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Full Length Research Paper

Genetic variation and trait correlations in a bird-resistant pearl millet landrace population

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Genetic variation and correlations among traits within a Ghanaian bird-resistant pearl millet landrace population were investigated by evaluating S_1 plants derived from the population, at two locations and for two years in Ghana. The objectives were to study genetic variation and correlations among traits in the population, determine the feasibility of selection and to suggest appropriate selection methods and selection indices for effective improvement. There was significant genetic variation for grain yield and most yield component traits, indicating that selection within the population would be feasible. Genetic variation was, however not significant for the percent incidence of downy mildew, implying that selection for improving resistance to the disease would not be effective. Heritabilities ranged from moderate to high (0.4- 0.73) for most traits, in view of which the use of recurrent selection methods, with progeny testing, could be effective for improvement of the population. Grain yield was observed to have significant phenotypic and genotypic correlations with days to 50% blooming and with earhead length, indicating that those two traits could be relied upon as selection indices for selection to improve grain yield. However, significant positive correlations were also observed between earhead length and plant height, which is undesirable, as plants with tall height tend to have a low harvest index and are also prone to lodging. In view of this, caution would be needed during selection, in order to achieve an improved population with good grain yielding ability and not very tall plant height.

Key words: Pearl millet, Ghanaian landrace, genetic variation, trait correlations, selection indices.

INTRODUCTION

Pearl millet [*Pennisetum glaucum,* (L.), R.Br.] is a cereal crop which is cultivated in the arid and semi arid zones, where the grain and vegetative products are used for human and animal consumption. It is an important crop for sustaining food security in poor environments, in view of its high tolerance to environmental stresses (Burton, 1983) and high content of nutrients (Singh and Naina-watee, 1999). However, pearl millet production is low in most countries due to lack of high yielding improved varieties. The exploitation of diverse germplasm resources of the crop for breeding improved varieties would therefore always be necessary.

The Bristled Long Population (BLP) is a valuable Ghanaian pearl millet landrace, in view of its long bristles, which provide resistance to bird destruction, a major constraint to pearl millet production. The population is a member of Iniadi type of pearl millet landraces found in Ghana and Togo, which have been observed (NRC, 1996) to have many promising potentials to contribute to pearl millet improvement. Other useful attributes of the BLP population, as reported by farmers, include its short maturity period, tolerance to downy mildew and large grain size.

Selection within the BLP population for improvement may improve its productivity as a cultivar for farmers and also enhance its use as germplasm material for breeding work. However, relevant information on the population for application in selection is currently not available.

S_1 inbred plants were derived from the BLP population and evaluated at two locations in Ghana for two years. The objectives were to study genetic variation and correlations among trait in the population, in order to de-

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termine the feasibility of selection and to determine appropriate selection indices, methods and strategies for its improvement.

MATERIALS AND METHODS

The BLP landrace is cultivated by some communities in the Upper East Region of Ghana. In 2002, a sample of earheads of the population was collected from farmers and planted on an area of 0.2 ha at Manga, near Bawku, to derive S_1 inbred plants. A random sample of about 300 plants were selfed with pollination bags from the start to end of the blooming period. After harvest, a total of 168 selfed earheads were further sampled for progeny evaluation. Manga Nara, an improved local pearl millet population was included as a check.

Progeny evaluation was conducted in 2003 and 2004 raining seasons at two locations, namely Manga and Tono, which are major pearl millet growing areas in the Upper East region of Ghana. Manga is situated roughly between Latitude11^o and 01' N and Longitude 00^o and 16^o W, while Tono is between Latitude 10^o 45' N and 10^o 50' and Longitude 1^o and 1^o 10'W. The soils at both locations are mostly Savannah Ochrosols (Sarpong, 2001), which according to Adu (1969), are sandy to sandy loam and acidic, with low organic matter and low nitrogen content.

However, farmers' practices, aimed at maintaining soil fertility differ between the two locations. At Manga, the plots were being used continuously for cultivating cereals, with occasional application of organic manure, whereas at Tono, farmers alternate the cultivation of cereals with legumes, in order to maintain soil fertility.

In 2003, the rainfall for Manga and Tono were respectively 1245.1 and 1140 mm, which would be considered adequate for pearl millet cultivation. However, late arrival of the rains at both locations resulted in late planting of the experiments in that year. The total annual rainfall for 2004 at Manga was low (717.8 mm), but the rains arrived early enough to permit early planting of the trials in that year.

An incomplete block design with two replications, each replication having 13 blocks and each block having 13 plots, was used for progeny evaluation. Two weeks after planting, fertilizer was applied at the rate of 57.5 kg ha^1 N, 37.5 kg ha^1 P and 12.5 kg ha^1 K. Data were recorded for major traits, namely plant population, days to 50% blooming (indicating maturity period), plant height, earhead length, number of effective tillers per plant, percent incidence of downy mildew (*Sclerospora graminicola* (Sacc.) J.Schrot), grain yield and weight of 1000 grains (grain size) according to procedures being used by ICRISAT (1995).

