

Interrelationship and Path Analysis of Yield Components in Tef [*Eragrostis tef*) Zucc. Trotter] Genotypes at Axum Northern Ethiopia

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Abstract
Understanding the nature of correlations among characters facilitates selection. The present study was undertaken to assess the nature of association of agronomic traits in 37 tef recombinant inbred lines. The experiment was conducted in 2014 main cropping season at Axum Agricultural Research Center using randomized complete block design with three replications. Correlation and path coefficient analyses were conducted for thirteen traits at genotypic and phenotypic levels. The result reviled that grain yield production rate per day (0.94, 0.934) followed by biomass yield kg ha^{-1} (0.831, 0.865) at both phenotypic and genotypic level respectively was computed highest positive and significant correlation with grain yield kg ha^{-1}. Twelve traits also considered in the path analysis. Base on its highest positive significant correlation, grain yield production rate per day exerted high positive genotypic direct effect (0.845) followed by biomass yield (0.342) on grain yield, respectively. This indicated that attention should be given for these traits in selection as these traits are helpful for direct selection. Highest unfavorable genotypic indirect effect was exerted on grain yield by Grain yield production rate per day through days to maturity. The overall study showed that grain yield production rate per day (0.845) and biomass yield (0.342) can be used as morphological markers for grain yield.
Keywords: Correlation, Path coefficient and Tef.

1. Introduction

Tef *(Eragrostis tef (*Zucc.) Trotter*)* is originated and diversified in Ethiopia (Vavilov, 1951). It is

Tef is a self-pollinated and chasmogamous annual plant. Unlike wheat, barley and rice, which are all C3 plants, tef along with maize and sorghum is a C4 plant having Krannz- type leaf anatomy with the vascular bundles surrounded in a circular manner by bundle sheath cells consisting of high concentration of chloroplasts, and depicting low CO_2 compensation point of the leaves which is typical of C_4 as opposed to C_3 species (Kebede *et al.*, 1989).

In Ethiopia, tef can be grown below sea level to 3,000 meter above sea level, indicating that the crop has great flexibility and plasticity in growing over a wide range of agronomic and edaphic conditions and under various rainfalls, temperature and soil regimes. It is unique in its ability to grow and yield on poorly drained Vertisols which most cereals cannot tolerate. Unlike other cereals, the seed of tef has better keeping quality under local storage conditions without losing viability since the grains are resistant to attack by storage pests (Ketema, 1997). This cereal crop takes 25-81 days to emerge the panicle tip, 60-140 days to mature and 29-76 days for the reproductive phase or grain filling period from panicle emergence to maturity (Assefa, 2001)

Tef is grown in almost all regions of Ethiopia since it is the preferred grain for local consumption, highly valued by farmers and consumers and earns the highest grain price compared with other cereals (Ketema, 1997). Tef grain is also a rich source of protein and nutrients and has additional health benefits including that the seeds are free from gluten (Spaenij-Dekking *et al*., 2005). Recently, Cannarozzi *et al.* (2014) has supported this fact by results from the genome sequence initiative. According to a recent study, the bio-available iron content was significantly higher in tef bread than in wheat bread (Alaunyte *et al*., 2012).

Despite its greater economic value and coverage of large area, the productivity of tef is relatively low in the country mainly due to the low yielding ability of unimproved local cultivars and other biotic and abiotic factors (Assefa et al., 2011). Determination of the interrelationships between various agronomic traits and their direct and indirect effect on grain yield could provide good information necessary for breeders in improving the productivity tef and also a pre- requisite to plan a meaningful breeding program.

The association among traits can be measured by genotypic and/or phenotypic coefficients of correlation. The path coefficient analysis is used to partition the correlation coefficients in to direct and indirect effects and to clarify the relationship between different morphological characters with the grain yield. In path coefficient analysis, grain yield is considered as dependent variable and the remaining traits are considered as independent variables (Singh and chaundhary, 1977). Therefore, the present study was to assess the correlation between different agronomic traits and their direct and indirect effect on grain yield of tef.

2. Materials and methods

2.1. Experimental Site: The field experiment was conducted at Axum Agricultural Research Center during 2014 main cropping season. The experimental site is located 250 Km North West of Mekelle and 1024km North of Addis Ababa at a latitude of 13^0 15' N, longitude of 38^0 34' E and an altitude of 2148 meter above sea level.

