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Research Article

Correlation and Path Coefficient Analysis of Yield and Yield Components of Quality Protein Maize (*Zea mays* L.) Hybrids at Jimma, Western Ethiopia

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Maize is one of the most important staple food crops in many parts of Ethiopia. However, it is not used extensively due to its poor nutritional quality and low productivity. It lacks two essential amino acids, namely, lysine and tryptophan. Knowledge of the interrelationships of grain yield and its various causal (contributory) components is very helpful to improve the efficiency of breeding programs using appropriate selection indices. This article reports the findings of a study conducted to determine the nature of relationships of grain yield and its contributing components and to identify those components with significant effects on yield with the intention of using them as selection criteria using path coefficient analysis (PCA). Therefore, PCA has shown that yield per hectare had a significant and positive phenotypic correlation with plant height, ear height, number of kernels per row, and 100-grain weight. Moreover, PCA had a significant and positive genotypic correlation with days to 50% tasseling, plant height, ear height, and 100-grain weight. The highest direct positive effect on yield per hectare was exhibited by ear height. The findings of this study showed that most genotypes are early maturing and are suitable for areas with short rainy seasons and prone to drought.

1. Introduction

Zea mays L. (*Poaceae*) is an important annual food crop of the world. It is the source of primary staple food as well as protein and calorie for millions of people in the world. Maize accounts for about 15 to 56% of the total daily calories in diets of people in several developing countries in Africa and Latin America, where animal protein is scarce and expensive [1]. It is produced for food among low-income families in Ethiopia and served in different dishes. Though several hundred million people depend on maize, its common (normal) variety lacks two essential amino acids, namely, lysine and tryptophan, which are required in the biosynthesis of proteins [2]. Therefore, the discovery of the recessive allele of the opaque-2 maize gene was a significant breakthrough in the alleviation of global protein deficiency.

The high level of lysine and tryptophan amino acids in the maize endosperm protein is due to the presence of the recessive allele of the opaque-2 gene in the genome of mutant maize [3]. This has created tremendous interest and enthusiasm in the scientific community for its potential in developing maize with superior protein quality. However, the gene was found to be closely associated with several undesirable traits. The opaque-2 maize kernels were dull and chalky, had 15 to 20% less grain weight, and were more susceptible to several diseases and insects [4], which led to the loss of interest among scientists to work on it. After several trials and systematic studies, breeders succeeded in finding modifier genes that produce the desirable hard endosperm phenotype in materials containing the recessive opaque-2 mutation. These agronomically acceptable and nutritionally enhanced materials later came to be known as quality protein maize (QPM) [2, 5–7]. QPM contains nearly twice as much usable protein as other maize varieties grown in the tropics and yields 10% more grain than traditional maize varieties [2].

The principal goal of maize breeding programs is to develop new inbred and hybrid varieties that outperform the existing varieties with respect to many traits. In this pursuit, special attention is given to grain yield as the most important agronomic characteristic. Grain yield is a complex quantitative trait affected by a number of factors. Thus, the knowledge of interrelationships between grain yield and its contributing components improves the efficiency of breeding programs through the use of appropriate selection indices [8, 9]. Path coefficient analysis has been widely used in crop breeding programs to determine the nature of relationships between grain yield and its contributing components and to identify the components with significant effects on yield to be used as selection criteria. Path analysis shows the direct and indirect effects of cause variables on effect variables [10–12]. According to this method, the correlation coefficient between two traits is separated into the components that measure the direct and indirect effects. This article reports the findings of a study that aimed at looking into the phenotypic and genotypic correlations between grain yield and other morphological traits and evaluating the direct and indirect effects of morphological traits on grain yield.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted between July and October 2009 at the Eladalle research station of the Jimma University College of Agriculture and Veterinary Medicine (alt.: 1722 m; lat.: 7°33″0′N; and long.: 36°57″0′E). The mean maximum and minimum annual temperatures of the Eladalle research station are 26.8°C and 11.4°C, respectively. Likewise, the mean maximum and the minimum annual relative humidity (RH) of the station are 91.4% and 39.92%, respectively. It also has a mean annual rainfall of 951.5 mm. Its soil is reddish-brown clay soil with pH ranging from 5.07 to 6.0 [13].