The days to 50% bloom was recorded only at Manga in both 2003 and 2004 cropping seasons, while the weight of 1000 grains was recorded only at Manga in 2004. All other traits were recorded at Manga and Tono in 2003 and 2004. However, data of the trials at Tono in 2004 had to be discarded because of very poor germination of the crop, resulting from heavy and continuous rains immediately after planting.

Statistical analysis

Data were analysed using the Residual Maximum Likelihood (REML) method, in Genstat (Genstat, 1995) to estimate components of variance of the traits measured. Data for each trait in each trial at each location and for each year were first analysed separately. The homogeneity of the variances of a trait in different trials was judged by calculating F = largest error variance/smallest error variance, and determining significance at the 5 % level. As the F was observed not to be significant for any trait, the variances were judged to be homogeneous. A pooled analysis was subsequently conducted for each trait across years or across locations and years.

The following models were assumed for the pooled analysis:

$Y_{ijkl} = \mu + g_i + B_{jkl} + R_{kl} + T_l + (gT)_{il} + e_{ijkl}$ (for the pooled analysis across years)

where, Y_{ijkl} = observation, μ = overall mean, g_i = effect due to genotype i, B_{jkl} = effect due to block j within replication k in year l, R_{kl} = effect due to replication k in year l, T_l = effect due to year l, $(gT)_{il}$ = effect of interaction of genotype i with year l and e_{ijkl} = effect due to error. Genotypes, blocks, replications, years and all interacttions were assumed random.

$Y_{ijklm} = \mu + g_i + B_{jklm} + R_{klm} + L_l + T_m + (LT)_{lm} + (gL)_{il} + (gT)_{im} + (gLT)_{ilm} + e_{ijklm}$ (for the pooled analysis across years and locations)

where, Y_{ijklm} = observation, μ = overall mean, g_i = effect due to genotype i, B_{jklm} = effect due to block j within replication k in location l in year m, R_{klm} = effect due to replication k in location l in year m, L_l = effect due to location l, T_m = effect due to year m, $(LT)_{lm}$ = effect of interaction between location l and year m, $(gL)_{il}$ = effect of interaction of genotype i with location l, $(gT)_{im}$ = effect of interaction of genotype i with year m, $(gLT)_{ilm}$ = effect of interaction of genotype i with location l and year m and e_{ijklm} = effect due to error. Genotypes, blocks, replications, locations and years and all interaction effects were all assumed random.

The estimated variances among S_1 progeny families were used to deduce the variance in the reference (or original) population according to Halluaer and Miranda (1982).

The heritability (h^2) of each trait was calculated using the following formulae:

$h^2 = s^2_g/(s^2_g + s^2_e/r)$ (for traits measured in individual trials)

where, s^2_g = estimated genetic variance, s^2_e = error variance, and r = number of replications.

$h^2 = s^2_g/(s^2_g + s^2_{gy} /y + s^2_e/ry)$ (for traits which were measured in both years at only 1 location)

where, s^2_g = genetic variance, s^2_{gy} = genotype by year interaction variance, s^2_e = error variance, y = number of years and r = number of replications.

$h^2 = s^2_g /[s^2_g + (s^2_{gl}/l) + s^2_{gy} /y) + (s^2_{gly}/ly) + s^2_e/rly)$ (for traits which were measured in both years and at both locations)

where, s^2_g = genetic variance, s^2_{gl} = genotype by location interaction variance, s^2_{gy} = genotype by year interaction variance, s^2_{gyl} = genotype by year by location interaction variance, s^2_e = error variance, l = number of locations, y = number of years and r = number of replications.

Correlation analysis was conducted on data, using the statistical program Correlation in Genstat (Genstat, 1995), in order to estimate the correlation coefficients between traits. Correlation analysis was first conducted separately for the data of each individual trial. Subsequently, the correlation coefficients for the set of trials were combined following Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Grain yield performances of S_1 progenies pooled across years and locations covered a wide range (452 - 1632 kg ha^1, not shown in tables). The mean grain yield of S_1 progenies was 1004 kg ha^1 compared to 774 kg ha^1 for the check, indicating a high productive ability of the BLP

Table 1. Variance components in the Ghanaian pearl millet landrace, Bristled Longhead Population (BLP).

Trait	σ^2_g	σ^2_{gl}	σ^2_{gy}	σ^2_{gly}	σ^2_e
Grain yield	57624**	37989**	20511*	9	89081
Days to 50% bloom	2.1**	-	3.8**	-	4.9
Downy mildew (%)	28.1	4.8	30.3	101.8**	154.7
Earhead length	3.9**	0.3	1.4	7.6**	5.4
Plant height	80.3*	0	0	236.2**	226.5
Effective tillers/plant	0	0	0.001	0.001	0.02
1000 grain weight	4.6**	-	-	-	3.4

*Significant at P = 0.05; **Significant at P = 0.01.

Table 2. Heritability estimates in the Ghanaian pearl millet landrace, Bristled Longhead Population (BLP).

