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Genotypic and phenotypic correlations between yield and yield components in some guar (*Cyamopsis tetragonoloba* L.) genotypes under rainfed condition

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Sixteen genotypes of guar were evaluated at five sites in Northern Kordofan State, Sudan in 1998/1999 rainy season. A 4×4 partially balanced lattice design with three replicates was used. Data were collected on yield and yield related characters. Genotypic and phenotypic correlations among these traits were determined. Days to 50% flowering was positively and significantly correlated with days to maturity at four locations. This indicates that days taken to maturity can be predicted by days taken to flowering. Seed yield per plant had significant positive phenotypic and genotypic correlations with number of fruiting nodes/main stem and number of reproductive branches per plant at three locations; number of pods per branch, number of pods per plant and number of seeds per pod at two locations. On the other hand, seed yield per plant had significant negative phenotypic and genotypic association with days to 50% flowering at two sites, height to first pod at one location. Hence, breeding for high yielding guar cultivar can be made through selection for early flowering, low height to first pod, numerous reproductive branches and fruiting nodes per main stem, and high number of pods per plant and seeds per pod.

Key words: Guar, *Cyamopsis tetragonoloba*, correlations, selection, Sudan.

INTRODUCTION

The correlation coefficient between two variables is important in plant breeding because it measures the degree and type, and genetic or non-genetic of association between two or more characters as proposed by Hallauer and Miranda (1982), who also stated that the existence of genetic association means that selection for one trait will cause changes in the other trait, this is called correlated response. Information on guar breeding, under Sudan conditions is meager. So correlations can be used directly in improving new varieties or indirectly to guide future efforts for developing new guar cultivars with high grain yield and acceptable phenological characteristics via multi- trait selection, that is, developing an acceptable ideotype.

MATERIALS AND METHODS

Sixteen genotypes of guar fourteen inbred lines and two standard commercial varieties (HFG53 and HFG408) were evaluated in a

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multi-location yield trial during 1998 crop season under rainfed conditions at five locations in North Kordofan State, namely, Kazgeil and Eljikka (sandy soil), Beinu and Elkheirasan (Gardud soil), and Jebel Hemdella (clay soil). Seeds of these genotypes were offered by Dr. Abdel Wahab Hassan Abdalla, Department of Agronomy, Faculty of Agriculture, University of Khartoum.

Data were recorded on days to 50% flowering and days to maturity. Then ten plants from each plot were randomly selected from the middle ridges for collecting data on plant height (cm), height to first pod (cm), number of fruiting nodes/main stem, number of reproductive branches per plant, number of pods per plant, number of seeds per pod, 1000 seed weight (g), seed yield per plant (g) and seed yield (kg/ha). The collected data were subjected to analysis of variance according to the method described by Gomez and Gomez (1984), and covariance according to Singh and Chaudhary (1979).

Analysis of variance and covariance were then used to estimate genotypic and phenotypic correlation coefficients between all possible pairs of characters at the five sites, according to the method described by Miller et al. (1958) as follows:

$$r_{gxy} = \sigma_{gxy} / \sqrt{(\sigma^2_{gx}) \cdot (\sigma^2_{gy})}$$

$$r_{phxy} = \sigma_{phxy} / \sqrt{(\sigma^2_{phx}) \cdot (\sigma^2_{phy})}$$

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.

RESULTS

The phenotypic and genotypic correlation coefficients among traits at the five sites are shown in Tables 1 to 5. Genotypic correlations tended to be larger than the phenotypic ones for most of the character combinations at the five sites. There were differences in magnitude and signs of genotypic and phenotypic correlation for some character combinations, at the five locations. Correlation coefficients greater than +1/or less than-1 were obtained in this study. Seed yield per plant had significant positive phenotypic and genotypic correlations (with number) of fruiting nodes/main stem and number of reproductive branches per plant at three locations (Tables 1 to 5), number of pods per branch, number of pods per plant and number of seeds per pod at two locations (Tables 1, 4 and 5), and 1000 seed weight at one location (Table 1). On the other hand, seed yield per plant had significant negative phenotypic and genotypic association with days to 50% flowering at two sites (Tables 1 and 4), plant height, height to first pod and days to maturity at one location (Tables 1 and 4). Seed yield per plant correlated significantly and positively at the phenotypic level, with plant height at three sites (Tables 2, 3 and 5). Seed yield kg/ha showed significant positive phenotypic correlation with seed yield per plant at the five sites, and significant positive genotypic correlation at three sites (Tables 1, 4 and 5).