2.2. Experimental Materials. The quality protein maize (QPM) hybrids used in this study were acquired from CIMMYT. The hybrids include 43 three-way hybrids and two checks (one commercial and another local). Details of materials are shown in Table 1.

2.3. Experimental Designs and Procedure. The materials were sown in the alpha lattice (5×9) with 5 plots per block with two replications in a 5 meters single row plot with the spacing of 0.75 meters between rows and 0.30 meters between plants. It may be argued that the number of replications is small. However, the efficiency of alpha-lattice design increases the precision of the experiment. All agronomic practices including land preparation, weeding, and fertilization were applied to all plots as per the standard practices for maize.

Table 1: List of QPM hybrids used in the study.

Entry	Name	Origin
1	CKH-08001	KB08B-0B20-1/2
2	CKH-08002	KB08B-0B20-21/22
3	CKH-08003	KB08B-0B20-23/24
4	CKH-08004	KB08B-0B20-27/28
5	CKH-08005	KB08B-0B20-31/32
6	CKH-08006	KB08B-0B20-33/34
7	CKH-08007	KB08B-0B20-35/36
8	CKH-08008	KB08B-0B20-39/40
9	CKH-08009	KB08B-0B20-41/42
10	CKH-08010	KB08B-0B20-45/46
11	CKH-08011	KB08B-0B20-47/48
12	CKH-08012	KB08B-0B20-49/50
13	CKH-08013	KB08B-0B20-51/52
14	CKH-08014	KB08B-0B20-55/56
15	CKH-08015	KB08B-0B20-59/60
16	CKH-08016	KB08B-0B20-61/62
17	CKH-08017	KB08A-0A51-1/2
18	CKH-08018	KB08A-0A51-3/4
19	CKH-08019	KB08A-0A51-5/6
20	CKH-08020	KB08A-0A51-9/10
21	CKH-08021	KB08A-0A51-13/14
22	CKH-08022	KB08A-0A51-15/16
23	CKH-08023	KB08A-0A51-17/18
24	CKH-08024	KB08A-0A51-19/20
25	CKH-08025	KB08A-0A51-21/22
26	CKH-08026	KB08A-0A51-29/30
27	CKH-08027	KB08A-0A51-31/32
28	CKH-08028	KB08A-0A51-35/36
29	CKH-08029	KB08A-0A51-37/38
30	CKH-08030	KB08A-0A51-43/44
31	CKH-08031	KB08A-0A51-51/52
32	CKH-08032	KB08A-0A51-53/54
33	CKH-08033	KB08A-0A49-9/10
34	CKH-08034	KB08A-0A49-17/18
35	CKH-08035	KB08A-0A49-21/22
36	CKH-08036	KB08A-0A49-23/24
37	CKH-08037	KB08A-0A49-25/26
38	CKH-08038	KB08A-0A49-41/42
39	CKH-08039	KB08A-0A49-43/44
40	CKH-08040	KB08A-0A49-27/28
41	QPMHYB1	KB07B-0B37-1/2
42	QPMHYB2	KB07B-0B35-1/2
43	QPMHYB3	KB08B-0B20-71/71
44	WH403	WS
45	BH-660	–

2.4. Data Sources and Analyses. Data for days to 50% tasseling, plant count, and grain yield of the hybrids were collected based on the whole plot. Likewise, data for plant height, ear height, number of kernel-rows per ear, and number of kernels per row were taken based on five randomly selected plants. Finally, 100-kernel weight was taken from composite seeds of all the plants from the plots after removing the plants at the ends of the rows. Their mean performances are given in Table 2. Phenotypic and genotypic correlations and path coefficient analysis were analyzed using GENRES Version 7.01. Phenotypic correlation (the observable correlation between two variables that include genotypic and environmental components) and genotypic correlation were computed using GENRES using the method described in Singh and Chaudhry [14] as

Table 2: Mean performance of QPM hybrids evaluated at the College of Agriculture and Veterinary Medicine (Jimma University, Ethiopia) for different characters.

