The Asian and Australasian Journal of Plant Science and Biotechnology ©2011 Global Science Books

Biometric Parameters in Certain Peanut (*Arachis hypogaea* L.) Varieties Varying in Drought Tolerance

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ABSTRACT

This study was based on the field performance of selected groundnut varieties namely VRI-2, VRI-3, VRI-4, VRI-5, VRI-6, TMV-13, ALR-1, ALR-3 and CO-2, collected from different parts of Tamil Nadu, South India. According to their yield performance during crop (without water deficit) season and drought (with water deficit) season under field conditions, these varieties were categorized into drought tolerant (DT) and drought susceptible (DS) types based on their drought response index (DRI) values. An array of biometric parameters was also analyzed in all the varieties during both seasons in order to understand how these parameters fluctuate due to water deficit. The results showed that variations in biometric parameters among the varieties were statistically significant. It is also clear that the DT types were different from the DS types in terms of biometric parameters. This research paper indicates that drought tolerance in peanut is a result of the interaction among many different biometric traits that work in a synergistic manner, conferring the ability to evade water deficit under field conditions.

Keywords: drought stress, groundnut, yield components, drought response index
Abbreviations: DRI, drought response index; **DMRT**, Duncan's multiple range test; **DT**, drought tolerant; **DS**, drought susceptible

INTRODUCTION

Water resources for agronomic uses are becoming inadequate in many areas (Flexas *et al*. 2006). Among the environmental stresses, drought is considered as the main source of legume yield instability in tropical areas. Groundnut (*Arachis hypogea* L.) is the most important oilseed and cash crop in the semi-arid tropics (Ntare *et al.* 2001). It is originally a native of South America. In Asia, groundnut has been readapted for environmental and agricultural requirements (Hammons 1994). It is a multipurpose crop providing cooking oil and vegetable protein for humans while immature and juvenile pods are used as cattle feed.

Indian agriculture is mainly based on the rainy season (July-Sep). Groundnut is grown largely as a rainfed crop in India. Drought is the major abiotic stress affecting yield and quality of rainfed groundnut in Andhra Pradesh, which is being the major cultivation area for groundnut in South India. The rise and fall in the yield and production coincided with the percentage deviation from the mean annual rainfall (DES 1990). Yield losses due to drought are highly variable depending on its timing, intensity and duration coupled with other location specific environmental factors such as irradiance and temperature (Nigam *et al.* 2001). To stabilize yield under rainfed conditions, it is necessary to develop varieties that tolerate moisture stress at different stages of crop growth. Drought tolerance traits namely low specific leaf area (SLA), high SPAD chlorophyll meter reading (SCMR) and high harvest index (HI) confer advantage under drought conditions (Vasanthi *et al.* 2006). ICGV 86031, CSMG 84-1, ICGS 76 and TAG 24 are some of the identified genotypes with most of the useful traits for the drought tolerance from Andhra Pradesh (Nageswara Rao and Wright 2003).

Understanding the mechanisms of drought tolerance in leguminous species naturally adapted to drought, such as bean or groundnut, can help to improve their agronomic performance (Subbarao *et al.* 1995; Cruz de Caravalho *et al.* 1998; Costa Franca *et al*. 2000). Photosynthesis is one of the key processes to be affected by water deficits, via decreased CO_2 diffusion to the chloroplast and metabolic constraints (Pinheiro and Chaves 2011). Considerable research has been undertaken on the physiological and molecular mechanisms involved in drought adaptation (Bohnert *et al.* 1995). Plants perceive and respond rapidly to alterations (even small) in water status via a series of physiological, cellular, and molecular events developing in parallel (Chaves *et al*. 2009). However, there is still no comprehensive standard system for measuring drought resistance (Blum 1999), especially because the physiological model approach is not always adequate for selection because of negative correlations between physiological traits involved in drought adaptation (Turner *et al.* 2001). A simple and direct link between a particular trait and maintenance of yield under drought has never been proven (Clavel *et al.* 2005). Consequently, plant improvement programmes have not been able to fully exploit existing physiological data (Richard 1996; Turner *et al.* 2001).