To some extent, the pattern of the correlations between seed yield kg/ha and other character was similar to that between seed yield per plant and other characters. Seed yield kg/ha had significant positive phenotypic and genotypic correlations with number of pods per branch at three sites (Tables 1, 3 and 5), number of fruiting nodes/main stem, number of reproductive branches per plant, number of pods per plant at two locations (Tables 1, 4 and 5) and number of seeds per pod and 1000 seed weight at one site (Table 1).

On the other hand, it had significant negative phenotypic and genotypic ones with days to 50% flowering at four sites (Tables 1, 2, 4 and 5), days to maturity at three sites (Tables 1, 2 and 4), height to first pod at two sites (Tables 1 and 4) and plant height at one site (Table 4). Plant height had significant positive phenotypic correlation with seed yield kg/ha at three locations (Tables 2, 3 and 5). However, seed yield kg/ha was not significantly and positively associated at the phenotypic and the genotypic levels with number of fruiting nodes/main stem and number of seeds per pod at one site (Table 4).

Number of pods per plant had significant positive phenotypic and genotypic association with number of fruiting nodes/main stem at two sites (Tables 1 and 4) and number of pods per branch at one site (Table 1). However, number of pods per plant had significant positive genotypic correlation with 1000 seed weight and a significant negative one with number of seed per pod at one site (Table 2). Number of seeds per pod had significant positive phenotypic correlation with number of reproductive branches per plant, 1000 seed weight at three locations (Tables 1, 2, 4 and 5) and number of fruiting nodes/main stem at one location (Table 1). However, it had non-significant phenotypic one with number of fruiting nodes main stem and number of pods per plant at four locations (Tables 1, 2, 3, 4 and 5). At the genotypic level, number of seeds per pod had significant positive correlation with number of fruiting nodes/main stem at three sites (Tables 1, 3 and 5) and number of pods per branch at two sites (Tables 1 and 5). On the other hand, it had significant negative ones with 1000 seed weight at two sites (Tables 2 and 5). However, number of seeds/pod exhibit non-significant genotypic correlation with number of reproductive branches per plant at three sites (Tables 1, 3 and 4). Number of fruiting nodes/main stem associated significantly and positively at the phenotypic and the genotypic levels, with number of reproductive branches per plant and number of pods/branch at two locations (Tables 1, 3 and 5). However, number of fruiting nodes/main stem had significant positive phenotypic correlations with 1000 seed weight at two sites (Tables 2 and 5), and significant negative one at one site (Table 5).

Number of reproductive branches per plant associated significantly and, negatively at the genotypic level with number of pods/branch and 1000 seed weight at two sites (Tables 1, 2 and 5). The association between

Table 1. Genotypic and phenotypic correlation coefficients between pairs of characters in guar (*Cyamopsis tetragonoloba* L.) genotypes evaluated at Kazgeil, Northren Kordofan State, Sudan, in 1998/99 rainy season.