Entry	Name	TS	PH	EH	PC	NRE	NKR	HGWt	Yield
1	CKH-08001	82.00^{ba}	156.80	58.40^{l}	14.50^{cb}	14.00	29.80	24.05	20.80^{h}
2	CKH-08002	79.00^{b-g}	173.90	84.80^{b-k}	12.00^{b-e}	13.00	31.30	27.15	33.88^{c-h}
3	CKH-08003	77.50^{b-g}	174.20	68.00^{ij}	12.50^{b-e}	14.00	30.30	22.00	26.03^{f-h}
4	CKH-08004	80.50^{b-d}	181.80	79.80^{c-k}	14.00^{b-d}	14.80	27.90	27.25	27.03^{f-h}
5	CKH-08005	75.50^{c-h}	198.10	91.28^{b-g}	15.00^{b}	14.20	35.30	26.50	49.95^{b-e}
6	CKH-08006	74.50^{f-i}	206.30	93.80^{b-f}	14.00^{b-d}	13.40	32.20	28.80	35.00^{c-h}
7	CKH-08007	73.50^{g-i}	204.00	96.80^{b-d}	14.00^{b-d}	16.80	33.60	22.85	37.12^{c-h}
8	CKH-08008	78.50^{b-g}	188.10	80.50^{c-k}	15.00^{b}	14.80	34.10	28.25	32.39^{c-h}
9	CKH-08009	76.50^{b-h}	185.50	88.40^{b-i}	12.50^{b-e}	14.60	33.60	26.65	39.86^{c-h}
10	CKH-08010	79.00^{b-g}	176.10	68.10^{ij}	13.00^{b-e}	14.25	35.25	33.95	30.15^{e-h}
11	CKH-08011	78.50^{b-g}	170.80	70.20^{g-j}	12.00^{b-e}	14.20	34.50	27.25	27.16^{f-h}
12	CKH-08012	77.50^{b-g}	192.80	87.30^{b-i}	12.50^{b-e}	14.60	36.50	29.05	39.36^{c-h}
13	CKH-08013	76.00^{c-h}	188.70	77.50^{d-j}	14.50^{bc}	13.60	34.30	29.55	34.13^{c-h}
14	CKH-08014	78.50^{b-g}	187.90	84.80^{b-i}	13.00^{b-e}	14.80	30.30	22.00	24.17^{gh}
15	CKH-08015	77.00^{b-g}	199.30	88.20^{b-i}	13.00^{b-i}	14.20	34.20	28.20	35.12^{c-h}
16	CKH-08016	71.00^{hi}	184.20	79.70^{c-k}	14.50^{bc}	14.40	32.80	29.35	42.23^{c-h}
17	CKH-08017	76.00^{c-h}	184.20	77.30^{d-j}	14.00^{b-d}	14.80	33.60	28.75	30.15^{e-h}
18	CKH-08018	78.00^{c-g}	171.00	70.80^{g-j}	13.50^{b-d}	15.40	29.60	24.05	29.52^{e-h}
19	CKH-08019	70.00^{i}	189.30	83.80^{b-i}	13.00^{b-e}	13.60	34.10	26.65	30.76^{c-h}
20	CKH-08020	80.00^{c-f}	195.60	94.80^{b-e}	12.50^{b-e}	15.20	33.80	27.05	47.83^{b-g}
21	CKH-08021	77.00^{b-g}	192.70	79.50^{c-k}	14.50^{bc}	14.00	33.80	29.30	27.77^{c-h}
22	CKH-08022	81.00^{b-d}	187.90	79.40^{c-k}	12.00^{b-e}	15.00	32.70	26.00	31.76^{c-h}
23	CKH-08023	75.00^{c-h}	196.70	95.50^{b-e}	14.00^{b-e}	13.60	34.50	34.25	53.18^{bc}
