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Assessment of Genetic Association among Seedling Traits in Guar (Cyamopsistetragonolobal) Genotypes under Water Stress Conditions

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Abstract: *The prescribed experiment was conducted in glasshouse of Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan during the growing season of 2011-2012 to access genetic associations of various traits in twenty Guar (CyamopsistetragonolobaL.) genotypes under water stress conditions. Water stress was applied as the 100% irrigation (control), 75% irrigation (moderate water stress) and 50% irrigation (sever water stress) based on the field capacity of the soil. The results indicated that highly significant phenotypic correlation was found for shoot length (SL) with leaf area (LA) and chlorophyll a (Chlo. a), Chlorophyll b (Chlo. b); root length (RL) with dry root weight (DRW) and leaf area; fresh shoot weight (FSW) with dry shoot weight (DSW) and Chlorophyll b; dry shoot weight with fresh root weight (FRW), leaf area and Chlorophyll b; dry root weight with leaf area and Chlorophyll a with Chlorophyll b while shoot length with Chlorophyll a and b; fresh shoot weight with dry shoot weight and Chlorophyll b; dry shoot weight with Chlorophyll b and Chlorophyll a with Chlorophyll b at genotypic level at 100% irrigation. Significant correlation was found at 75% irrigation level for SL with DSW; RL with LA; FSW with DRW and Chlo. a with Chlo. b at phenotypic level while only Chlo. a with Chlo. b at genotypic level. At highest water stress (50% irrigation) significant phenotypic correlation was found for SL with RL; RL with FSW and LA; FSW with DSW, FRW and Chlo. b; LA with Chlo. a and Chlo. a with Chlo. b while SL with RL and Chlo. a with Chlo. b at genotypic level. It was concluded from significant correlation of shoot length, chlorophyll a and b, fresh and dry shoot weight that selection of drought resistance genotypes may be helpful to improve yield under water stress conditions.*

Keywords: *Genotypes, water stress, genotypic, phenotypic, correlation*

1. INTRODUCTION

With adequate amount of irrigation and fertilizers application under the hot climatic conditions, guar has a high tolerability to abiotic stress especially against salinity stress and water deficit conditions (Omer *et al.,* (1993) and Ashraf *et al.,* (2005)). Due to its smaller seed, short plant texture and tolerability to water deficit stress, have an ease of growing in hot climatic condition with low water availability all around the world. The bulk production of the guar lies in the semiarid and deserts of India, Pakistan, Africa, Australia and USA where rainfall is the major contributor to crop production. Guar is an excellent drought avoider and has a large and deeper tap root system for efficient water extracting ability from the soil (Pathak *et al.,* 2010). Drought stress world wild has been reported as a major environmental factor for reduction in agricultural productivity and a threat to food security. It affects the carboxylation, photosynthetic efficiency, electron transport chain and ultimately yield. It may also alter the cell membrane composition and permeability (Lauriano *et al.,* 2000). Water deficiency in plants remarkably decreases the photosynthetic pigments especially chlorophyll a and b contents which alters the whole plant growth and mechanisms (Manivannan*et al.,* 2007) and hence decrease in total biomass production, net yield and grain filling occurs (Kamara*et al.,* 2003). Drought stress results in retorted plant growth as it effects the water relations, cell membrane activity, osmotic adjustments and photosynthesis (Benjamin and Nielsen, (2006) and Praba*et al.,* 2009).Leaves per plant, leaf dry weight, shoot dry weight, stem dry weight, ion accumulation, carbon fixation, chlorophyll contents and leaf to stem ratio in corn decreases with increase in drought stress severity (Hajibabaee*et al.,* 2012).Drought stress at earlier stages of plant growth reduces the root and shoot dry mass, net biomass, sodium and potassium ion concentration and suppresses the chlorophyll a, chlorophyll b and total chlorophyll but differ in different genotypes of the same specie (Anjum*et al.,* (2003); Ebrahim, (2012)).

