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ASSOCIATION BETWEEN YIELD COMPONENTS OF SORGHUM (*SORGHUM BICOLOR* L. (MOENCH) UNDER DIFFERENT WATERING INTERVALS

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ABSTRACT

A field experiment was conducted in the Sudan to study the extent of variability in grain yield and yield components of ten sorghum (Sorghum bicolor L. (Moench) genotypesat three environments: Shendi (season, 2005/06), Shambat (season, 2005/06) and Shambat (season, 2006/07). A split- plot design with four replications was used. Two levels of water treatments were used, namely, irrigation every 10 days and every 21 days (drought stress condition). The main plots were allocated for water treatments and the sub plots for genotypes. Data on five characters, namely seed yield/plant, number of seeds/head, 1000-seed weight, seed yield (kg/ha) and harvest index, were collected. Genotypic and phenotypic correlations between different traits were determined. Grain yield exhibited strong positive phenotypic and genotypic correlations with its components. Significant positive associations were detected between performance of the evaluated genotypes under normal irrigation at Shendi and under water stress at Shamba tseasons (2005/06-2006/07) for number of seeds/head and 1000-seed weight. On the other hand, negative correlations were obtained between the performances at Shendi and Shambat (2006/07) under normal irrigation for seed yield/plant. Generally, these relations influenced the degree of associations between these traits and with the other traits in these environments.

Keywords: *Sorghum bicolor*, Grain sorghum, Correlation, Normal irrigation, Stress condition.

Contribution/ Originality

This study contributes in the existing literature by providing data and information concern with interrelationships among grain yield and some of its components in ten grain sorghum (*Sorghum bicolor* L. (Moench) genotypes under normal irrigation and water stress conditions in three different environments of Sudan

1. INTRODUCTION

Grain sorghum (*Sorghum bicolor* L. (Moench) is one of the main staple food for the world poorest and most food in secured people (El Naim *et al.*, 2012). Among the cereal crops, it ranks fourth in importance in the world following rice, wheat and maize (FAO, 2006). A primary determinant of grain yield in cereal crops is the number of effective tillers/plant. Many tillers that emerge do not survive to contribute to grain yield (Davidson and Chevalier, 1990). Evaluation of nineteen sorghum lines (Bhongle *et al.*, 2002) indicated that plant height, grain yield/plant and 1000-seed weight possessed high amount of genotypic coefficient of variation and exhibited high estimates of expected genetic advance.

Thirty landraces of sorghum were evaluated for one year across two locations (Bello *et al.*, 2007) to determine general and specific combining abilities for morphological character, yield and yield components. Significant differences were detected for all characters. Some genotypes were superior in grain yield and some yield components.

The wide genetic variability detected in the tested materials could be utilized in the different breeding programes. Since grain yield has low heritability estimates, the indirect selection through its components assumes importance. 1000-grain weight, number of grains/spike proved to be the most reliable yield components (Fadlalla and Abdalla, 1994).

The objectives of this study were to estimate the interrelationships among grain yield and some of its components in some sorghum genotypes under normal irrigation and water stress conditions.

2. MATERIALS AND METHODS

Ten accession of sorghum (*Sorghum bicolor* L. (Moench) of Sudanese origin were evaluated at three sites Shendi (season, 2005/06), Shambat (season, 2005/06) and Shambat (season, 2006/07). Thus data were recorded for three environments. The first site, Shendi is 200 km north Khartoum (33°.26´ E. Longitude, 16°.41´ N. Latitude and 376 meters above the sea level). The second site was the experimental Farm of the Faculty of Agriculture, University of Khartoum at Shambat (32°.32´ E. longitude, 15°.40´ N. Latitude and 380 meters above the sea level) (Fadlalla, 2003).