Characters	Day to 50% flo.	Day to mat.	Plant ht. (cm)	Ht. to 1st pod (cm)	No. of fr. nodes/m.stem	No. of rep. br./pl.	No. of pods/br.	No. of pods/pl.	No. of seeds/pod	1000-seed wt. (g)	Seed yld./pl. (g)	Seed yield kg/ha
Days to 50% flo.		1.04**	0.67**	0.93**	-1.00**	-0.09	-0.65**	-0.88**	-0.75**	-0.92**	-0.96**	-0.83**
		0.65**	0.23	0.72**	-0.53**	0.01	-0.29*	-0.32*	-0.45**	-0.75**	-0.51**	-0.57**
Days to mat.			1.29**	0.88**	-0.79**	0.63**	-0.45**	-0.66**	-0.96**	-1.00**	-1.13**	-0.92**
			0.42**	0.52**	-0.35*	0.22	-0.10	-0.08	-0.42**	-0.59**	-0.53**	-0.57**
Plant ht. (cm)				0.93**	-0.35*	-0.11	-0.87**	-0.76**	-0.58**	-0.68**	-1.66**	-1.22**
				0.20	-0.10	0.09	0.02	-0.02	-0.29*	-0.28	-0.20	-0.25
Ht. to 1st . pod (cm)					-1.04**	-1.28**	-0.68**	-1.09**	-0.64**	-0.56**	-0.83**	-0.69**
					-0.49**	0.17	-0.18	-0.13	-0.31*	-0.45**	-0.24	-0.38**
No. of fr. nodes/m.stem						1.25**	0.81**	1.32**	0.84**	0.71**	0.99**	0.81**
						0.24	0.49**	0.53**	0.29*	0.27	0.34*	0.47**
No. of rep. br./plant							-11.81**	0.20	-0.13	-0.998**	-1.39**	-0.57**
							3.38**	0.82**	0.30*	-0.13	0.32*	0.24
No. of pods/br.								0.92**	0.31*	0.62**	0.59**	0.52**
								0.82**	0.25	0.16	0.46**	0.48**
No. of pods/Pl.									0.49**	0.56**	0.57**	0.66**
									0.41**	0.14	0.55**	0.52**
No. of seeds/pod										0.35**	0.93**	0.82**
										0.39**	0.50**	0.52**
1000-seed wt. (g)											0.91**	0.76**
											0.47**	0.51**
Seed yld. /pl. (g)												1.003**
												0.81**
Seed yield kg/ha												

For each character, figures in the upper and lower parts represent the genotypic and phenotypic correlations, respectively.*, ** are the level of significance at 5 and 1%, respectively. Fr= Fruiting nodes, flo = flowering,mat= maturity,No. of rep. br./pl. = reproductive branches per plant,m.stem = main stem,No. of fr. nodes/m.stem = Number of flowering nodes per main stem,No. pods/br = number of pods per branch,Plant ht. = Plant height,Seed yield./pl = Seed yield per plant,Day to mat. = Days to maturity.

number of pods/branch and 1000 seed weight at the phenotypic and the genotypic levels was significantly negative (except at the phenotypic level at one site) at two locations (Tables 4 and 5). At four locations, the phenotypic and genotypic correlations between days to 50% flowering and days to maturity were significant and positive.

DISCUSSION

In the present study, the genotypic correlation coefficients exceeded the corresponding phenotypic ones for most of the character combinations at the five sites, indicating presence of strong inherited association between the characters. However, Weber and Morthy (1952) referred the low phenotypic correlations to the masking or modifying effect of environment on the genetic associations between characters. Similar result were reported by Abdelmula et al. (1993) in faba bean, Brindha et al. (1997), Gasim and khidir (1998b) and Ibrahim (2001) in rosselle. The

Table 2. Genotypic and phenotypic correlation coefficients between pairs of characters in guar (*C. tetragonoloba* L.) genotypes evaluated at Eljikka, Northren Kordofan State, Sudan, in 1998/1999 rainy season.