Physiological response of plants and their morphological adaptations against drought stress depends on their genomic material and varies even within species (Mehdi and Ahsan, 2000b). A number of studies around the scientific world have been done to correlate the genotypic characters with their phenotypic response against drought stress at early growth stages in wheat (Ahmad *et al.,* (2000); Wajid*et al.,* (2011), cotton (Voloudakis*et al.* 2002), maize (Mehdi and Ahsan, (2000a); Ahsan*et al.,* (2011); Ali *et al.,* (2011a, b); Ali *et al.,* (2012); Ali *et al.,* (2013a, b, c) and Ahsan*et al.,* (2013), sunflower (Petcu*et al,* 2003) and Chickpea (Ali *et al.,* 2010). It was deduced that plants varies in their response to drought stress genetically; even close-relative genotypes within a specie. In the light of above scientific evidences following research study was designed to evaluate the genetic correlation among various seedling traits in guar under various water stress levels.

2. MATERIALS AND METHODS

Seedling growth and morpho-physiological characters of twenty (20) Guar (*Cyamopsistetragonoloba*L.) Genotypesunder water stress conditions were studied in a wire-netting green house during the crop season of 2011-2012 at Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad, Pakistan (longitude 73°74 East, latitude 30°31.5 North and 184 meters elevation). Twenty genotypes comprised of V-S-1, V-S-3, V-S-4, V-Brook, V-1034, V-4880, V-1131, V-1181, V-2536, V-2756, V-4055, V-4617, V-4642, V-4749, V-4763, V-2-1, BR-90, BR-99, BR-99-Super and V-4621, were collected from different agricultural institutes of Pakistan. Sixty (60) pots of 30 cm high and 15 cm diameter size were filled with 1.5 kg of air dried, crushed and well pulverized clay loam soil. Water stress was applied as 100% irrigation (at field capacity = control), 75% irrigation (moderate water stress) and 50% irrigation (sever water stress) based on the field capacity of the soil used; calculated before the start of experiment. The holes of the pots were blocked with polythene sheet to avoid the leaching of nutrients and water loss. Experiment was arranged under the Completely Randomized Design (20 × 2 factorial CRD) with three replications. Green house temperature was maintained at 25 ± 5^{0}C with 12 hours of light on average. Ten (10) seeds of each genotype were sown in each pot in three replications. After 14 and 28 days of germination data for growth and morpho-physiological characters was recorded according to the standard procedure. Shoot and root length was recorded for five (5) plants from each replication for all genotypes and water stress treatments. Fresh shoot and root weights after water washing was taken by electric balance at lab while dry weights for both were recorded by air drying followed by oven drying at 65 ^{0}C till content weight was obtained. Leaves obtained from randomly selected competent plants from each pot were used to record leaf area (LA) according following formula:

Leaf area = Leaf length (cm) × maximum leaf width (cm) × 0.74

To measure the chlorophyll content**,** 50 to 100 mg of tissue from 10 leaves was obtained randomly from each plot. The tissues were then placed into a mortar, 10 mL of 80% acetone (v/v) was added, and the tissue was ground with a pestle. The leaf homogenate was vacuum-filtered using a vacuum pump. The filtrate volume was then brought up to 30 mL with 80% acetone (v/v). Absorbance was measured at 663 nm and 645 nm using a UV/VIS spectrophotometer (Beckman DU-530). The amount of chlorophyll a, chlorophyll b and total chlorophyll were calculated according to Arnon's equation (1949).

Chlo a (mg/g) =	((12.7×Abs663)-(2.6×Abs645))×ml Aseton
	mg leaf tissue
Chlo a (mg/g) =	((22.9×Abs645)-(4.68×Abs663))×ml Aseton
	mg leaf tissue

Phenotypic and genotypic correlation coefficient was calculated as outlined by Kwon and Torrie (1964).

$$\text{rp} = \frac{\text{Mij}}{(\text{Mii})(\text{Mjj})}$$

Where; rp = the estimate of phenotypic correlation coefficient, Mij = the mean product of genotypes for the ith and jth traits, Mii and Mjj = Variety mean squares for ith and jth traits, respectively.

Standard error of genotypic correlation coefficients (SE of rg) were calculated according to Reeve (1955). Genotypic correlation coefficient was considered significant if their absolute value exceeded twice their standard error. Phenotypic correlation coefficients were tested using t-test (Steel and Torrie, 1997) as given below.

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

Where; r = the phenotypic correlation coefficient; n-2 = correlation error degree of freedom

The recorded data were recorded and analyzed through analysis of variance (ANOVA) Steel *et al.,* (1997) to estimate the morpho-physiological and genetic variability and its components for drought tolerance in guar. Individual comparisons of means were made by using Duncan Multiple Range Test (DMRT).