Trait	h^2
Grain yield	0.57
Days to 50% bloom	0.4
Downy mildew (%)	0.29
Earhead length	0.52
Plant height	0.45
Effective tillers/plant	0
1000 grain weight	0.73

to serve as selection material. The pooled analyses across years and locations showed either highly significant (p< 0.01) or significant genetic variation (p< 0.05) for all the traits studied, except the number of effective tillers per plant and percent incidence of downy mildew (Table 1).

The above observations would imply that selection within the BLP population would be feasible to improve grain yield and most yield component traits, but would not be effective for improving the resistance of the population to downy mildew.

Significant genotype by environment interactions were observed in the population. The genotype by location interaction variance was observed to be highly significant for grain yield (Table 1), but was not significant for any of the yield component traits. By contrast, the genotype by year and the genotype by location by year interaction variances were significant for grain yield and most yield component traits.

These results were an indication that the BLP population had unstable performance in the different environmental conditions of testing. In view of this, the evaluation and selection of superior progenies from the population would have to be conducted at target locations and within an adequate number of years, in order to develop improved varieties, which would be specifically adaptable to those locations and to the variable seasonal conditions.

The estimated heritabilities ranged between 0 and 0.73. High heritabilities (h^2 above 0.5; Khairwal and Singh, 1999) were observed for the traits earhead length, grain yield and weight of 1000 grains (Table 2). The highest heritability was observed for the weight of 1000 grains. However, in view of the last trait having been measured in only one trial, its genetic variance and heritability estimate could be biased upwards by genotype by environment interactions. Relatively moderate heritabilities were observed for days to 50% bloom and plant height, while very low heritabilities (below 0.3) were observed for number of effective tillers per plant and percent incidence of downy mildew.

The heritabilities observed in the current study were similar to those reported by Yadav et al. (2001) in Indian pearl millet landrace populations. Based on the very high heritabilities they observed in pearl millet composites, Rattunde et al. (1989) suggested that the use of mass selection would be effective for their improvement. In view of the heritabilities not being very high in this experiment; however, the use of more efficient selection methods, such as recurrent selection, with progeny testing would be more appropriate for effective improvement of the BLP.

The estimated correlation coefficients among traits are presented in Table 3. All traits studied, except plant height, were observed to have significant phenotypic correlations with grain yield. However, the genotypic or heritable correlations were significant for only a few of the traits, namely days to 50% bloom (maturity period) and earhead length. The phenotypic and genotypic correlations between grain yield and days to 50% period were negative, while those between grain yield and earhead length were positive. It was observed, in general, that the genotypic correlations were often higher than the phenoltypic correlations.

Yadav et al. (2001) and Muhammad et al. (2003) observed similar correlations among traits, respectively in Indian and Pakistani pearl millet populations. Muhammad et al. (2003) also observed that the genotypic correlations were most often higher than the phenotypic and environmental correlations in those populations. In contrast to the findings of this experiment however, Harer and Karad (1998) observed tiller number per plant to have the highest positive correlation with grain yield.

The results here show that selection for plants with long

Table 3. Genotypic and phenotypic (in brackets) correlation coefficients among traits of the Ghanaian pearl millet landrace, Bristled Longhead Population (BLP).

	Days to 50% bloom	Earhead length	Downy mildew (%)	Effective tillers/plant	Plant height
Grain yield	**-0.44* (-0.30*)**	**0.42* (0.40**)**	**-0.30 (-0.25*)**	**-0.16 (0.19*)**	**0.34 (0.25*)**
Days to 50% bloom		-0.16 (-0.14)	0.13 (0.17*)	-0.66** (-0.20*)	-0.05 (-0.05)
Earhead length			-0.36 (-0.21*)	-0.16 (0.04)	0.33 (0.29*)
Downy mildew (%)				-0.50** (-0.09)	0.06 (-0.08)
Effective tillers/plant					0.16 (0.06)

* Significant at P = 0.05; ** Significant at P = 0.01.

earheads and short maturing periods would be the best way to achieve effective grain yield improvement in the BLP. Table 3 further shows that days to 50% bloom in the BLP was significantly negatively correlated with the number of effective tillers per plant, suggesting that selecting for early maturing plants would improve the tillering ability in the population. Among resource poor farmers in Africa, selection for plants with short maturity periods in pearl millet also often serves to provide improved cultivars which could be harvested early, as a form of food security.

Earhead length was also observed to have a significant and positive correlation with plant height, which is however undesirable, as tall pearl millet plants tend to have low harvest index and are also prone to lodging. In view of this, it would be appropriate to conduct selection with caution, in order to achieve an improved BLP with satisfactory earhead length, good yielding ability, as well as, not very tall plant height.

Conclusion

The above results show that there is adequate genetic variation to permit feasible selection within the BLP population for its improvement. In view of the heritability of traits not being very high, recurrent selection, with progeny testing, would be appropriate to achieve effective population improvement. Judging from the correlations observed among traits, maturity period and earhead length would be ideal selection indices for improving grain yield in the BLP.

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