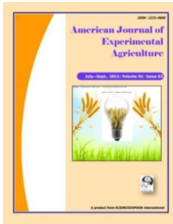

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Character Association and Path Analysis in Pearl Millet (*Pennisetum glaucum* L.)

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Research Article

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ABSTRACT

Fifteen genotypes of pearl millet (*Pennisetum glaucum* L.) were studied at two locations (Elrawakeeb and Shambat) of Sudan, during the years 2003 and 2004. The study was conducted to determine the interrelationship between yield and yield components and other quantitative traits, including days to 50%flowering, date to maturity, panicle length, dead part length/main head and plant height. The path analysis and phenotypic and genotypic correlation coefficients were calculated. The results showed that strong positive significant genotypic and phenotypic correlations were observed between grain yield/plant and harvest index (rp=0.754, rg=1.08), grain yield/plant and biomass dry weight (rp=0.639, rg=1.064) and grain yield/plant and number of seeds per panicle (rp=0.608, rg 0.820) and with other quantitative characters. However, grain yield/plant has negative association with days to 50% flowering, date to maturity and dead part length/main head. The path analysis indicated that number of fertile tillers/plant had the highest direct effect (0.512) on grain yield/plant. However, thousand-seed weight was greatly reduced by the negative indirect effects, through number of fertile tillers/plant and number of seeds/head. Based on the present results, it could be concluded that the number of fertile tillers/plant, number of seeds/head, thousand-seeds weight and panicle length/main head could be identified as the most important characters that associated with yield, and therefore can be used as selection criteria for yield improvement of pearl millet.

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Keywords: Genotypic correlation; phenotypic correlation; path coefficients; quantitative traits.

1. INTRODUCTION

Pearl millet (*Pennisetum glaucum* L.R.Br*)* is a diploid species (2n=14) believed to be originated in West Africa (Jauhar, 1981; Stoskopf, 1985). It is now widely cultivated in different parts of the world. Pearl millet is of great importance in the semi – arid tropics, where it is the stable food for millions of people. The crop is grown commonly under the most difficult farming conditions, including those in drought – stricken areas, where soil fertility is low and food supplies are dependent on rainfall. Pearl millet growing in areas suffers from erratic rainfall which has high variability within and between year (Vanderlip, 1991). In Sudan, pearl millet (*Pennisetum gluacum* L.) is the preferred staple food for the majority of inhabitants in Western Sudan (Kordofan and Darfur regions). Among the cereals, it comes second to sorghum in area and total production. The crop is mainly raised under traditional farming methods, where the rainfall is between 200 – 800 mm (Abuelgasim, 1999) and the average yield was 653 kg/ha (AOAD, 2008). The short rainy season and fluctuation in rainfall expose the crop to drought stress; therefore, there is a need to breed for drought tolerant and early maturing cultivars. Grain yield as a character in pearl millet as well as in all crop plants is quantitative in nature and is poly genetically controlled. Selection on the basis of grain yield character alone is usually not very effective and efficient. However, selection based on its components and secondary characters could be more efficient and reliable. Knowledge of the association and interrelationship between yield and its components and among the component characters themselves can improve the efficiency of selection in plant breeding (Izge et al., 2006). This study was conducted to determine the correlation and path analysis among pearl millet genotypes to determine criteria for selection that could be effectively used to identify the desirable genotypes with high yield potential.