3. RESULTS AND DISCUSSION

Phenotypic expression of plant genomes is a complex phenomenon and it becomes much more complicated when a plant exposed to a particular stress e.g. drought stress. Hundreds and thousands of genes are being translated simultaneously, thousands of polypeptides chains, number of hormones, hundreds of physiological phenomena works together to cop the stress situation and response to drought stress is one of the most composite action of plant. As the genotypes within specie vary in their genetic codes, their phenotypic adaptation and physiological responses are also different under different circumstances. To avoid the complexity and in ease to express results meaningfully, here in presented research work, discussed the statistically significant correlations among the different traits of guar as the measure of drought resistance capability and a sudden or noticeable fluctuations in the correlation data.

3.1. Correlation among Guar Seedling Traits under High Water Stress (50% Water Applied) Shoot Length

Findings in Table 1 showed positive genotypic association ofshoot lengthwith root length (0.996) and phenotypic association (0.666) which are significantly higher than all other correlations of shoot length. Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. A positive genotypic correlation (0.118) and phenotypic (0.169) with fresh shoot weight was also observed. Positive genotypic correlation estimates for shoot length with dry shoot weight (0.005), leaf area (0.064), chlorophyll a (0.237) and chlorophyll b (0.427) while phenotypically positive correlation was found with DSW (0.144), FRW (0.008), LA (0.030) chlorophyll a (0.105) and chlorophyll b (0.182). Positive and significant correlation of chlorophyll contents indicated that photosynthetic rate will be higher due to which crop productivity may be enhanced due to which the selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Negative genotypic correlation with FRW (-0.085) and DRW (-0.617) has been resulted while phenotypically shoot length is negatively correlating only with DRW (-0.191) under 50% irrigation (highest drought stress). Positive genotypic correlation indicated that selection will be effective for the improvement of drought tolerance in guar. Similar results were reported by Mehdi and Ahsan, (2000a); Ali *et al*., (2011a, b);Ali *et al*., (2012), Anjum*et al*., (2003); Ebrahim, (2012) and Ali *et al*., (2013a, b, c).

3.2. Root Length

Root length (RL) has significantly positive genotypic correlation with FSW (0.568) (Table: 1) and highly significant phenotypic correlations FSW (0.511) while a negative phenotypic correlation with LA (-0.303). Overall DSW (0.166) and chlorophyll a (0.134) have recorded positively in correlation for genotype whereas DSW (0.164), DRW (0.075) and chlorophyll b have found phenotypically in positive correlation.All other genotypic and phenotypic parameters were in negative correlation with root length. The greater root length indicated that the roots may go for higher depth to absorb more water and long roots may also be helpful to plant to enhance water absorption area to compete with drought conditions. Positive correlation here indicating the additive role while negative stands for suppression of one character by the increase in the other one. On the basis of positive genotypic correlation it may be suggested that selection will be effective for the improvement of drought tolerance in guar(Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000); Anjum*et al*., (2003); Ali *et al*., (2011a, b);Wajid*et al.*, (2011); Ali *et al*., 2012 andEbrahim, (2012)).

3.3. Fresh Shoot Weight

A perusal of Table: 1 revealed significant and positive genotypic correlation (0.204) and positive phenotypic correlation (0.271) of fresh shoot weight with dry shoot weight (RSW). It showed positively genotypic and phenotypic association (0.435) and (0.353) with fresh root weight and negative genotypic and phenotypic correlation (-0.653) and (-0.219) with dry root weight. Leaf area also negatively correlates in both genotypic and phenotypic (-0.334) and (-0.149) with FSW.Fresh shoot weight showed negative genotypic correlation (-0.227) and negative phenotypic correlation (-0.114) with chlorophyll a while chlorophyll b also negatively associates in both genotypic (-0.551) and phenotypic (-0.299) with FSW.Higher fresh shoot weight indicated that the accumulation of organic compounds in the seedling body may be higher due to higher photosynthesis for higher chlorophyll contents. The higher shoot weight also indicated that roots were prolonged for deeper depth to absorb large quantities of water used in efficient photosynthetic process. It was suggested that fresh shoot weight was positively correlated with root length that may be effective for the improvement of yield under drought conditions in guar (Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a);Ali *et al*., (2012) andEbrahim, (2012)).