The experiment was conducted for two seasons, namely; 2005/2006 and 2006/2007 at Shambat and Shendi season, 2005/2006 under two levels of water treatments, namely; normal irrigation every 14 days, and water stress, every 21 days. A split-plot design with four replications was used to execute the experiment. The water treatments were assigned to the main-plots and the genotypes to the sub-plots. Each genotype was grown in a plot of 3×5 meters, consisting of four ridges 70 cm apart. The spacing was 10 cm between holes along the ridge. Four or five seeds were sown per hole on the shoulder of the ridge during the second week of July at the three environments. Three weeks after sowing, the plants were thinned to raise two plants/hole. Water stress treatment was started a month after sowing at the three environments. Other cultural practices were carried following the recommended cultural practices. Ten randomly selected plants from the two middle ridges of each plot were used for data collection in 2005/2006 and 2006/2007. Five characters, namely number of seeds/head, 1000-seed weight, seed yield/ha, harvest index and seed yield/plant were chosen for this study. Analysis of variance of the data was carried out according to the procedures described by Gomez and Gomez (1984), and covariance analysis was used according to method of Singh and Chaudhary (1979).

Phenotypic and genotypic correlation coefficients between pairs of the characters under condition using the formula suggested by Miller *et al.* (1958) as follows:

$$r_{gxy} = \sigma_{gxy}\sqrt{(\sigma\, 2_{gx}) \,.\, (\sigma\, 2_{gy})}$$

$$r_{phxy} = \sigma_{phxy}\sqrt{(\sigma\, 2_{phx}) \,.\, (\sigma\, 2_{phy})}$$

Where:

r_g: is the genotypic correlation coefficient.

r_{ph}: is the phenotypic correlation coefficient.

σ_{gxy} : is the genotypic covariance between two traits, x and y.

σ_{phxy}: is the phenotypic covariance between two traits, x and y.

σ^2_{gx} and σ^2_{gy} are the genotypic variances for traits x and y, respectively.

3. RESULTS

Phenotypic and genotypic correlation coefficients between pair wise combinations of the different characters under normal irrigation and stress condition, at the three environments, are presented in Tables 1 and 2, respectively. Different values of the correlation coefficients were obtained, between the five characters. The results can be summarized as follows:

(a) Correlation between Seed Yield/Ha and Other Character

There were highly significant ($p \leq 0.01$) positive genotypic and phenotypic correlation coefficients between seed yield/ha and all seed yield components at Shendi season (2005/06), Shambat (2005/06) and Shambat (2006/07) under normal irrigation, except 1000-seed weight. It exhibited a highly significant negative genotypic correlation and non-significant phenotypic correlation at Shendi and Shambat (2005/06). Seed yield/ha had significant positive phenotypic and genotypic correlations with harvest index at Shambat (2005/06) and Shambat (2006/07), while it had non-significant genotypic correlation with this trait at Shendi.

Under water stress condition, seed yield/ha had highly significant positive correlation with all yield components at all environments, except 1000-seed weight which showed a non-significant genotypic association at Shendi and non-significant phenotypic one at Shambat (2005/06). At Shambat (2006/07), seed yield/ha presented highly significant positive genotypic and phenotypic correlations with all yield component; namely: seed yield/ plant (0.99 –1.00), number of seeds/head (1.94 – 0.21) and 1000-seed weight (0.93 –0.71).

Table-1. Genotypic and phenotypic correlation coefficients between the different characters of ten sorghum (*Sorghum bicolor* L. Moench) genotypes evaluated under normal irrigation at Shendi and Shambat.