2. MATERIALS AND METHODS

Fifteen pearl millet genotypes, originated from different parts of Sudan (Table 1), were used in this study. The experiments were conducted at two locations, i.e., in Elrawakeeb (Latitude: 15º25’ N, Longitude: 32º15’ E) and Shambat (Latitude: 15º40’ N, Longitude: 32º32’ E) of Sudan, during the years 2003 and 2004. Split – plot design with three replications was used to layout the experiments in the field. The watering treatments were assigned to the main plots, while the genotypes to the subplots. Each genotype was planted in 5 ridges, 4 meters length and 70 cm between ridges. Seed rate was three seeds per hole spaced at 20 cm between holes. Sowing was carried out in the first week of July 2003 in Elrawakeeb and in the second week of July 2004 in Shambat. Thinning was carried out one week after sowing to raise two plants/hill. Weeding was done twice at both sites, using the hand hoeing. Data were collected on the following traits: the 50% flowering, plant height, date to maturity, panicle length, number of seeds/panicle, thousand-seed weight, grain yield/plant and grain yield/ha. Phenotypic and genotypic correlation coefficients were calculated for all possible comparisons, using the formula suggested by Al-jibouri, (1959). The correlation coefficients were partitioned into direct and indirect effects, using the path coefficient analysis according to Dewey and Lu (1959).

Table 1. Names and sources of the pearl millet genotypes used in the study

Code	Accession	Origin
1	JM 49	Darfur , Sudan
2	JM25	Darfur, Sudan
3	JM21	Darfur Sudan
4	JM44	Darfur Sudan
5	JM45	Darfur Sudan
6	JM48	Darfur Sudan
7	JM/97	Darfur Sudan
8	Modelkawiya	Kordofan. Sudan
9	JM3	Darfur Sudan
10	JM30	Darfur Sudan
11	Jm23	Darfur Sudan
12	JM38	Darfur Sudan
13	BS/Sh/94	Shambat
14	JM24	Darfur Sudan
15	Ugandi	Uganda, adapted

3. RESULTS

The genotypic and phenotypic correlation coefficients between all possible combinations of traits and the direct and indirect effect of some characters are presented in Tables 2, 3 and 4. The correlation coefficient for most of the pairs of characters revealed the presence of strong positive genotypic association between yield and its components. Moreover, genotypic correlation coefficients were higher than their respective phenotypic correlation coefficients for most of the characters under study.

3.1 Correlation between Grain Yield/Plant and its Components

Correlation of grain yield /plant with all yield components was significant and positive at both locations except with thousand-seed weight and panicle length at Elrawakeeb (Table 2) as well as the number of seeds per head, thousand-seeds weight and biomass dry weight per plant at Shambat (Table 3). Grain yield/plant had significant phenotypic and genotypic correlation with number of seeds/head at Elrawakeeb, but it had negative genotypic and phenotypic correlations with grain yield/ha at Shambat (Table 2 and Table 3).

3.2 Correlation between Yield Components

The number of fertile tillers/plant had highly significant ($P \leq 0.01$) positive genotypic and phenotypic correlations with grain yield/ha and number of seeds/head at ELrawakeeb (Table 2). Whereas, it had highly vegetative genotypic correlation with all yield components at Shambat, except panicle length and thousand – seeds weight (Table 3). Also, the number of seeds/head was highly and positively correlated, at the genotypic and phenotypic level, with all yield components at ELrawakeeb, except with panicle length/head and dead part length (Table 2).

Table 2. Phenotypic (Ph) and Genotypic (G) correlation coefficients between characters in pearl millet genotypes at Elrawakeeb averaged over four water treatments during year 2003

Characters	**1** **PH 75**	**2** **TL 75**	**3** **50% Flr**	**4** **Matur**	**5** **LAI 75**	**6** **FTL**	**7** **Dpleng**
PH 75 (Cm)		0.637*	0.075	0.016	0.649**	0.990**	0.146
TL 75	0.707 **		-0.286	-0.382	0.667**	0.341	-0.134
50% Flr (Days)	0.074	-0.369		0.878**	-0.228	-0.420	0.346
Matur (Days)	0.016	-0.472	0.905 **		-0.205	-0.457	0.425
LAI 75	0.689 **	0.821**	-0.243	-0.224		0.129	-0.034
FTL	0.111	0.485	0.491	0.534*	0.148		-0.179
Dpleng (Cm)	0.157	-0.198	0.364	0.458**	-0.039	-0.147	
Y(g)/p (g)	0.433	0.608 *	-0.088	-0.083	0.444	0.509	0.125
Yd(t)/h (Ton/ha)	0.0.49	0.663**	0.965**	-0.979 **	0.392	0.730**	-0.531*
HI%	0.482	0.426	0.163	0.126	0.346	0.560	0.117
Biomass (g)	0.275	0.811**	-0.470	0.467	0.520*	0.550*	0.084
Pnlng (Cm)	0.237	0.545*	-0.628 *	-0.777**	0.356	0.430	-0.184
Sd/pn	0.340	0.577*	0.330	-0.291	0.428	0.696**	0.105
1000-sd (g)	-0.779**	-0.348	-0.175	0.200	-0.466	-0.204	-0.497