Table 1. *Genotypic and phenotypic correlation between different traits in guar under highest water stress level (50% water applied)*

Traits		RL	FSW	DSW	FRW	DRW	LA	Chlo.a	Chlo.b
SL	**g**	0.996*	0.118	0.005	-0.085	-0.617	0.046	0.237	0.427
	p	0.666**	0,169	0.144	0.008	-0.191	0.030	0.105	0.182
RL	**g**		0.568*	0.166	-0.349	-0.048	-0.578	0.134	-0.090
	p		0.511**	0,164	-0.033	0.075	-0.303*	0.049	-0.048
FSW	**g**			0.204	0.435	-0.653	-0.334	-0.227	-0.551
	p			0.271*	0.353**	-0.219	-0.149	-0.114	-0.299*
DSW	**g**				0.035	-0.221	-0.015	-0.249	-0.267
	p				0.194	0.031	0.049	-0.141	-0.173
FRW	**g**					-0.322	-0.082	0.017	-0.225
	p					-0.086	0.104	-0.083	-0.228
DRW	**g**						-0.183	-0.714	-0.452
	p						-0.568	-0.240	-0.148
LA	**g**							0.477	0.279
	p							0.345**	0.231
Chlo.a	**g**								0.881*
	p								0.795**

** = Significant at 5% probability level, ** = Significant at 1% probability level, SL = Shoot Length, RL = Root Length, FSW = Fresh Shoot Weight, DSW = Dry Shoot Weight, FRW = Fresh Root Weight, DRW = Dry Root Weight, LA = Leaf Area, Chlo.a = Chlorophyll a,Chlo.b = Chlorophyll b*

3.4. Dry Shoot Weight

It was concluded from Table: 1 that DSW had significant correlation with FRW at genotypic (0.035) and phenotypic (0.194) levels. DSW had negative correlation with DRW at genotypic level (-0.221) but positive correlation at phenotypic level (0.031).Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. LA had negative genotypic correlation (-0.015) and positive phenotypic correlation (0.049) with dry shoot weight. Correlations of DSWwere negative at genotypic (-0.249) and phenotypic (-0.141) levels with chlorophyll a. Chlorophyll b showed non-significant association at genotypic (-0.267) and phenotypic (-0.173) levels with dry shoot weight.Dry shoot weight indicated that the photosynthetic compounds were stored in the seedlings that improve shoot weight, the reserved organic compounds in the shoot may be used by plant to compete under drought conditions. The selection of drought tolerance guar genotypes may be helpful to improve yield under drought condition. Finding were similar as reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Anjum*et al*., (2003); Petcu*et al.,* (2003); Ali *et al*., (2011a, b);Wajid*et al.,* (2011); Ali *et al*., (2012) andEbrahim, (2012).

3.5. Fresh Root Weight

FRW had negative genotypic (-0.322) and phenotypic (-0.086) correlation with dry root weight (Table: 1). It showed negative correlation at genotypic (-0.082) and positive at phenotypic (0.104) with LA.Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Chlorophyll a showed positive genotypic (0.017) and negative phenotypic (-0.083) association with fresh root weight. FRW showed negative correlation with chlorophyll b at both genotypic (-0.225) and phenotypic (-0.228) levels. Higher fresh root weight indicated that the root volume was increased to absorb higher water quantity under drought condition. The higher root weight also indicated that the root were spread in all direction to keep the seedling withstand under drought condition. Selection on the basis of fresh root weight may be helpful to improve drought tolerance (Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000); Voloudakis*et al*.,(2002); Anjum*et al*., (2003); Petcu*et al.,* (2003); Ali *et al*., (2011a, b); Wajid*et al.,*(2011); Ali *et al*., (2012) and Ebrahim, (2012)).