Temperature and drought stresses may occur simultaneously (Machado and Paulsen 2001), but temperature stress is far more detrimental to reproductive development in canola (*Brassica napus* L.) and mustard (*Brassica juncea* L.) (Angadi *et al.* 2000; Gan *et al.* 2004). The high temperature stress decreased seed yield per plant by 39% for desi chickpea and 42% for kabuli chickpea ($P < 0.01$) (Wang *et al.* 2006).

The aims of this study were (1) to classify certain South Indian peanut varieties into DT and DS types based on DRI, and (2) to study the influence of drought and crop seasons on biometric parameters in DT and DS peanut varieties.

These objectives once fulfilled, will form a strong foundation for our further studies on physiological, biochemical and molecular basis of drought tolerance in peanut, which in turn will help in the development of markers for drought tolerance.

Received: 4 January, 2011. Accepted: 4 March, 2011.

MATERIALS AND METHODS

The field experiments were carried out both during crop (July-October) and drought seasons (April-June) of 2007 at Karpagam Arts and Science College, Coimbatore. This study involved 9 South Indian groundnut cultivars, whose biometric parameters were measured and yield was determined in both the crop and drought seasons.

The experiments were carried out with 27 plots (3 plots for each variety). Nine groundnut cultivars such as VRI-2, VRI-3, VRI-4, VRI-5, VRI-6, TMV-13, ALR-1, ALR-3 and CO-2, were used in this study. Among these, six varieties (VRI-2, VRI-3, VRI-4, VRI-5, VRI-6 and TMV-13) were from the Regional Research Station of Tamilnadu Agriculture University (TNAU), Vridhachalam and three varieties (ALR-1, ALR-3 and CO-2) were from Regional Research Station of Tamilnadu Agriculture University (TNAU), Aliyar.

The experiment was conducted in a randomized block design with 3 plots for each variety. The soil had a pH of 8.72 and the texture was sandy clay loam. To tide over the surface crusting, lime was applied at 2 t/ha along with composted coir pith at 12.5 t/ha. The NPK level was supplied as prescribed by TNAU, Coimbatore. A nutrient package of urea, super phosphate and potash (50 kg/ha, 245 kg/ha, 43kg/ha) on pre-sowing and 400 kg/ha gypsum on the 45th DAS (days after sowing) was applied.

The varieties were sown by hand in the fields. Each plot consisted of a 4-m row ridge. The distances between the rows were 30 cm and between plants within a row 10 cm. Care was taken to ensure uniform depth of planting. Sound, mature and good quality kernels were only selected for sowing. The plots were uniformly distributed with plants. About 10 plants were planted in each row. All together there were 10 rows, thereby about 100 plants in a plot. Each plot was given a water passage surrounding each plot. The plots were prepared according to the instructions in the groundnut cultivation manual provided by TNAU, Vriddachalam.

The seeds were treated with Mancozeb at 4 g/kg of seeds just before sowing. The seeds were also treated with 3 packets 600 g/ha of rhizobial culture, TNAU 14 developed at TNAU using rice kanji as binder. This was done to protect the young seedlings from root-rot and collar-rot infection.

In each variety, 10 representative plants from all three plots were selected randomly to record the biometric parameters at 60 DAS both in the crop and drought seasons. Parameters like, days to 50% flowering, flowering duration, plant height, plant width and days of maturity were recorded before harvest. Number of pods/plant, seeds/pod, seed yield/plant, pod yield, pod length, pod width, length of the kernel, width of the kernel, weight with the shell, weight without shell, seed color, pod constriction and pod beak were recorded after harvest. Pod length, pod width, length of the kernel and width of the kernel were recorded on 10 mature pods while 100 mature seeds were used to record weight.

The entire plot was harvested and pods were dried and weighed. The varieties were classified in to DT and DS types as per the values of DRI (in kg/ha).

DRI= Yield during drought / Yield during crop season.

The statistical design used was Randomized Block Design. DMRT analysis was performed to find out whether the differences between the varieties are statistically significant. Critical Difference (CD) values were also calculated at 0.05 level. A correlation matrix was formed using the biometric parameters and yield of the different peanut varieties to study the relationship between biometric parameters and yield.