Characters	Day to 50% flo.	Day to mat.	Plant ht. (cm)	Ht. to 1st pod (cm)	No. of fr. nodes/m.stem	No. of rep. br./pl.	No. of pods/ br.	No. of pods /pl.	No. of seeds/pod	1000-seed wt. (g)	Seed yld./pl. (g)	Seed yield kg/ha
Days to 50% flo.		0.83**	-1.66**	2.44**	2.88**	-0.42**	-9.74**	-------	-------	-------	-------	-0.75**
		0.47**	-0.37**	0.27	-0.36*	-0.02	-0.38**	-0.16	-0.41**	-0.35*	-0.24	-0.32*
Days to mat.			-2.86**	2.56**	-1.40**	-1.43**	-13.62**	-------	-------	-------	-------	-0.61**
			-0.49**	-0.02	0.09	0.10	-0.18	-0.13	-0.52**	-0.51**	-0.57**	-0.50**
Plant ht. (cm)				-2.34**	6.98**	2.25**	-28.47**	-------	-------	-------	-------	-1.42**
				0.24	0.18	0.28	0.40**	0.51**	0.51**	0.26	0.59**	0.64**
Ht. to 1st . pod (cm)					-17.12**	3.21**	-36.21**	-------	-------	-------	-------	-6.07**
					0.01	-0.21	-0.05	-0.0003	-0.08	-0.06	-0.03	-0.05
No. of fr. nodes/m.stem						2.56**	17.88**	-------	-------	-------	-------	2.35**
						-0.08	0.28	0.32*	-0.07	-0.09	-0.08	0.04
No of rep. br./pl.							-16.01**	-------	-------	-------	-------	2.29**
							0.19	0.34*	-0.12	-0.08	0.02	0.09
No. of pods/br.									-------	-------	-------	-12.24**
								0.75**	0.20	-0.003	0.17	0.18
No. of pods/Pl.									-0.91**	0.32*	-2.12**	-------
									0.21	0.02	0.33*	0.29*
No of seeds/pod										-6.88**	-2.16**	-------
										0.59**	0.73**	0.65**
1000-seed wt. (g)											-0.54**	-------
											0.45**	0.46**
Seed yld. /pl. (g)												-------
												0.85**
Seed yield kg/ha												

For each character, figures in the upper and lower parts represent the genotypic and phenotypic correlations, respectively.*, ** are the level of significance at 5 and 1%, respectively.
Fr= Fruiting nodes, flo = flowering,mat= maturity,No. of rep. br./pl. = reproductive branches per plant,m.stem = main stem,No. of fr. nodes/m.stem = Number of flowering nodes per main stem,No. pods/br = number of pods per branch,Plant ht. = Plant height,Seed yield./pl = Seed yield per plant,Day to mat. = Days to maturity

correlation coefficients greater than +1/or less than -1 registered in this study, are similar to results reported by Elsyed (1999), Abdelmula et al. (1993) in faba bean, Elzilal (1996) and Ismail (2000) in peanuts. The significant positive number of fruiting nodes/main stem and number of reproductive branches per plant at three locations; number of pods per branch, number of pods per plant and number of seeds per pod at two sites, suggest genetic basis for these relationships and lesser influence of environment on these estimates.

The significant negative genotypic correlation between height to first pod and seed yield per plant suggests that selection of plants with high height to first pod will produce low yield per plant and consequently low yield kg/ha. This was further substantiated by the strong positive

Table 3. Genotypic and phenotypic correlation coefficients between pairs of characters in guar (*C. tetragonoloba* L.) genotypes evaluated at Beinu, Northren Kordofan State, Sudan, in 1998/1999 rainy season.

Characters	Day to 50% flo.	Day to mat.	Plant ht. (cm)	Ht. to 1st pod (cm)	No. of fr. nodes/m.stem	No. of rep. br./pl.	No. of pods/br.	No. of seeds/ pod	1000-seed wt. (g)	Seed yld./pl. (g)	Seed yield kg/ha
Days to 50% flo.		0.92**	1.30**	1.12**	-0.20	0.33*	-------	-0.61**	0.26	1.71**	-------
		0.70**	0.05	0.47**	-0.27	-0.08	0.05	-0.31*	0.12	0.03	0.02
Days to mat.			083**	089**	-0.16	-0.17	-------	0.37**	0.34*	0.97**	-------
			0.21	0.52**	-0.12	0.01	0.18	0.15	0.12	0.16	0.15
Plant ht. (cm)				0.58**	0.20	0.58**	-------	0.27	1.13**	2.45**	-------
				0.05	0.49**	0.41**	0.43**	0.23	0.25	0.42**	0.45**
Ht. to 1st . pod (cm)					-0.35*	-0.05	-------	-0.35*	0.34*	0.18	-------
					-0.09	0.15	0.25	-0.17	0.04	0.11	0.14
No. of fr. nodes/m.stem						0.36*	-------	0.54**	0.37**	0.63**	-------
						0.51**	0.39**	0.24	0.26	0.42**	0.40**
No. of rep. br./pl.							-------	0.17	1.01**	2.61**	-------
							0.66**	-0.05	0.19	0.55**	0.61**
No. of pods/br.								-------	-------	-------	7.65**
								-0.12	0.21	0.71**	0.75**
No. of seeds/pod									0.10	-0.71**	-------
									-0.05	-0.04	-0.04
1000-seed wt. (g)										1.20**	-------
										0.28	0.26
Seed yld. /pl. (g)											-------
											0.98**
Seed yield kg/ha											