2.2. Experimental Materials: a total of 34 tef recombinant inbred lines (RILs), two improved varieties (Quncho and Kora) along with one local check were evaluated in randomized complete block design with three replications. The 34 RILs were randomly taken from hundreds of RILs at the seventh filial generation from the National Tef Research Project of Debre Zeit Agricultural Research Center (DZARC). A 2.5 m by 1.2 m standard plot size each with six rows having 0.2 m spacing between rows was used. The spaces between plots and replications were 1 m and 1.5 m, respectively. Sowing was done by manual drilling along the rows at a seed rate of 1.5 g per row on the basis of 25 kg/ha recommended rate. Fertilization was also done on a rate of 100/100 N/P O kg ha^{-1}. All the DAP and 50% of Urea were applied at planting and the remaining 50% of the Urea at tillering. Land preparation and all other agronomic practices were at their optimum.

2.3. Data Collected: Data were collected from the14 quantitative traits based on plot and plot bases. Data on days to heading, days to maturity, biomass yield, grain yield, harvest index, and lodging index were assessed on plot basis of the four middle rows. Derived data like harvest index, biomass production rate per day and grain yield production rate per day was calculated as a ratio of grain yield to shoot biomass, above ground biomass yield to days to physiological maturity and grain yield to physiological maturity, respectively. On the other hand, plant height, panicle length, panicle weight, number of fertile titters per plant and thousand kernel weight were recorded on previously selected and tagged ten random samples of plants from the central four middle rows of each plot. Mean values of the ten random samples of plants per plot of the four middle rows were then used for the analyses of data collected on individual plant basis.

2.4. Data Analysis: The phenotypic and genotypic correlation coefficients were calculated using the formula

$$r_{xy} = \frac{PCOVxy}{\sqrt{\sigma^2 Px * \sigma^2 Py}}$$

Coefficients of correlation at phenotypic level were tested for significance using the formula described by Robertson (1959) indicated below.

$$t = \frac{r}{\sqrt{(1-r^2)/n-1}}$$

at (n-2) degree of freedom, where 'n' is number of genotypes while the genotypic correlation coefficients were tested with the following formula described by

$$t = \frac{rg_{xy}}{SErg_{xy}}$$

where SE (rgxy) $= \sqrt{\frac{1-rg_{xy}^2}{2*h_x^2*h_y^2}}$ and h^2_x and h^2_y are the respective broad sense heritability values of traits x and y.

The path coefficients were estimated following the method used by Dewey and Lu (1959) Rij = $Pij + \sum r_{ik} p_{jk}$

Where: Rij = Mutual association between independent variable (i) and dependent variable (j) as measured by genotypic correlation coefficient. Pij = component of direct effect of independent variable (i) on the dependent variable (j) as measured by the genotypic path coefficient and $\sum rik * pjk$ = summation of components of indirect effects of a given independent variable (i) on a given dependent variable (j) via all other independent variables. The residual factor was estimated as described in Singh and Chaudhary (1985) 1= $p^2r + \sum pi\ Y^r iY$ where i = any trait in the model, Y = dependant variable (grain yield) and r = correlation coefficient between any trait i and the dependant variable. Residual (R) is the square root of non determination; known as coefficient of alienation which measures the lack of association between variables (Sokal and Rohlf, 1995).

3. Results and discussion

3.1. Genotypic (r_g) and Phenotypic (r_p) correlation

***3.1.1.Correlation of grain yield with other traits*:** Besides on the mean of 34 tef Recombinant inbred lines, two improved varieties and one local check for 13 quantitative traits showed that about 74% of the total traits association showed genotypically positive association (Table 1). This positive correlation could be resulted from the presence of strong coupling linkage between their genes or the traits may be the result of pleiotropic genes that control these traits in the same direction indicated that improvement of these traits could improve grain yield (Ali *et al.*, 2009; Kearsey and Pooni, 1996). Similar finding were reported by Lule *et al.* (2012) for finger millet and Ayana (2001) for sorghum.

Grain yield (kg ha$^{-1)}$ showed positive and highly significant ($P \leq 0.01$) genotypic correlation with plant height (r_g = 0.349), biomass yield kg ha^{-1} (r_g = 0.865), lodging index (r_g = 0.482), biomass production rate per day (r_g = 0.855) and grain yield production rate per day (r_g = 0.934). Therefore, any improvement of these traits would result in a substantial increment on grain yield. This result is in light with Chanyalew (2010) also observed that ground biomass had positively and significantly correlated with grain yield.