Shendi (2005/06)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight(g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		1.02**	-0.71**	0.99**	0.03
	Number of seeds/head	0.85**		-0.84**	1.02**	0.43**
	1000-seed weight(g)	0.03	-0.31*		-0.71**	-0.62**
	Seed yield (kg/ha)	0.99**	0.85**	0.03		0.04
	Harvest index	0.91**	1.03**	-0.34*	0.91**	
Shambat (2005/06)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight(g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		1.24**	-1.11**	1.00**	2.00**
	Number of seeds/head	0.79**		0.94**	1.24**	0.94**
	1000-seed weight(g)	-0.19	0.58**		-1.11**	-0.56**
	Seed yield (kg/ha)	0.99**	0.79**	-0.19		0.59**
	Harvest index	0.85**	0.74**	-0.31*	0.82**	
Shambat (2006/07)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight(g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		0.42**	0.44**	0.99**	0.76**
	Number of seeds/head	0.69**		-0.66**	0.42**	1.06**
	1000-seed weight(g)	0.31*	-0.38*		0.44**	-0.34*
	Seed yield (kg/ha)	1.00**	0.69**	0.31*		0.72**
	Harvest index	0.70**	0.71**	-0.22	0.68**	

The values in the upper triangle are the genotypic and in the lower one are the phenotypic correlation coefficients.

*and** are the levels of significance at 5% and 1%, respectively.

Table-2. Genotypic and phenotypic correlation coefficients between the different characters of ten sorghum (*Sorghum bicolor* L. Moench) genotypes evaluated under water stress at Shendi, and Shambat.

Shendi (2005/06)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight (g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		0.76**	0.12	0.99**	0.66**
	Number of seeds/head	0.77**		-0.56**	0.76**	0.48**
	1000-seed weight(g)	0.30	-0.30*		-0.11	0.05
	Seed yield (kg/ha)	0.99**	0.79**	0.30		0.68**
	Harvest index	0.52**	0.49**	0.13	0.54**	
Shambat (2005/06)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight (g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		0.83**	-0.64**	1.00**	1.01**

	Number of seeds/head	0.83**		-0.99**	0.83**	0.75**
	1000-seed weight(g)	-0.16	-0.60**		-0.64**	-0.49**
	Seed yield (kg/ha)	1.00**	0.83**	-0.16		0.99**
	Harvest index	0.66**	0.59**	-0.29	0.64**	
Shambat (2006/07)	**Character**	**Seed yield/ plant (g)**	**Number of seeds/head**	**1000-seed weight (g)**	**Seed yield (kg/ha)**	**Harvest index**
	Seed yield/plant (g)		1.94**	0.93**	0.99**	-0.09
	Number of seeds/head	0.21		-1.43**	1.94**	-0.38*
	1000-seed weight(g)	0.71**	0.25		0.93**	-0.25
	Seed yield (kg/ha)	1.00**	0.21	0.71**		-0.11
	Harvest index	0.42**	0.45**	0.07	0.43**	

The values in the upper triangle are the genotypic and in the lower one are the phenotypic correlation coefficients.

*and** are the levels of significance at 5% and 1%, respectively.

(b) Correlation between Seed Yield/Plant and Its Components

At shendi, Seed yield/plant had highly significant positive genotypic and phenotypic correlations (1.02 – 0.85) with number of seeds/head; highly significant positive phenotypic one (0.91) with harvest index and significant negative genotypic association (- 0.71) with 1000-seed weight (Table 1).

At Shambat (2005/06), under normal irrigation, seed yield/plant was highly and positively correlated, at the genotypic and phenotypic levels, with number of seeds/head (1.24 – 0.79) and harvest index (2.00 – 0.85).

Seed yield/plant had highly significant positive genotypic and phenotypic correlations with all the other seed yield components under normal irrigation at Shambat (2006/07), namely number of seeds/head, 1000-seed weight, and harvest index (Table 1).

Under water stress at all environments (Table 2), seed yield/plant was strongly and positively associated, genotypically and phenotypically, with all yield components, except 1000-seed weight at Shendi and Shambat (2005/06).

(c) Correlation between Yield Components

Number of seeds/head, under normal irrigation (Table 1), had a highly significant positive correlation with 1000 - seed weight and harvest indexat both genotypic and phenotypic levels, except 1000-seed weight, which was negatively associated with it at Shendi and Shambat (2006/07). Under water stress (Table 2), highly significant negative associations were observed between seeds/head and 1000-seed weight at the three environments, except at the phenotypic level at Shambat (2006/07). Whereas, highly significant positive correlations were obtained between seeds/head and harvest index at all environments, except at the genotypic level at Shambat (2006/07). Table 1 shows that 1000-seed weight, in general, had strong association with harvest index under normal irrigation at all environments, except at Shambat season (2006/07).