PH (cm) = Plant height (cm); FTL= Number of fertile tillers/plant; HI% = Harvest index; Flr (days)= 50% flowering; Dpleng= Dead part length/main head; Biomass (g)= Biomass dry weight; Matur (days)= Date to maturity; Y(g)/p = Grain yield/plant; Pnlng (cm)= Panicle length/main head; LAI = Leaf area index; yd(t)/h= Grain yield(ton/ha); Sd/pn= Number of seeds/main head; 1000-SD=1000-seed weight (g); TL= Number of tillers/plant.

Table 2 continues……..

	8	9	10	11	12	13	14
Characters	**Y(g)/p**	**Yd(t)/h**	**HI%**	**Biomass**	**Pnlng**	**Sd/pn**	**1000 - sd**
PH 75 (Cm)	0.365	0.039	0.292	0.149	0.199	0.282	-0.592*
TL 75 (Cm)	0.411	0.446	0.229	0.337	0.404	0.383	-0.233
50% Flr (Days)	-0.071	-0.756**	0.088	-0.247	-0.515*	-0.294	-0.126
Matur (Days)	-0.180	-0.095	0.077	-0.261	-0.649**	-0.244	0.163
LAI 75	0.363	0.312	0.143	0.333	0.278	0.344	-0.327
FTL	0.371	0.517*	0.247	0.320	0.331	0.536*	-0.113
Dpleng (Cm)	0.109	0.446	0.076	0.053	-0.143	0.064	-0.374
Y(g)/p (g)		0.205	0.754**	0.639*	-0.289	0.608*	-0.377
Yd(t)/h (Ton/ha)	0.272		0.056	0.280	0.484	0.443	0.064
HI%	1.027**	0.105		0.015	-0.353	0.460	-0.409
Biomass (g)	1.064**	0.568*	1.166**		0.104	0.392	-0.073
Pnlng (Cm)	-0.392	0.704**	-0.666**	0.229		0.032	0.217
Sd/pn	0.820**	0.592*	0.869**	0.793**	0.138		-0.509
1000-sd (g)	-0.582*	0.046	-0.880**	-0.180	0.441	-0.681**	

** and ** are levels of significance at 5% and % respectively.*
The value in upper triangular are the phenotypic and in the lower one are the genotypic correlation coefficient

Table 3. Phenotypic (Ph) and Genotypic (G) correlation coefficients between characters in pearl millet genotypes at Shambat averaged over four water treatments during year 2004