On the other hand, grain yield had non-significant but positive genotypic correlation with days to heading (r_g = 0.016), yield per panicle (r_g = 0.229), number of productive tillers per plant (rg = 0.02), panicle weight (r_g = 0.203) and panicle length per plant (r_g = 0.04). This suggested that selection for these traits would not improve grain yield. However, grain yield had negative genotypic correlation with days to maturity. Indicating that selection of genotypes for delayed maturity might reduce grain yield where selection for early varieties would improve grain yield.

This result agrees with the finding of Van Ginkel *et al*. (1998).

Grain yield showed positive and highly signifcant ($P \leq 0.01$) phenotypic association with plant height (r_p = 0.322), biomass yield kg ha^{-1} (r_p=0.831), lodging index (r_p = 0.422), biomass production rate per day (r_p = 0.822) and grain yield production rate per day (r_p = 0.94). Ayalew *et al*. (2011) and Chanyalew *et al*. (2010) also reported positive and signifcant phenotypic association of grain yield with plant height, panicle length, and above ground biomass.

Plant height, lodging index, biomass yield, biomass production rate per day and grain yield production rate per day showed positive and highly significant correlation ($P \leq 0.01$) at both genotypic and phenotypic levels with grain yield while plant height showed positive and significant association at phenotypic and genotypic levels ($P \leq 0.05$). This indicated that selection for higher plant height, lodging index, biomass yield, biomass production rate per day and grain yield production rate per day would improve grain yield. Similar results were reported by Hundra *et al.* (2000) and Assefa *et al.* (2002). Plant height and grain yield per main panicle were also positively correlated with grain yield per plant in other study (Tefera, 1988).

Grain yield (kg ha^{-1}) exhibited a low magnitude of positive genotypic and phenotypic correlation coefficients with days to heading. However, grain yield had both negative genotypic and phenotypic correlation with days to maturity. Tefera (1988) and Assefa *et al.* (2002) also found that grain yield per plant was correlated negatively with days to maturity and harvest index. Grain yield had highest positive and significant genotypic correlation with grain yield production rate per day followed by biomass yield, biomass production rate per day, lodging index and plant height

***3.1.2. Phenotypic correlation among the component traits*:** The study indicated that days to maturity had negative and significant phenotypic association with panicle yield per plant (r_p=0.369), biomass production rate per day (r_p=-0.287) and grain yield production rate per day (r_p=-0.441) while non-significantly correlated with the rest of the traits.

Plant height showed highly significant correlation with panicle length (r_p=0.347), biomass yield (r_p=0.407), grain yield (r_p=0.322), biomass production rate per day (r_p=0.369) and grain yield production rate per day (r_p=0.271). Moreover, it was positively (r_p=0.216) and significantly associated with lodging index (r_p=0.216). This suggested that selection of genotypes for high plant height might increase panicle length, biomass yield, biomass production rate per day, grain yield production rate per day and lodging index. Biological yield depicted positive and significant correlation with plant height (r_p=0.407), lodging index (r_p=0.422), biomass production rate per day (r_p=0.956), grain yield production rate per day (r_p=0.756), whereas it was negatively and significantly associated with harvest index. Similar with the present finding ground biomass observed was also phenotypically to have positive and significant correlation with plant height (Hunrda *et al*., 2000, Chanyalew *et al*., 2010 and Ayalneh *et al*., 2012).

Harvest index showed negative and significant correlation with biomass yield (r_p=-0.531), plant height (r_p=-0.267) and biomass production rate per day (r_p=-0.473). This suggested that selection of genotypes for high harvest index might lower biomass yield and plant height. However, Harvest index had positive and highly significant phenotypic correlation with number of tillers per plant. Panicle length had positively and significantly associated with plant height, panicle yield per plant, number of tillers per plant, panicle weight per plant and non-significantly with the rest of the traits. This is consistent with Debebe *et al*. (2014) who reported panicle length positively and significantly associated with plant height.

Lodging index showed positive and significant association with plant height (r_p=0.216), panicle weight per plant (r_p=0.213), panicle yield per plant (r_p=0.244) and biomass yield (r_p=0.424) in agreement with Mewa *et al*. (2013) and Chanyalew *et al*. (2006) also found similar results.