For each character, figures in the upper and lower parts represent the genotypic and phenotypic correlations, respectively.*, ** are the level of significance at 5 and 1%, respectively.
Fr= Fruiting nodes, flo = flowering,mat= maturity,No. of rep. br./pl. = reproductive branches per plant,m.stem = main stem,No. of fr. nodes/m.stem = Number of flowering nodes per main stem,No. pods/br = number of pods per branch,Plant ht. = Plant height,Seed yield./pl = Seed yield per plant,Day to mat. = Days to maturity

correlation between seed yield per plant and seed yield kg/ha. The significant negative associations between days to 50% flowering and each of seed yield per plant at two sites and yield kg/ha at four sites, indicate that early flowering plants will tend to produce more seed yield/plant and seed yield kg/ha.

The present findings that days to 50% flowering was positively and significantly correlated with days to maturity at four locations, suggesting that days taken to maturity can be predicted by days taken to flowering. Similar results were reported in a number of crops such as cowpea (Singh and Mehndiratta, 1969), mungbean (Singh and Malhotra, 1970) and faba bean (Abdelmula et al., 1993).

In the present study, different patterns of association were exhibited by yield components. Baker and Milburn (1994) stated that the various sink organs within a plant compete for assimilates. The resultant partitioning usually follows an order of priority between the sink organs which often undergoes change during plant development. Furthermore, the strength of individual competing

Table 4. Genotypic and phenotypic correlation coefficients between pairs of characters in guar (*C. tetragonoloba* L.) genotypes evaluated at Jebel Hemdella Northren Kordofan State, Sudan, in 1998/1999 rainy season.

Characters	Day to 50% flo.	Day to mat.	Plant ht. (cm)	Ht. to 1st pod (cm)	No. of fr. nodes/m.stem	No. of rep.br./pl.	No. of pods/br.	No. of pods/pl.	No. of seeds/pod	1000-seed wt. (g)	Seed yld./pl. (g)	Seed yield kg/ha
Days to 50% flo.		0.95**	0.50**	0.93**	-0.42**	-0.92**	-------	-1.17**	-0.37**	-------	-1.04**	-0.96**
		0.69**	0.31*	0.52**	-0.20	-0.10	-0.28	-0.28	-0.07	0.06	-0.39**	-0.52**
Days to mat.			0.82**	0.52**	0.13	-0.05	-------	-0.27	-0.13	-------	0.65**	-0.73**
			0.40**	0.42**	0.06	-0.03	-0.29*	-0.18	0.01	-0.09	0.003	-0.47**
Plant ht. (cm)				0.64**	0.15	-0.94**	-------	-0.77**	-0.36*	-------	-1.06**	-1.18**
				0.36*	0.33*	0.06	0.16	0.13	-0.03	0.10	-0.37**	-0.44**
Ht. to 1st pod (cm)					-0.71**	-1.30**	-------	-1.07**	-0.04	-------	-0.90**	-0.96**
					-0.22	-0.33*	-0.32*	-0.43**	-0.03	-0.25	-0.52**	-0.55**
No. of fr. nodes/m.stem						0.13	-------	0.73**	-0.15	-------	0.31*	0.21
						0.45**	0.59**	0.59**	0.16	0.28	0.11	0.20
No. of rep. br./pl.							-------	0.31*	0.21	-------	0.84**	0.45**
							0.58**	0.81**	0.33*	0.54**	0.35*	0.32*
No. of pods /br.								-------	-------	-5.49**	-------	-------
								0.85**	0.30*	0.52**	0.35*	0.37**
No. of pods/Pl.									1.08**	-------	0.99**	0.97**
									0.33*	0.58**	0.43**	0.50**
No. of seeds/pod										-------	0.55**	0.26
										0.30*	0.31*	0.20
1000-seed wt. (g)											-------	-------
											0.48**	0.33*
Seed yld./ plant (g)												1.14**
												0.86**
Seed yield kg/ha												