3.6. Dry Root Weight

Results in Table: 1 showed that DRWhad negative phenotypic (-0.568) and genotypic (-0.183) correlation with LA. Chlorophyll a had non-significant and negative correlation at both genotypic (-0.714) and phenotypic (-0.240) levels with DRW.Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. It showed negative association at both genotypic (-0.452) and phenotypic (-0.148) levels with chlorophyll b. The higher value of dry root weight indicated that the accumulation of photosynthetic compounds was enhanced in root under drought conditions. The roots keep higher moisture contents due to higher root volume and root length that help seedling survive under drought environment. Higher yielding guar genotypes may be selected on the basis of dry root weight under drought (Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Anjum*et al*., (2003); Petcu*et al.,* (2003); Ali *et al*., (2011a, b);Wajid*et al.,* (2011); Ali *et al*., (2012) andEbrahim, (2012)).

3.7. Leaf Area

Table: 1 described the positive and significant genotypic (0.477) and phenotypic (0.345) correlation between LA and chlorophyll a. Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Results showed positive genotypic (0.279) and phenotypic (0.231) correlation between leaf area and chlorophyll b.Due to increase in leaf area the chlorophyll contents, water absorption, root length and root weight may be increased and hence photosynthetic rate that may be helpful to improve plant efficiency to compete against drought.Finds were similar as reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al.*, (2002); Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a, b);Wajid*et al.*, (2011); Ali *et al*., (2012) andEbrahim, (2012).

3.8. Chlorophyll a

Results indicated a positive and highly significant association between chlorophyll a and chlorophyll b at both genotypic (0.881) and phenotypic (0.795) levels.Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions.Higher chlorophyll contents indicated that photosynthetic rate will be higher due to improve in water absorption, higher root volume, higher root length and weight which indicated that crop productivity may be enhanced under water stress conditions (Ahmad *et al*., (2000); Voloudakis*et al.*,(2002); Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a); Wajid*et al.*,(2011) and Ebrahim, (2012)).

a) Correlation among traits of guar under moderate water stress (75% water applied) (Table: 2)

Under moderate water stress all the traits of guar showed different associations among each other as compare to high water stress (50% water application) as revealed in Table: 1. Results are described below.

3.9. Shoot Length

Only DSW (-0.256) has been found significantly in correlation with SL for phenotype (Table: 2). RL (0.403), FSW (0.133), FRW (0.114), LA (0.123), Chlorophyll a (0.042) and chlorophyll b (0.032) has been found non-significantly correlated with SL for phenotype.Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. On the other hand FSW (0.338), chlorophyll a (0.076) and chlorophyll b (0.726) were found non-significantly positive for SL whereas all other phenotypic and genotypic correlations have been found negative but non-significant. Higher shoot length indicated that the seedling ability of photosynthesis was efficient and accumulation of organic compounds was much higher as compare to the use of photosynthesizes. Higher shoot length under drought suggested that selection for drought tolerance genotypes may be effective to enhance crop plant productivity and yield (Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a, b);Wajid*et al.*, (2011) and Ali *et al*., (2012).

3.10. Root Length

Root length (RL) for genotypic correlation had recorded positive non-significantly for all traits except LA and chlorophyll b (-0.625), (-0.161) respectively (Table: 2). Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. LA (-0.322) was found significantly negative in correlation with RL for phenotypic correlation while all other parameter (except chlorophyll b) were although positive but non-significant at 5% probability level. The seedlings with greater root length can penetrate under deeper depths to absorb water and nutrients and under drought longer root indicated the ability of seedling to withstand and survive under drought. Findings were similar as reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a);Wajid*et al.*, (2011) and Ali *et al*., (2012).

3.11. Fresh Shoot Weight

Under moderate water stress fresh shoot weight showed significant and positive correlation with DRW (0.280) for phenotypic correlation (Table: 2). Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. All other parameters were found in positive correlation with FSW for both phenotypic and genotypic correlation but non-significant. Fresh shoot weight indicated that the moisture contents were higher in the seedlings and stored organic compounds. Selection of drought tolerance guar genotypes may be helpful to improve yield and productivity under drought conditions. Similar results were found by Anjum*et al*., (2003); Wajid*et al.*, (2011); Ali *et al*., (2012) andEbrahim, (2012).

3.12. Dry Shoot Weight, Fresh Root Weight, Dry Root Weight and Leaf Area

Correlation with all parameters or guar at 75% irrigation were recorded non-significant for all the phenotypic as well as genotypic traits. Most of the traits were negatively correlating among themselves but non-significant at 5 % probability level (Table: 2).Higher dry shoot weight, fresh and dry root weight and leaf area indicated that the seedlings showed higher photosynthetic rate as chlorophyll contents were higher and water absorption was also higher due to greater length and volume of roots. Due to higher leaf area the fresh biomass of seedlings also increased that helps to tolerate drought conditions. Positive and significant correlations suggested that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Results were similar with findings of reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Wajid*et al.*, (2011) and Ali *et al*., (2012).