***3.1.3. Genotypic correlation among the component traits*:** Panicle length showed positive and significant correlation with plant height (0.347), number of tillers per plant (r_g=0.208), panicle weight per plant (r_g=0.389) and panicle yield per plant (r_g=0.222), while it had non-significant correlation with the rest of the traits. Mewa *et al*. (2013) also reported that panicle length showed positive genotypic correlation with plant height and lodging index. Panicle weight per plant had positive and significant correlation with panicle length (r_g=0.389), number of tilles per plant (r_g=0.249), panicle yield (r_g=0.767), lodging index (r_g=0.213) and grain yield production rate per day (r_g=0.190) and was insignificant with the rest traits. Biomass yield had positive and significant correlation with plant height (r_g=0.407), grain yield (r_g=0.831) lodging index (r_g=0.424), biomass production rate per day (r_g=0.965) and grain yield production rate per day (r_g=0.756) and negative and significant correlation with harvest index (-0.531). This is in line with the findings by of Ayalneh *et al*. (2012) in tef.

Harvest index had negative and significant correlation with plant height, biomass yield and biomass production rate per day and was positive and significant with number of tillers per plant. Lodging index showed positive and significant correlation with plant height, Panicle weight per plant, and panicle yield per plant, Biomass yield, biomass production rate per day and grain yield production rate per day. However, it had insignificant correlation with the other traits.

Biomass production rate per day observed positive and significant association with plant height (r_g=0.413), Biomass yield (r_g=0.954), grain yield (r_g=0.855), lodging index ($r_{g=}$0.463) and grain yield production rate per day (r_g=0.876) and but negative and correlation with day to maturity (r_g= -0.292) and negative significant correlation with harvest index (r_g=-0.519). Moreover, grain yield production rate per day showed negative and significant association with day to maturity (r_g=-0.434) but positive and significant association with panicle yield per plant (r_g=0.376), biomass yield (r_g=0.778), lodging index (r_g=0.454) and biomass production rate per day (r_g=0.876). **Table 1. Estimates of genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients for 13 traits of 37 genotypes studied at Laelay-Maichew district during 2014.**

Trait	DH	DM	PH	PL	NT	PW	PY	BY	GY	HI	LI	BPR	GYPD
DH	1	0.18	-0.017	-0.032	-0.139	-0.179	-0.122	-0.007	0.016	0.027	-0.2	-0.06	-0.05
DM	0.167	1	0.058	-0.095	0.102	-0.248	-0.491**	0.006	-0.084	-0.132	-0074	-0.292	-0.434**
PH	0.012	0.065	1	0.41*	-0.057	0.007	-0.012	0.451**	0.349**	-0.363*	0.24	0.413*	0.295
PL	-0.011	-0.074	0.347**	1	0.084	0.368*	0.262	0.047	0.04	-0.075	0.108	0.075	0.065
NT	-0.054	0.082	0.001	0.208*	1	0.084	0.084	-0.105	0.02	0.228	0.386*	-0.139	-0.024
PW	-0.115	-0.164	0.075	0.389**	0.249**	1	0.813**	0.183	0.203	-0.036	0.326*	0.251	0.269
PY	-0.094	-0.369**	-0.004	0.222*	0.121	0.767**	1	0.171	0.229	0.043	0.328*	0.307	0.376*
BY	-0.018	0.005	0.407**	0.059	-0.078	0.131	0.133	1	0.865**	-0.587**	0.47**	0.954**	0.778**
GY	0.004	-0.075	0.322**	0.070	0.065	0.149	0.150	0.831**	1	-0.108	0.482**	0.855**	0.934**
HI	0.026	-0.107	-0.267**	-0.24	0.245**	-0.001	-0.001	-0.531**	0.022	1	-0.123	-0.519**	-0.05
LI	-0.171	-0.064	0.216*	0.083	0.186	0.213*	0.244*	0.424**	0.422**	-0.089	1	0.463**	0.454**
BPR	-0.066	-0.287**	0.369**	0.080	-0.103	0.174	0.232*	0.956**	0.822**	-0.473**	0.814**	1	0.876**
GYPD	-0.054	-0.411**	0.271**	0.088	0.030	0.190**	0.258**	0.756**	0.940**	0.057	0.402**	0.849**	1

DH = days to heading, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), NT = number of tillers per plant per plant, PW = panicle weight per plant per plant (g),YPP = yield panicle^{-1}(g) , BY = biomass yield(kgha^{-1}), GY = grain yield (kgha^{-1}), HI = harvest index, LI = lodging index, BPR = biomass production rate (kg ha-1 day-1), GYPG = grain yield production rate per day (kg ha-1 day-1), **,*= significant at 1% and5% level, respectively.