For each character, figures in the upper and lower parts represent the genotypic and phenotypic correlations, respectively. *, ** are the level of significance at 5% and 1%, respectively.

sinks reflects both genetic determinants and regulation by environmental factors. The significant positive correlation between number of pods per plant and each of number of fruiting nodes/main stem at two sites and number of pods per plant at one site, show that each of them could be used as an indicator for the other. However, the negative genotypic correlation between number of pods per plant and number of seeds per pod and the positive one between number of pods per plant and 1000 seed weight, means that the number of pods per plant increase at the expense of number of seeds per pod. This is in accordance with conclusion obtained by Jain (1975), who reported that in grain legumes, the photosynthetic rate register a sharp decline as pods begin to develop. The significant negative genotypic correlation of each of number of reproductive branches per plant, number of pods per branch and number of seeds per pod at two sites, number of fruiting nodes/main stem at one site with 1000 seed weight, suggest that selection for any of the former components will result in small seed size. Therefore, special consideration should be given to those components when they are to be improved simultaneously with seed size. The negative association between 1000 seed weight and number of seeds per pod is in accordance with the findings of Seiler and Stafford (1985).

Table 5. Genotypic and phenotypic correlation coefficients between pairs of characters in guar (*Cyamopsis tetragonoloba* L.) genotypes evaluated at Elkheirasan Northren Kordofan State, Sudan, in 1998/1999 rainy season.

Characters	Day to 50% flo.	Plant ht. (cm)	Ht. to 1st pod (cm)	No. of fr. nodes/m.stem	No. of rep. br./pl.	No. pods/br.	No. of seeds/pod	1000-seed wt. (g)	Seed yield./pl. (g)	Seed yield kg/ha
Days to 50% flo.		-------	0.67**	-0.51**	-1.12**	-0.92**	-1.01**	0.67**	-0.01	-1.19**
		-0.23	0.14	-0.38**	-0.44**	-0.52**	-0.37**	0.10	-0.38**	-0.40**
Plant ht. (cm)			-------	-------	-------	-------	-------	-------	-------	-------
			0.62**	0.31*	0.68**	0.31*	0.04	0.13	0.48**	0.48**
Ht. to 1st . pod (cm)				-0.46**	-0.78**	-0.77**	-0.65**	-0.01	-0.44**	-0.45**
				-0.08	0.33*	-0.13	-0.02	0.14	0.06	0.07
No. of fr. nodes/m.stem					0.46**	0.65**	0.39**	-0.69**	0.65**	0.84**
					0.39**	0.50**	-0.05	-0.24	0.42**	0.46**
No. of rep. br./pl.						1.28**	2.25**	-1.53**	1.55**	1.42**
						-------	0.32*	0.003	0.70**	0.70**
No. of pods/br.							0.80**	-1.18**	1.34**	1.39**
							0.24	-0.37**	0.65**	0.64**
No. of seeds/pod								-1.09**	0.41**	0.47**
								0.02	0.13	0.14
1000-seed wt. (g)									-0.66**	-0.73**
									-0.003	-0.01
Seed yld. /pl. (g)										2.13**
										0.97**
Seed yield kg/ha										

For each character, figures in the upper and lower parts represent the genotypic and phenotypic correlations, respectively.*, ** are the level of significance at 5 and 1%, respectively.

Conclusion

Selection for ideotype characterized to some degree, by early flowering, low height to first pod, numerous reproductive branches, fruiting nodes/main stem and high number of seeds/pod might result in high seed yield/plant. However, days taken to maturity can be predicated by days taken to flowering. Because of the negative correlations detected at some locations between seed yield and its components and among yield components, multi- trait index selection would be the most efficient method to combine improvements in seed yield and phenological performance.

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