24	CKH-08024	76.50^{b-h}	206.20	99.90^{b}	12.50^{b}	14.40	31.60	28.20	43.97^{b-g}
25	CKH-08025	76.50^{b-h}	187.80	85.60^{b-i}	15.00^{b}	14.60	32.30	27.50	29.39^{e-h}
26	CKH-08026	76.50^{b-h}	196.60	89.40^{b-h}	11.00^{b-e}	14.80	29.50	23.40	33.01^{c-h}
27	CKH-08027	77.50^{b-g}	199.40	85.20^{b-i}	14.50^{cb}	14.00	34.70	29.15	37.87^{c-h}
28	CKH-08028	76.00^{c-h}	199.10	88.30^{b-i}	12.00^{b-e}	14.00	31.50	24.85	36.62^{c-h}
29	CKH-08029	81.50^{a-c}	182.60	76.20^{d-j}	12.50^{b-e}	14.40	37.70	26.65	31.89^{c-h}
30	CKH-08030	81.00^{b-d}	184.70	78.60^{d-j}	12.50^{b-e}	14.60	35.40	26.15	37.87^{c-h}
31	CKH-08031	77.50^{b-g}	186.80	81.20^{b-i}	10.00^{e}	14.20	34.00	27.60	47.71^{c-g}
32	CKH-08032	77.00^{b-g}	199.20	101.50^{b}	13.50^{b-d}	13.40	31.90	30.10	35.88^{c-h}
33	CKH-08033	80.50^{b-d}	163.60	68.30^{h-j}	13.50^{b-d}	13.60	31.90	26.30	24.79^{gh}
34	CKH-08034	78.50^{b-g}	188.00	84.00^{b-i}	13.00^{b-e}	12.80	32.30	27.85	26.41^{f-h}
35	CKH-08035	75.50^{c-h}	205.80	82.10^{b-i}	11.50^{c-e}	13.60	37.40	28.00	31.39^{c-h}
36	CKH-08036	76.50^{b-h}	202.60	92.50^{b-f}	14.50^{cb}	14.60	30.90	25.55	33.38^{c-h}
37	CKH-08037	78.00^{b-g}	174.80	73.50^{f-j}	14.50^{cb}	14.80	29.90	23.30	27.41^{e-h}
38	CKH-08038	74.50^{f-i}	192.90	88.10^{b-i}	14.00^{b-d}	15.60	35.20	29.90	52.44^{b-d}
39	CKH-08039	74.50^{f-i}	191.50	78.20^{b-j}	12.50^{b-e}	13.80	33.40	26.75	34.384^{c-h}
40	CKH-08040	73.50^{g-i}	203.80	95.80^{b-d}	13.00^{cb}	14.20	34.10	33.00	61.54^{b}
41	QPMHYB1	77.00^{b-g}	187.30	77.90^{d-j}	14.00^{b-d}	14.00	32.30	24.95	26.03^{f-h}
52	QPMHYB2	79.50^{b-f}	168.70	77.00^{d-j}	14.00^{b-d}	14.20	34.30	25.50	30.64^{c-h}
43	QPMHYB3	78.00^{c-g}	177.50	74.50^{e-j}	14.00^{b-d}	14.40	30.30	28.90	24.54^{gh}
44	WH403	77.50^{b-g}	188.20	83.90^{b-i}	13.00^{b-e}	14.40	34.70	28.45	42.10^{b-h}
45	BH-660	86.50^{a}	261.40	147.20^{a}	24.00^{a}	—	—	42.90	106.76^{a}
	Mean	77.37	189.67	84.17	13.52	14.31	37.7	27.64	36.48
	CV (%)	3.07	8.62	10.28	12.16	6.78	9.70	13.67	30.26
	LSD (0.05)	2.05	NS	17.72	3.37	NS	NS	NS	22.61