3.2. Path coefficient analysis: In this study, twelve characters were selected as casual variable and both the genotypic and phenotypic correlations were partitioned into direct and indirect effects using grain yield as a dependent variable was shown in (Tables 2 and 3) a cording to Dewey and Lu (1959).

3.2.1. Phenotypic direct and indirect effects of various traits on grain yield: Biological yield and grain yield production rate per day exerted highest direct effect on grain yield. However, biomass production rate per day followed by days to maturity, harvest index and lodging index had negative phenotypic direct effect on grain yield. Similarly, Chanyalew *et al.* (2006) also reported that shoot biomass has high and positive direct effect on grain yield of tef recombinant inbred lines. The magnitude of the direct effects that the two traits namely biological yield and grain yield production rate per day exerted, were higher than their of the phenotypic correlation coefficients with grain yield. This justifies that the correlation explains the true relationships and selection through this trait will be effective.

Table 2. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at phenotypic level of twelve traits on grain yield in 37 tef genotypes tested at Laelay-Maichew district 2014.

Trait	DH	DM	PH	PL	NT	PW	PY	BY	HI	LI	BPR	GYPD	rp
DH	**-0.010**	-0.109	0.000	0.000	0.002	-0.003	0.002	-0.063	-0.011	0.002	0.298	-0.102	0.004
DM	-0.002	**-0.654**	-0.002	-0.001	-0.002	-0.005	0.006	0.018	0.046	0.001	1.294	-0.774	-0.075
PH	0.000	-0.043	**-0.025**	0.003	0.000	0.002	0.000	1.427	0.114	-0.002	-1.664	0.511	0.322**
PL	0.000	0.048	-0.009	**0.008**	-0.006	0.011	-0.004	0.207	0.010	-0.001	-0.361	0.166	0.070
NT	0.001	-0.054	0.000	0.002	**-0.030**	0.007	-0.002	-0.273	-0.105	-0.002	0.464	0.057	0.065
PW	0.001	0.107	-0.002	0.003	-0.007	**0.029**	-0.013	0.459	0.000	-0.002	-0.785	0.358	0.149
PY	0.001	0.241	0.000	0.002	-0.004	0.022	**-0.017**	0.466	0.000	-0.002	-1.046	0.486	0.150
BY	0.000	-0.003	-0.010	0.000	0.002	0.004	-0.002	**3.505**	0.227	-0.004	-4.311	1.424	0.831**
HI	0.000	0.070	0.007	0.000	-0.007	0.000	0.000	-1.861	**-0.427**	0.001	2.133	0.107	0.022
LI	0.002	0.042	-0.005	0.001	-0.006	0.006	-0.004	1.486	0.038	**-0.010**	-1.885	0.757	0.422**
BPR	0.001	0.188	-0.009	0.001	0.003	0.005	-0.004	3.351	0.202	-0.004	**-4.510**	1.599	0.822**
GYPD	0.001	0.269	-0.007	0.001	-0.001	0.005	-0.004	2.650	-0.024	-0.004	-3.829	**1.884**	0.940**

DH = days to heading, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), NT = number of tillers per plant per plant, PW = panicle weight per plant per plant (g),YPP = yield panicle^{-1}(g), BY = biomass yield(kgha^{-1}), GY = grain yield (kgha^{-1}), HI = harvest index, LI = lodging index, BPR=biomass production rate (kg ha-1 day-1), GYPG = grain yield production rate per day (kg ha-1 day-1)

Days to maturity exerted both negative direct effect on grain yield and it has also negative indirect effects through grain yield production rate per day. Therefore, the phenotypic correlation of this trait with grain yield was due to both the direct effect and the indirect effect through grain yield production rate per day. Whenever selection is made for improving grain yield, days to maturity accompanied by grain yield production rate per day should be considered. Chanyalew (2009) also reported negative correlation of days to maturity with grain yield resulted from both the direct and indirect negative effects. Harvest index had negative direct effect with grain yield. Hence its positive correlation with grain yield was mainly through the positive indirect effect of biomass production rate per day.