	1	2	3	4	5	6	7
Characters	**PH 75**	**TL 75**	**50% Flr**	**Matur**	**LAI 75**	**FTL**	**Dpleng**
PH 75 (Cm)		0.291	0.248	0.291	0.305	0.068	0.008
TL 75	0.439		-0.456	-0.413	0.143	0.259	-0.173
50% Flr (Days)	0.351	-0.880**		0.667**	-0.143	-0.218	0.138
Matur (Days)	0.439	-0.803**	0.736**		-0.342	-0.055	0.226
LAI 75	0.687**	0.781**	-0.350	-0.342		0.224	-0.063
FTL	0.066	0.550*	-0.279	-0.055	0.994**		0.006
Dpleng (Cm)	-0.095	-0.508	0.289	0.326	-0.450	-0.032	
Y(g)/p (g)	-0.668**	0.230	0.295	-0.103	-0.325	-0.241	-0.489
yd (t)/h (Ton / ha)	-0.795**	0.315	-0.138	-0.466	-0.479	-0.187	-0.489
HI%	-0.709**	0.158	0.391	-0.021	-0.318	-0.288	-0.245
Biomass (g)	0.431	0.264	0.364	-0.079	0.365	0.481	0.681**
Pnlng (Cm)	-0.690**	0.819**	-0.608*	-0.285	-0.373	0.490	-0.040
Sd/pn	-0.404	0.514*	-0.770**	-0.789**	0.163	-0.385	-0.433
1000-sd (g)	-0.172	0.278	0.086	0.054	0.037	0.230	-0.186

PH (cm) = Plant height (cm); FTL= Number of fertile tillers/plant; HI% = Harvest index; 50% Flr (days) = 50% flowering; Dpleng= Dead part length/main head; Biomass (g)= Biomass dry weight; Matur (days)= Date to maturity; Y(g)/p = Grain yield/plant; Pnlng (cm)= Panicle length/ main head; LAI = Leaf area index; yd (t)/h= Grain yield (ton/ha); Sd/pn= Number of seeds/ main head; 1000-sd= 1000- seed weight (g)

Table 3 continues……..

	8	9	10	11	12	13	14
Characters	**Y(g)/p**	**Yd(t)/h**	**HI%**	**Biomass**	**PnIng**	**Sd/pn**	**1000 – sd**
PH 75 (Cm)	-0.293	-0.341	-0.321	0.248	-0.363	-0.246	-0.052
TL 75 (Cm)	0.053	0.115	-0.002	0.165	0.305	0.233	0.150
50% Flr (Days)	0.199	-0.088	0.260	0.181	-0.466	-0.570*	0.065
Matur (Days)	-0.058	-0.296	-0.004	-0.032	-0.213	-0.519*	0.073
LAI 75	-0.195	-0.262	-0.251	0.226	-0.104	0.036	0.087
FTL	-0.105	-0.060	-0.137	0.212	0.279	-0.204	0.085
Dpleng (Cm)	-0.042	-0.245	-0.076	0.121	-0.085	-0.153	-0.033
Y(g)/p (g)		0.796**	0.942**	-0.036	0.080	-0.105	0.292
yd (t)/h (Ton/ha)	0.891**		0.694**	0.112	0.222	-0.041	0.235
HI%	0.965**	0.807**		-0.347	0.027	-0.255	0.304
Biomass (g)	-0.212	-0.109	-0.459		0.144	0.009	-0.046
Pnlng (Cm)	0.260	0.402	0.177	0.304		0.126	-0.043
Sd/pn	-0.241	-0.043	-0.488	-0.015	0.295		-0.250
1000-sd (g)	0.485	0416	0.522*	-0.171	-0.015	-0.550	

** and ** are levels of significance at 5% and % respectively .*
The value in upper triangular are the phenotypic and in the lower one are the genotypic correlation coefficient

Table 4. Path Coefficient analysis of the direct and indirect effects of the different yield components and their genotypic correlation coefficient with grain yield/plant

Effect on grain yield/plant							
Traits	Direct effect	Indirect effect					
		FTL	Sd/pn	1000-sd	Pnlng	Dpleng	Genotypic correlation
FTL	0.512	-	0.040	0.001	-0.117	0.081	0.517
Sd/pn	0.120	0.173	-	-0.042	- 0.131	- 0.002	0.119
1000-sd	0.072	-0.004	-0.071	-	0.021	0.325	0.352
Pnlng	-0.294	0.204	0.053	-0.005	-	0.062	0.020
Dpleng	-0.385	-0.108	0.001	-0.061	0.047	-	-0.507