NS: nonsignificant; TS: days to 50% tasseling; PH: plant height; EH: ear height; PC: plant count; NRE: number of kernel-rows per ear; NKR: number of kernels per row; HGWt: hundred-grain weight. Means in the same column with the same letter are not statistically different at $p \leq 0.05$.

$$r_p = \frac{p\mathrm{cov}\, x \cdot y}{\sqrt{\delta^2 px \cdot \delta^2 py}},$$
$$r_g = \frac{g\mathrm{cov}\, x \cdot y}{\sqrt{\delta^2 gx \cdot \delta^2 gy}}, \quad (1)$$

where r_p and r_g are phenotypic and genotypic correlation coefficients, respectively; p cov $x \cdot y$ and $g\mathrm{cov}\, x \cdot y$ are phenotypic and genotypic covariances between variables x and y, respectively; $\delta^2 px$ and $\delta^2 gx$ are phenotypic and genotypic variances, respectively, for variable x; and $\delta^2 py$ and $\delta^2 gy$ are phenotypic and genotypic variances, respectively, for variable y.

2.5. Path Coefficient Analysis. Path coefficient analysis was computed as suggested by Dewey and Lu [15] by using genotypic correlation coefficients as

$$r_{ij} = P_{ij} + \sum r_{rk} P_{kj}, \quad (2)$$

where r_{ij} denotes the mutual association between the independent character i (yield-related trait) and dependent character j (grain yield) as measured by the genotypic correlation coefficients; P_{ij} refers to the components of direct effects of the independent character i on the dependent character j as measured by the path coefficients; and $\sum r_{ik} P_{kj}$ refers to the summation of components of indirect effects of a given independent character i on a given dependent character j via all other independent characters k. The contribution of the remaining unknown characters is measured as the residual as given by

$$P_R = \sqrt{\left(1 - \sum P_{ij} r_{ij}\right)}. \quad (3)$$

3. Results and Discussion

3.1. Phenotypic and Genotypic Correlations. Phenotypic and genotypic correlations among the traits considered in the study are presented in Table 3. In the following, the implications of the data generated by the analyses are provided.

3.2. Phenotypic Correlation. Study of the values of the phenotypic correlation coefficients indicated in Table 3 below the diagonal line shows that grain yield per hectare gave a positive phenotypic correlation with all traits except days to 50% tasseling and plant count. Grain yield has the highest statistically significant correlations with plant height ($rp = 0.697$; $p \leq 0.01$) followed by number of kernels per row ($rp = 0.626$; $p \leq 0.01$), ear height ($rp = 0.440$; $p \leq 0.05$), and 100-grain weight ($rp = 0.436$; $p \leq 0.05$). Some researchers reported similar observations, e.g., [11, 16–22]. The researchers observed that plant height, ear aspect, ear height, ear length, grains per row, and 100-grain weight or grain yield were positively and significantly inter-correlated implying that hybrids with these traits possess high yield potential.

The highest positive phenotypic correlation was observed between plant height and ear height ($rp = 0.788$; $p \leq 0.01$). Similar observation was reported by several researchers [19–23]. These observations indicate that improvements in each of the traits would lead to overall improvements of the genotypes. Such correlations help in making reasonable decisions in selecting traits controlled by multiple genes. Grain yield, as a quantitative trait, is polygenically controlled [24]. These findings imply that effective yield improvement depends on simultaneous improvements in all yield components. In fact, selection efforts based on grain yield alone are often less effective and efficient [9]. Selections need to be made based on various traits of the crop at hand.

3.3. Genotypic Correlation. Observation of genotypic correlation coefficients shows that all traits examined in our study have a positive correlation with yield per hectare except plant count and number of kernel-rows per ear (Table 3). Traits that showed high genotypic correlations with grain yield per hectare are plant height ($rg = 0.873$; $p \leq 0.01$), ear height ($rg = 0.698$; $p \leq 0.01$), days to 50% tasseling ($rg = 0.585$; $p \leq 0.01$), and 100-grain weight ($rg = 0.506$; $p \leq 0.01$). Similar findings were reported elsewhere [9, 24, 25]. On the contrary, significant and negative genotypic correlation was observed between yield per hectare and number of kernel-rows per ear ($rg = 0.744$; $p \leq 0.01$). This finding is contrary to the findings of some researchers [26, 27]. The fact that the higher number of kernel-rows per ear does not correlate with yield may imply that the kernels are smaller and lighter. It is helpful to note that the number of rows per ear and the number of grains per row of the local check were not studied.

In general, genotypic correlations among traits affecting grain yield explain true association as they exclude the environmental influences. It can be suggested that improvements in grain yield of maize can be accomplished through selections based on these correlations. Hence, knowledge of associations between yield and its component traits as well as among the component traits themselves can promote the efficiency of selection in maize breeding programs. In fact, it is well established that correlation studies between yield and yield components are pre-requisite in planning effective breeding programs. The same is true with maize breeders [27]. Quantitative traits like grain yield express themselves in close association with many other traits. Change in the expression of one trait is usually associated with changes in the expression of many other traits. Therefore, the correlations obtained in the present study are useful in the selection of traits having direct and significant correlation in improving grain yield.

