013	-0.0516	-0.0107	-0.0053	-0.0396	-0.0024	-0.258**
Days to 75% dry husk	5	0.0919	-0.0087	-0.0375	-0.0032	-0.0102	-0.0262	0.0138	-0.0885	0.0042	-0.0014	-0.0257	-0.0257	-0.0081	-0.0185	0.0066	0.0218	-0.0042	-0.0055	-0.125
Days to maturity	6	0.0605	-0.0015	-0.0513	-0.0012	-0.0075	-0.0356	0.0082	-0.0683	0.0052	0.0046	-0.0185	-0.0243	-0.0086	-0.0347	0.0145	0.0198	0.0036	-0.0074	-0.142
Anthesis and Silking Interval	7	-0.0047	-0.0147	-0.0145	0.0133	-0.0025	-0.0052	0.0570	-0.0785	0.0076	0.0060	-0.0231	-0.0223	-0.0025	0.0053	-0.0089	-0.0057	-0.0037	-0.0003	-0.097
No. of Tassel branches	8	-0.0126	-0.0584	0.0313	-0.0054	0.0022	0.0059	-0.0109	0.4097	-0.0342	-0.0102	-0.0027	0.0227	0.0067	0.0168	-0.0196	0.0059	0.0016	0.0102	0.359**
No. of leaves	9	0.0183	-0.0594	0.0350	-0.0035	0.0003	0.0014	-0.0034	0.1088	-0.1286	-0.0108	0.0039	0.0378	0.0051	0.0626	0.0404	0.0000	0.0573	0.0093	0.175*
Plant height (cm)	10	-0.0686	-0.0386	0.0512	-0.0003	-0.0001	0.0015	-0.0031	0.0379	-0.0126	-0.1099	0.0044	0.0216	0.0080	0.0235	0.0319	-0.0080	0.0220	0.0066	-0.033
Lodging percentage	11	0.1301	-0.0215	-0.0815	0.0108	-0.0032	-0.0079	0.0158	0.0133	0.0061	0.0058	-0.0832	-0.0425	-0.0076	-0.0258	-0.0342	0.0001	-0.0392	-0.0032	-0.168*
Cob length (cm)	12	-0.0674	-0.0445	0.1109	-0.0114	0.0026	0.0085	-0.0125	0.0918	-0.0480	-0.0234	0.0349	0.1014	0.0136	0.1540	0.0243	-0.0092	0.0671	0.0100	0.403**
Cob Diameter (cm)	13	-0.0886	-0.0658	0.0964	-0.0019	0.0027	0.0099	-0.0045	0.0889	-0.0209	-0.0284	0.0203	0.0442	0.0311	0.0658	0.0008	-0.0027	0.0420	0.0079	0.197*
No. of kernels/row	14	-0.0303	-0.0281	0.0579	-0.0096	0.0008	0.0051	0.0012	0.0284	-0.0332	-0.0107	0.0089	0.0644	0.0084	0.2423	-0.0103	0.0029	0.0546	0.0081	0.361**
No. of kernels row/cob	15	0.0429	0.0066	0.0163	-0.0029	-0.0004	-0.0031	-0.0030	-0.0480	-0.0311	-0.0210	0.0170	0.0147	0.0002	-0.0150	0.1674	-0.0022	0.0359	0.0036	0.178*
Seed Moisture (%)	16	-0.0240	0.0071	0.0089	0.0017	0.0016	0.0050	0.0023	-0.0171	0.0000	-0.0062	0.0001	0.0065	0.0006	-0.0050	0.0026	-0.1421	-0.0095	0.0009	-0.167*
100 Seed weight (g)	17	0.0131	-0.0092	0.0867	-0.0124	0.0003	-0.0009	-0.0015	0.0046	-0.0510	-0.0168	0.0226	0.0471	0.0090	0.0916	0.0417	0.0093	0.1444	0.0045	0.383**
Protein content (%)	18	-0.0023	-0.0476	0.0724	-0.0037	0.0020	0.0092	-0.0006	0.1463	-0.0416	-0.0252	0.0093	0.0353	0.0086	0.0684	0.0211	-0.0046	0.0226	0.0286	0.298**

Residuals: 0.0428

*,**Significant at 5% and 1% probability level respectively.

For instance, days to 75% dry husk shows an indirect connection via leaf length (0.1359), while days to maturity is influenced indirectly through leaf length (0.1079). The number of leaves finds its indirect link through the number of tassel branches (0.1341), as observed by Rani G *et al*. in 2017. Furthermore, lodging percentage is affected indirectly through leaf length (0.1671), while cob length is influenced through the timing of 50% tassel flowering (0.1890), the number of tassel branches (0.1297), and the count of kernels per row (0.2008), as elucidated by Begum *et al*. in 2016. Cob diameter is intricately connected through the timing of 50% tassel flowering (0.1400), while the number of kernels per row indirectly links through the same timing (0.1203). Likewise, 100-seeds weight finds an indirect pathway through the timing of 50% tassel flowering (0.1307) and the number of kernels per row (0.1298), while protein content follows suit, influenced indirectly through the timing of 50% tassel flowering (0.1352) and the abundance of tassel branches (0.1906). These connections collectively contribute to the maize grain yield, as evidenced by Saleem *et al*. in 2007 and Akshaya *et al*. in 2022 [1].

However, it's worth noting that certain traits exhibit either negligible or mixed positive and negative, but relatively low, indirect effects on seed yield, rendering them of limited consequence in this context. The residual factor estimates of 0.0347, as determined in this path analysis, attests to the relatively modest impact of these remaining factors on the overall equation of maize grain yield.

Conclusions

Maize stands as a crucial cereal crop, not only offering significant nutritional value but also boasting high protein content. In the face of a rapidly growing population and a swiftly evolving environment, the demand for high-yielding and stress-resistant maize varieties has never been greater. In this pursuit, the tools of correlation and path coefficient analysis play a pivotal role, serving as indispensable parameters for the efficient selection of such coveted maize strains. Our investigation reveals compelling associations between various traits and grain yield per plant. Notably, a highly positive and statistically significant correlation is observed between grain yield and cob length. This is closely followed by correlations with 100-seed weight, the number of tassel branches, the count of kernels per row, protein content, the number of leaves per plant, cob diameter, and the number of kernel rows per cob. Conversely, negative associations are noted with leaf length, leaf width, days to 50% silking, and days to maturity. Delving deeper into the direct impact on grain yield per plant, we find that the number of tassel branches per plant exerts the most substantial positive effect, closely trailed by the number of kernels per row, the number of kernel rows per cob, 100-seed weight, and cob diameter. Furthermore, leaf width exhibits a prominent positive indirect influence on grain yield per plant, mediated through the timing of 50% tassel flowering and the abundance of tassel branches. These intricate associations hold immense potential for harnessing hybridization techniques to enhance grain productivity and yield substantially.

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