Lodging index exerted negative direct effect on and the positive phenotypic correlation with grain yield was mainly due to the favorable indirect counter balance through grain yield production rate per day and biomass yield. Biomass production rate per day exerted negative indirect effect on grain yield (kg ha^{-1}) through lodging index, days to maturity, biomass yield, harvest index and grain yield production rate per day. However, unfavorable direct and indirect effects outweighed the favorable indirect effects causing a positive correlation of biomass production rate per day with grain yield (rg = 0.822**).

Biomass yield, lodging index, biomass yield production rate per day and grain yield production rate per day were reported as the major contributor for phenotypic variation observed among the recombinant inbred lines.

3.2.2. Genotypic direct and indirect effects of various traits on grain yield: Genotypic path coefficient analysis showed positive direct effects of days to maturity, biomass yield, harvest index and grain yield production rate per day on grain yield whereas grain yield production rate per day and biomass yield showed the highest direct positive on grain yield. This indicated that emphasis should be given to grain yield production rate per day and biomass yield in the process of selection as these traits are helpful for direct selection. In this study, Harvest index also reported relatively low positive genotypic direct effects on grain yield. This is in contrary with the study reported by Lule and Mengstu (2014).

Table 3. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level of twelve traits on grain yield in 37 tef genotypes tested at Laelay-Maichew district 2014.

Trait	DH	DM	PH	PL	NT	PW	PY	BY	HI	LI	BPR	GYPD	**rg**
DH	**0.002**	0.051	0.000	0.000	-0.001	0.001	-0.001	-0.002	0.004	0.000	0.003	-0.042	0.016
DM	0.000	**0.285**	0.000	-0.001	0.001	0.001	-0.002	0.002	-0.019	0.000	0.015	-0.367	-0.084
PH	0.000	0.017	**0.001**	0.004	0.000	0.000	0.000	0.154	-0.052	-0.001	-0.022	0.249	0.349**
PL	0.000	-0.027	0.000	**0.010**	0.001	-0.002	0.001	0.016	-0.011	0.000	-0.004	0.055	0.040
NT	0.000	0.029	0.000	0.001	**0.007**	0.000	0.000	-0.036	0.033	-0.001	0.007	-0.020	0.020
PW	0.000	-0.071	0.000	0.004	0.001	**-0.004**	0.003	0.063	-0.005	-0.001	-0.013	0.227	0.203
PY	0.000	-0.140	0.000	0.003	0.001	-0.004	**0.004**	0.058	0.006	-0.001	-0.016	0.318	0.229
BY	0.000	0.002	0.000	0.000	-0.001	-0.001	0.001	**0.342**	-0.085	-0.001	-0.050	0.657	0.865**
HI	0.000	-0.038	0.000	-0.001	0.002	0.000	0.000	-0.201	**0.144**	0.000	0.027	-0.042	-0.108
LI	0.000	-0.021	0.000	0.001	0.003	-0.001	0.001	0.161	-0.018	**-0.002**	-0.024	0.384	0.482**
BPR	0.000	-0.083	0.000	0.001	-0.001	-0.001	0.001	0.326	-0.075	-0.001	**-0.052**	0.740	0.855**
GYPD	0.000	-0.124	0.000	0.001	0.000	-0.001	0.002	0.266	-0.007	-0.001	-0.046	**0.845**	0.934**

DH = days to heading, DM = days to maturity, PH = plant height (cm), PL = panicle length (cm), NT = number of tillers per plant per plant, PW = panicle weight per plant per plant (g), PY = yield panicle^{-1}(g), BY = biomass yield(kgha^{-1}), GY = grain yield (kgha^{-1}), HI = harvest index, LI = lodging index, BPR = biomass production rate (kg ha-1 day-1), GYPG = grain yield production rate per day (kg ha-1 day-1).

4. Conclusion

Genotypic correlations were found to be higher in magnitude than that of phenotypic correlations for the majority of the traits studied. This indicated that genetic factors played a major role in these associations among the majority of the traits. Grain yield (kg ha^{-1}) was found to be positively and significantly correlated with plant height, lodging index, biomass yield, biomass production rate per day and grain yield production rate per day both at phenotypic and genotypic level. Grain yield was also correlated positively with days to heading, panicle length, number productive tillers per plant, panicle weight per plant and yield per panicle.

Path coefficient analysis based on the correlation coefficient revealed that, the direct favorable effect of biomass yield kg ha^{-1} on grain yield. Plant height, biomass yield, biomass production rate per day and grain yield production rate per day were identified as the major contributor to grain yield. This implied that selection criteria that focused on these traits would have a tremendous value for yield improvement.

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