3.4. Path Coefficient Analyses. Results of path coefficient analysis of all other traits to grain yield per hectare are given in Table 4 and Figure 1. The results of path coefficient analysis revealed that all the characters studied except plant height, plant count, and number of kernel-rows per ear had positive direct effects on grain yield. The highest direct positive effect on yield per hectare was exhibited by ear height (0.6514). This implies that higher ear height leads to increased grain yield; the genotypic correlation between ear height and grain yield ($rg = 0.698$; $p \leq 0.01$) is predominately attributed to the direct effect ($rg = 0.651$; $p \leq 0.01$) of ear height on the grain yield per hectare (Figure 1). Many research findings were in line with this finding [12, 28, 29]. Similarly, it is also in agreement with the findings of Asrar-ur-Rehman et al. [23] and Bello et al. [24]. These researchers reported positive and significant direct effects of ear length and thousand-kernel weight on grain yield. However, the finding of the present study contradicts with the findings of Rafiq et al. [25].

Days to 50% tasseling has yielded the next highest and direct effect on grain yield (0.245). It is stated above that the genotypic correlation between the traits is positive and statistically significant ($rg = 0.585$; $p \leq 0.01$). The correlation explains the true relationship between the two traits; thus,

Table 3: Genotypic and phenotypic correlation coefficients among the traits.

Traits	TS	PH	EH	PC	NRE	NKR	HGWt	Yield
TS	—	−0.490	−0.176	−0.120	−0.204	−0.347	0.334*	0.585**
PH	−0.274	—	0.579**	0.412*	−0.218	0.374*	0.205	0.873**
EH	−0.331	0.786**	—	−0.094	0.286	−0.079*	−0.140	0.698**
PC	−0.130	−0.164	−0.031	—	0.683**	0.321	0.789**	0.242
NRE	−0.140	0.146	−0.074	−0.483*	—	−0.698	−0.613**	−0.744**
NKR	−0.151	0.546**	0.481*	−0.088	0.405*	—	0.719**	−0.233
HGWt	−0.363	0.162	0.210	0.166	−0.085	0.280	—	0.506**
Yield	−0.244	0.697**	0.448*	−0.040	0.323	0.626**	0.626**	—

*Statistically significant correlation at $p \leq 0.05$; **statistically significant correlation at $p \leq 0.01$; TS: days to 50% tasseling; PH: plant height; EH: ear height; PC: plant count; NRE: number of kernel-rows per ear; NKR: number of kernels per row; HGWt: hundred-grain weight.

Table 4: Direct (boldface) and indirect effects of different traits on grain yield.

Traits	TS	PH	EH	PC	NRE	NKR	HGWt	*rg*
TS	**−0.023**	−0.013	0.074	0.330	0.262	0.113	0.161	0.585**
PH	0.099	**−0.213**	0.930	0.530	0.396	0.506	0594	0.873**
EH	0.070	−0.372	**0.700**	0.570	0.099	−0.217	0.095	0.698**
PC	0.212	−0.367	0.618	**−0.041**	0.110	−0.230	0.095	−0.242
NRE	−0.208	0.308	−0.526	0.183	**0.205**	0.222	−0.099	−0.744**
NKR	−0.159	0.306	−0.580	0.192	−0.111	**0.176**	−0.078	0.233
HGWt	0.055	−0.104	0.453	−0.117	0.120	−0.057	**0.338**	0.506**

Residual: 0.204; TS: days to 50% tasseling; PH: plant height; EH: ear height; PC: plant count; NRE: number of kernel-rows per ear; NKR: number of kernels per row; HGWt: hundred-grain weight.