Residual effects = 0.892; FTL= Number of fertile tillers/plant; Pnlng= panicle length/main head Sd/pn= Number of seeds/main head; Dpleng= Dead part length; 1000-SD=1000-seed weight

On the other hand, number of seeds/head had negative association with other yield components, except with panicle length, which exhibited positive association at Shambat (Table 3). Thousand-seeds weight has significant negative correlation with grain yield/plant and number of seeds/head at Elrawakeeb, while it has non-significant correlation with other components at both locations (Table 2 and Table 3). At Shambat, panicle length/head exhibited highly significant ($P \leq 0.01$) positive correlation with grain yield/ha, although it had positive non-significant correlation with fertile tillers/plant and harvest index. However, it had negative association at phenotypic and genotypic levels with dead part length. Moreover, strong positive genotypic correlations were observed between panicle length and grain yield/ha at Elrawkeeb (Table 2). Grain yield/ha had significant positive phenotypic correlations with the number of seeds/head, and panicle length/head at Elrawakeeb. While, it had positive genotypic correlation with thousand-seed weight (Table 2).

3.3 Correlation of grain yield/plant with other characters

Grain yield/plant had significant ($P \leq 0.01$) positive genotypic and phenotypic correlations with plant height and leaf area index at Elrawakeeb (Table 2) and it had negative phenotypic and genotypic correlation with 50 % flowering and date to maturity (Table 2)**.** On the other hand, at Shambat grain yield/plant had significant negative genotypic and phenotypic correlation with plant height, although it positively associated with leaf area index and 50% flowering (Table 3).

3.4 Path Coefficient Analysis

Direct and indirect effect for some characters is given in Table 4. Fertile tillers/plant had strong positive direct effect (0.513) on grain yield/plant, followed by number of seeds/head (0.120). On the other hand, grain yield/plant was directly and negatively affected with dead part length (-0.385) and panicle length (- 0.294). The relatively high positive indirect effects on grain yield/plant were caused by number of seeds/head (0.173) and panicle length/head (0.131). The highest vegetative indirect effects on grain yield/plant were caused by panicle length (-0.117) and fertile tillers/plant (-0.108). The number of fertile tillers/plant had positive direct and indirect effects on grain yield/plant through other characters (Table 4). The highest vegetative indirect effect of number of fertile tillers/plant was expressed through panicle length (-0.117). The number of seeds/head exhibited low direct effect on grain yield/plant (0.120). Its low association with grain yield was mainly caused by its negative indirect effect through number of fertile tillers/plant, thousand-seed weight and panicle length (Table 4). Thousand-seed weight showed the least positive direct effect (0.072) on grain yield/plant. The negative indirect effect of thousand-seed weight was expressed through fertile tillers/plant (-0.004) and number of seeds/head (-0.071). The panicle length/head showed the vegetative direct effect (-0.294) on grain yield/plant. On the other hand, the positive indirect effect was expressed through fertile tillers/plant (0.204), dead part length/head (0.062) number of seeds/head (0.053). Dead part length/head showed the highest vegetative direct effect (-0.385). This character exhibited its indirect vegetative effect through fertile tillers/plant (-0.108) and thousand-seed weight (-0.061). Whereas, it expressed positive indirect effect on grain yield/plant through panicle length and number of seeds/head (Table 4).