3.13. Chlorophyll a

Positive and significant association between chlorophyll a and chlorophyll b at genotypic (0.038) while highly significant at phenotypic (0.881) was observed.Positive genotypic correlation indicated that due to increase in leaf area the chlorophyll contents may be increased and hence photosynthetic rate may also be increased due to which yield may be improved and selection will be effective for the improvement of drought tolerance in guar.Similar results were found by Ali *et al*., (2011a, b);Wajid*et al.*, (2011) and Ebrahim, (2012).

Table 2. *Genotypic and Phenotypic Correlations of Different Traits in Guar (75% water applied)*

Traits		RL	FSW	DSW	FRW	DRW	LA	Chlo.a	Chlo.b
SL	g	-0.076	0.338	-0.341	-0.158	-0.252	-0.136	0.076	0.726
	p	0.043	0.133	-0.256*	0.114	-0.041	0.123	0.042	0.032
RL	g		0.017	0.378	0.125	0.058	-0.625	0.158	-0.161
	p		0.065	0.211	0.008	0.139	-0.322*	0.042	-0.180
FSW	g			0.078	0.660	0.769	0.201	0.312	0.108
	p			0.073	0.350	0.280*	0.173	0.086	0.058
DSW	g				-0.003	0.481	-0.412	0.072	-0.038
	p				0.029	0.089	-0.198	0.114	0.046
FRW	g					-0.268	-0.300	0.313	0.252
	p					-0.115	-0.116	0.168	0.149
DRW	g						-0.188	-0.353	-0.269
	p						-0.181	-0.181	-0.151
LA	g							-0.138	-0.047
	p							-0.070	-0.057
Chlo. a	g								0.038*
	p								0.881**

** = Significant at 5% probability level, ** = Significant at 1% probability level, SL = Shoot Length, RL = Root Length, FSW = Fresh Shoot Weight, DSW = Dry Shoot Weight, FRW = Fresh Root Weight, DRW = Dry Root Weight, LA = Leaf Area, Chlo.a = Chlorophyll a,Chlo.b = Chlorophyll b*

b) Correlation among traits of guar without water stress (100% water applied) (Table: 3):

3.14. Shoot Length

Under normal water conditions, shoot length showed significantly positive correlation for chlorophyll a (0.861) and chlorophyll b (0.828) while non-significantly negative correlation with all other traits for genotype. Shoot length is related with photosynthetic rate of seedlings and chlorophyll contents. The seedlings that have higher root length showed greater water absorptions and helps seedlings to withstand under all types of environmental conditions. Selection on the basis of higher shoot length may be helpful to improve crop productivity under drought conditions. A highly significant phenotypic correlation was found positive between SL and chlorophyll a (0.438) and chlorophyll b (0.413) while negative with LA (-0.559). All other associations were recorded non-significantly negative for both genotypic as well phenotypic correlations. Similar findings were reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000); Anjum*et al*., (2003);Ali *et al*., (2011b) andAli *et al*., (2012).

3.15. Root Length

Root length (RL) for phenotypic correlation had recorded positive significant for DRW (0.254) and LA (0.287) while non-significantly positive for DSW (0.062) and chlorophyll a (0.061) (Table: 3).Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Genotypic correlation of RL was found positive with DRW (0.413) and LA (0.480) while all other phenotypic as well as genotypic parameter in correlation with RL have been recorded non-significantly negative. Long roots can go deep in the soil to absorb higher water and nutrients for seedlings under drought conditions and hence selection for drought tolerance may be helpful to improve yield in crop plants(Voloudakis*et al*., (2002); Anjum*et al*., (2003); Ali *et al*., (2011a);Wajid*et al.*, (2011); Ali *et al.*, (2012) andEbrahim, (2012)).