On the other hand, it had non significant correlations with harvest index, under water stress condition, at all environments, except at Shambat season (2005/06).

4. DISCUSSION

Grain yield is a complex character, which depends on many components and highly influenced by the environment. Correlation coefficients, as indicators of the degree of relationship between different attributes, is useful in determining those characters which are highly associated with grain yield and consequently, can be used as indicators in selection for yield. Adams (1967) attributed the association between characters to developmentally induced relationship between components that were only indirectly the consequence of gene action. The association between traits is often determined as phenotypic or genotypic correlation, which reflects the association of breeding values and environmental conditions.

The correlation coefficients of grain yield per hectare and per plant with other related characters exhibited different patterns. Grain yield/ha exhibited strong positive phenotypic and genotypic correlations with yield/plant under the six environments, indicating that grain yield/plant can be used as indicator in selecting for grain yield/ha. Also grain yield/ha had significant positive phenotypic and genotypic correlations with some of yield components. On the other hand, grain yield/ha was significantly and negatively genotypicly correlated with 1000-seed weight at Shendi and Shambat season (2005/06), under normal irrigation and water stress. It was positively phenotypicly and genotypicly correlated at Shambat seson (2006/07), under normal irrigation and water stress. However, it was non-significantly associated with harvest index at Shendi, under normal irrigation, and Shambat season (2006/07), under water stress. Also, it was non-significantly associated at the phenotypic level with 1000-seed weight, under normal irrigation and water stress at Shendi and Shambat season(2005/06) and number of seeds/head under water stress condition, at Shambat season(2006/07). The results of this study are in agreement with those of Nimbalkar *et al.* (1988), Bakheit (1990) and Sankarapandian *et al.* (1996) in sorghum, Balakrishnan and Das (1995) and Fadlalla (2003) in pearl millet.

Similar to the trend of grain yield/ha, grain yield/plant possessed highly significant positive phenotypic and genotypic correlations with other yield components under most of the environments used in this study. On the other hand, it had negative association with 1000-seed weight under most of the environments. Generally, the negative association would indicate that selection for improvement of one character would lead to deterioration of another character. Thus, special consideration should be paid for simultaneous improvement of the negatively associated characters. The application of the selection index procedure, would provide a weighed compromise, and consequently, is expected to result in simultaneous improvement of these genetically associated characters. The change in the sign and degree of the correlation observed for some characters could be attributed to the magnitude of the change in the environment.

Number of seeds/head had highly significant positive genotypic and weak positive phenotypic correlations with the other yield components in some environments. On the other hand, it had negative associations with 1000-seed weight in most environments and harvest index under water stress condition at Shambat seson (2006/07). 1000-seed weight had a negative association with number of seeds/head and harvest index under normal irrigation at Shendi and under water stress at Shambat season (2005/06). These results indicate that the degree of association of the characters is modified by the change in the environment. Again the fluctuation in the direction of and degree of the association between characters could be due mainly to the differential influence of the environment on the expression of the different traits under the different conditions as well as the competition among the different traits for assimilates, such as that between number of seeds/head and 1000-seed weight. Similar results were reported by Sankarapandian *et al.* (1996) in sorghum, Abraham *et al.* (1989) in finger millet and Fadlalla (1994) in bread wheat. Falconer (1980) attributed the difference in the sign of phenotypic and genotypic correlations between certain character to the effects of the genotypic and environmental sources of variations on these traits through different physiological mechanisms.

5. CONCLUSIONS

Based on the results obtained in this study, it could be concluded that the characters which exhibited strong associations with seed yield/ha could be used as selection criteria for yield improvement, if especial consideration is given to those traits which are negatively correlated with each other.

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