4. DISCUSSION

The phenotype of a plant is the result of interaction of a large number of factors. Hence, the final yield is sum total of effects of several component factors. Therefore, it is important to know the extent and nature of interrelationship between grain yield and its contributing characters and also among themselves. The correlation coefficient helps the breeder in determining the direction and number of characters to be considered in improving the grain yield. In the present study, the estimated genotypic correlations for most of the characters were greater than their corresponding phenotypic ones. Similar results were reported by Salih and Khidir, (1975) in Castor bean and Mohammed et al., (1988) in faba bean. This was attributed to the fact that the strong inherent association between the different characters studied were reduced and modified under the influence of the environment. With few exceptions, the different associations of grain yield/plant with its components arrived at in this study were in accordance with the findings obtained by Bakhiet and Mahdy, (1988). Furthermore, the grain yield/plant had significant positive phenotypic and genotypic correlation with number of seeds/head, grain yield/ha and number of fertile tillers/plant. Similar results were reported by Tolok et al., (1998) in pearl millet. The results of the present study showed a significant positive phenotypic correlation between grain yield/plant and thousand-seed weight. These results are in accordance with those obtained by Balakrishnan and Das, (1995) and Singh et al., (1995). However, negative genotypic correlation between these two traits was reported. This difference in sign of the phenotypic and genotypic association between the two characters may be due to, as stated by Falconer, (1980), the fact that the genetic and environmental sources of variation affect these traits through different physiological mechanisms. Furthermore, the difference between the two locations in estimates of the genotypic correlations of grain yield with its components could be attributed to the fact that estimates of genetic correlation are affected by environmental factors and sampling errors, so they are seldom very precise (Falconer, 1980). Significant genotypic and phenotypic correlations were indicated between the yield components, namely number of seeds/plant, grain yield/ha, thousand-seed weight and number of fertile tillers/plant however, these characters are less influenced by the environment and they could be improved in diverse environments. This finding is in agreement with Ezeaku and Mohammed, (2006). In the present study, the negative association of number of seeds/head with thousand- seeds weight, on the other hand, is attributed to the competition between these characters for assimilates during their development (Abraham et al., 1989 and Kulkarni et al., 2000) in pearl millet.

4.1 Path Analysis

When a great number of variables are included in a correlation study, the association among them will be very complex. Thus path analysis is necessary to elucidate the true direct and indirect relationship among such characters. In this study, path analysis was carried out to examine the relationship between grain yield/plant and its components. With regards to the grain yield/plant and its components, the analysis showed that the number of fertile tillers/plant had the highest direct effect on grain yield/plant, followed by number of seeds/head and thousand-seed weight. This great direct influence of these components is indicative of their important role in deterring yield. Similar results were found by Muhammed et al. (2003) in pearl millet. Each of these four yield components had a positive genotypic correlation with grain yield/plant, except the panicle length and the dead part length. This unexpected negative correlation of the panicle length and dead part length had resulted from its high negative indirect effect (-0.108) through the number of fertile tillers/plant. Although the number of fertile tillers/plant had the highest positive direct contribution, it exhibited the lowest genotypic correlation with grain yield/plant. This can be attributed to the negative indirect effects of this character through the panicle length (-0.117). Grain yield/plant was negatively and directly affected by panicle length (-0.294) and dead part length (-0.380). However, these traits had the highest positive indirect effects on grain yield/plant (0.204) through number of fertile tillers/plant and (0.047) for dead part length through panicle length. Their high positive indirect effects were reduced by their negative indirect effects. The negative direct effects and the reduction in positive indirect effects of these character resulted in their low genotypic correlation with grain yield/plant. The number of seeds/head and thousand-seeds weight had the highest negative indirect effects on grain yield/plant. These negative indirect effects resulted from the inverse relationship with the panicle length. The results are in agreement with findings of Abraham et al., (1989); Harver and Karad, (1998); Kulkarni et al., (2000); Yadav et al., (2001) and Chaudhry et al., (2003).

5. CONCLUSION

Based on results of this study it could be concluded that, number of seeds/head, thousands-seed weight and panicle/main head appeared to be the prominent characters when selecting for total grain yield in pearl millet, because of their highly significant genotypic and phenotypic correlations with total grain yield. These characters also had the highest direct effects on total grain yield/plant and high indirect effects through most of the other characters. This investigation therefore suggests that number of seeds/head, thousands-seed weight and panicle/main head should be given maximum consideration for total yield improvement as the appropriate selection criteria.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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