3.16. Fresh Shoot Weight

Under moderate water stress fresh shoot weight showed significantly positive correlation with DSW (0.026) and chlorophyll b (0.676) while non-significantly positive with LA (0.274) for genotypic correlation (Table: 3). It was recorded highly significant for phenotypic correlation with DSW (0.657) and chlorophyll b (0.387).Higher fresh shoot weight indicated the higher reserved moisture contents in shoot that help seedlings to withstand under drought. It was suggested that selection for drought tolerance may be effective. All other correlations were non-significantly negative. Similar findings were reported by Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a, b);Wajid*et al.*, (2011); Ali *et al*., (2012) andEbrahim, (2012).

3.17. Dry Shoot Weight

According to results presented in Table: 3, dry shoot weight had positive and highly significant correlation with chlorophyll b (0.558) and negative with FRW (-0.706) while significantly positive with LA (0.283) for phenotype. Positive and significant correlations indicated that selection of drought tolerance genotypes may be helpful to improve yield under water stress conditions. Only chlorophyll b (0.855) has shown a significantly positive correlation with DSW. Fresh root weight and leaf area were non-significantly correlated with each other. Dry shoot weight indicated that the storing ability of organic compounds in shoot was higher that may help seedling to withstand and survive under drought. Findings were similar as reported by Mehdi and Ahsan, (2000a); Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Anjum*et al*., (2003); Ali *et al*., (2011a);Wajid*et al.*, (2011) and Ali *et al*., (2012).

3.18. Dry Root Weight

DRW was recorded significantly high and positive in correlation with LA (0.390) for phenotype (Table: 3) while all other associations have been found no significant.Higher dry root weight indicated that accumulation of organic compounds was higher in roots, length and volume of roots was also higher. It was suggested that selection of drought tolerance genotypes on the basis of dry root weight may be fruitful to improve crop yield (Voloudakis*et al*., (2002); Anjum*et al*., (2003); Petcu*et al.*, (2003); Ali *et al*., (2011a, b);Ali *et al*., (2012) andEbrahim, (2012)).

3.19. Chlorophyll a

Highly significant genotypic association between chlorophyll a and chlorophyll b at phenotypic (0.542) while significant at genotypic (0.975) levels were observed (Table: 3). Higher chlorophyll contents indicated that leaf area will also be higher due to which photosynthetic rate increased and accumulation of organic compounds also enhanced. Similar findings were reported by Ahmad *et al*., (2000);Voloudakis*et al*., (2002); Ali *et al*., (2011a);Wajid*et al.*, (2011) andAli *et al*.,(2012).

Table 3. *Genotypic and Phenotypic Correlations of Different Traits in Guar (100% applied)*

Traits		RL	FSW	DSW	FRW	DRW	LA	Chlo.a	Chlo.b
SL	**g**	-0.347	-0.415	-0.106	-0.258	-0.259	-0.186	0.861*	0.828*
	p	-0.117	-0.170	-0.023	-0.102	-0.130	-0.559**	0.438**	0.413**
RL	**g**		-0.148	-0.115	-0.421	0.413	0.480	-0.058	-0.155
	p		-0.038	0.062	-0.213	0.254*	0.287*	0.061	-0.106
FSW	**g**			0.026*	-0.600	-0.188	0.274	-0.126	0.676*
	p			0.657**	-0.241	-0.030	0.185	-0.142	0.387**

DSW g **p**				-0.316 -0.706**	-0.107 -0.091	0.336 0.283*	-0.081 0.063	0.855* 0.558**
FRW g **p**					0.003 -0.067	-0.356 -0.216	-0.383 -0.228	-0.577 -0.253
DRW g **p**						0.727 0.390**	-0.092 0.015	-0.153 0.017
LA g **p**							-0.093 0.016	0.337 0.046
Chlo. a g **p**								0.975* 0.542**

** = Significant at 5% probability level, ** = Significant at 1% probability level, SL = Shoot Length, RL = Root Length, FSW = Fresh Shoot Weight, DSW = Dry Shoot Weight, FRW = Fresh Root Weight, DRW = Dry Root Weight, LA = Leaf Area, Chlo.a = Chlorophyll a,Chlo.b = Chlorophyll b*

4. Conclusion

The higher water absorption due to longer and healthy roots the photosynthetic rate increased due to which the plant can tolerate adverse environmental conditions efficiently. It was concluded from significant correlation of shoot length, chlorophyll a and b, fresh and dry shoot weight that selection of drought resistance genotypes may be helpful to improve yield under water stress conditions.

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