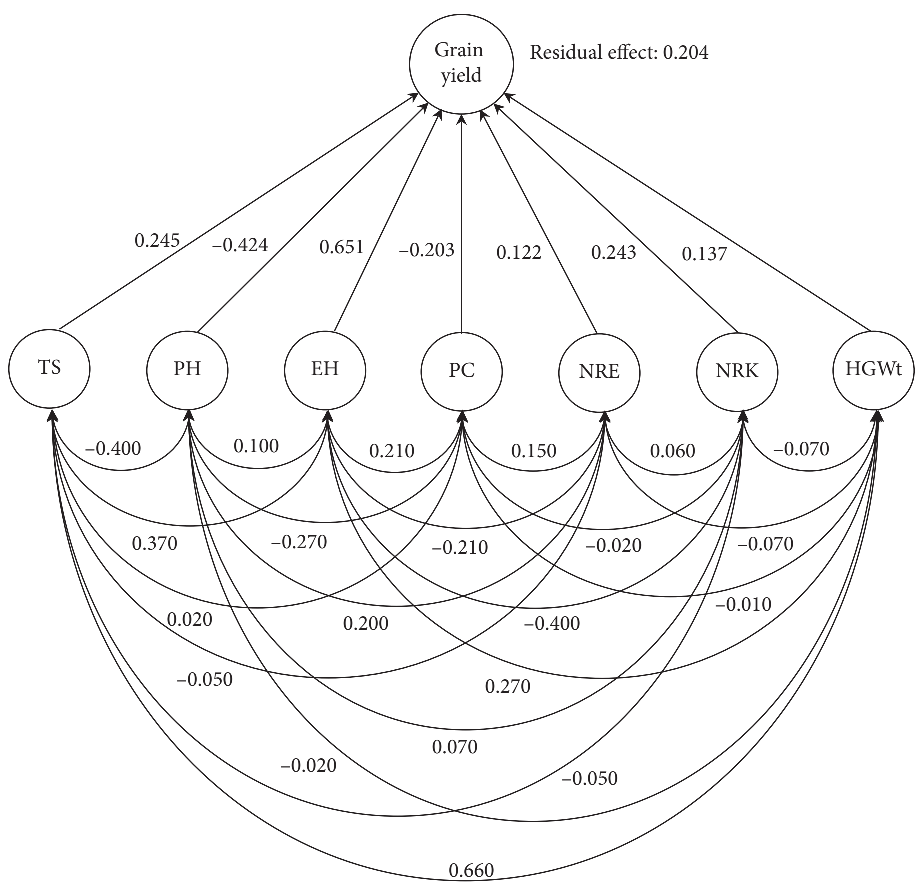

Figure 1: Average genotypic path coefficient diagram representing cause and effect relationships among quantitative traits and grain yield (TS: days to 50% tasseling; PH: plant height; EH: ear height; PC: plant count; NRE: number of kernel-rows per ear; NKR: number of kernels per row; HGWt: hundred-grain weight).

selection based on days to 50% tasseling would be effective. This is in contrast with the findings of Arsode et al. [28] who reported significant negative association of days to 50% tasseling with grain yield per plant and plant height, ear length, ear girth, number of kernel-rows per ear, and number of kernels per row.

Plant count showed negative direct effect on grain yield (−0.041) like its genotypic correlation with grain yield (−0.242), implying that there is true association of the two traits. However, plant count yielded high positive indirect effect on grain yield through ear height (0.570). Likewise, number of kernel-rows per ear and number of kernels per row showed higher positive indirect effect on grain yield through plant height. These results are in line with the reports of different authors [10–12, 30]. The negative and significant genotypic correlation between number of kernel-rows per ear and grain yield ($rg = -0.744$; $p \leq 0.01$) explains the true relationship of the traits. Plant height resulted in high and negative direct effect on grain yield (−0.424). Other researchers have reported similar findings [25, 32]. However, we observed highest and significant genotypic correlation between plant height and grain yield ($rg = 0.873$; $p \leq 0.01$). This may be due to the indirect effect of plant height on ear height. Thus, we recommend that selection based on plant height is made cautiously. We also observed that 100-grain weight had positive and significant direct effect on the grain yield as indicated in Table 4 (0.338; $rg = 0.506$; $p \leq 0.01$). Other studies reported similar results [33, 34]. The correlations and intercorrelations show that the seven causal traits (i.e., the causal variables) explain much of the variability in grain yield. In fact, a residual effect of 0.204 (Figure 1) implies that the causal traits explained about 79.6% of the variability in the grain yield, leaving 20.4% of the variability unexplained.

4. Concluding Remarks

Genotypic correlation coefficients showed that all the traits considered in our study have positive correlation with yield per hectare except plant count and number of kernel-rows per ear. Plant height, ear height, days to 50% tasseling, and 100-grain weight showed high genotypic correlations with grain yield per hectare. Genotypic correlations among traits affecting grain yield explain the true association as they exclude any environmental influences. Hence, it can be concluded that plant height, ear height, days to 50% tasseling, and 100-grain weight are the best traits for selection to improve grain yield per hectare of the maize genotypes tested in our study.

Data Availability

Data used in preparing this manuscript is available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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