RESULTS AND DISCUSSION

The pod yield of different peanut varieties has been estimated during crop and drought seasons and the data are presented in **Table 1**. Statistically significant variations in yield are observed among the different varieties. The DRI values were computed using the formula given under "Materials and Methods". Based on these values, all the nine varieties have been divided into DT and DS types (**Table 2**). DT types have DRI values above 0.94 and DS types have below 0.79. This categorization would surely help in the various further physiological, biochemical and molecular analysis of drought tolerance mechanisms in these selected peanut varieties. Although the varieties namely, CO-2, TMV-13 have registered highest yields during crop season (**Table 1**), they belong to DS types. The varieties, namely VRI-2, VRI-5 gave high yield during drought season than other varieties (**Table 1**), and hence they are of DT types (**Table 2**). It is imperative to note that all the peanut varieties have registered lesser yield during drought season which is statistically significant at 5% level (**Table 1**). This is in agreement with Vorasoot *et al.* (2003). This reduction in yield is attributed to soil moisture deficits that usually occur during drought season which usually falls between April-June in Southern India. Soil water deficits common during drought season harm the crops especially in the flowering phase to the start of pod growth phase and significantly reduced the pod yields, when compared to the crops grown during crop season. The greatest reduction in yield occurred when severe stress occurred during the pod filling phase (Wright *et al.* 1991). Pegging and seed set responses of various peanut cultivars varied substantially under water stress, this leads to a large reduction in pod yield, and the reduction percentage varies among peanut cultivars (Nageswara Rao *et al.* 1989). Peg elongation, which is turgor dependent, is delayed due to drought stress (Boote and Ketring 1990). Once pegs are in the soil, adequate moisture and darkness are needed for pod development (Reddy *et al.* 2003).

Those varieties which showed less reduction in yield during drought season are considered to be DT types and those varieties which showed more reduction in yield during drought season are considered to be DS types. The values of DRI support this hypothesis. From an agricultural

Table 1 Pod yield of peanut varieties during crop and drought seasons and their drought response index (DRI).

Variety name	Pod yield - crop season (Kg/ha) (July-Oct 2007)	Pod yield - drought season (Kg/ha) (April-June 2007)	DRI
VRI-2	2550	2450	0.96
VRI-3	2012	1550	0.77
VRI-4	2302	1800	0.78
VRI-5	2450	2400	0.98
VRI-6	2350	2225	0.95
TMV-13	2800	2150	0.77
ALR-1	2050	1950	0.95
ALR-3	2200	1600	0.73
C0-2	2975	2310	0.78

Statistical significance: CD (5 %) between varieties = 39.69; CD (5 %) between seasons = 22.92; CV (%) = 16.21

Table 2 Classification of peanut varieties into drought tolerant and susceptible ones based on DRI. Figures in parenthesis are the values of DRI.

Drought tolerant varieties (0.95-0.98)	Drought susceptible varieties (0.73-0.78)
VRI-2 (0.96)	VRI-3 (0.77)
VRI-5 (0.98)	VRI-4 (0.78)
VRI-6 (0.95)	TMV-13 (0.77)
ALR-1 (0.95)	ALR-3 (0.73)
	C0-2 (0.78)

Table 3 Seed color, pod constriction and pod beak in the different peanut varieties.

Variety name	Seed color	Pod constriction	Pod beak
VRI-2	Pink	Moderate	Yes
VRI-3	Pink	Low	No
VRI-4	Reddish brown	High	Yes
VRI-5	Brown	Low	No
VRI-6	Pinkish brown	Low	No
TMV-13	Reddish brown	Low	No
ALR-1	Reddish brown	Moderate	Yes
ALR-3	Pink	High	Yes
C0-2	Pink	Low	No

Table 4 Biometric parameters of different groundnut varieties during the drought season.

Attributes	VRI-2	VRI-3	VRI-4	VRI-5	VRI-6	TMV-13	ALR-1	ALR-3	CO-2	CD (P=0.05)
Days to 50% flowering	33.40 a	44.40 b	47.40 c	43.60 db	48.00 ec	50.20 f	48.20 gc	49.60 hfg	47.20 ic	2.34
Flowering duration (days)	50.20 a	57.00 b	54.60 c	51.20 da	49.20 ea	54.40 fc	58.40 gb	56.80 hb	56.40 ib	2.09
Plant height (n = 10) (cm)	24.00 a	18.20 b	19.20 cb	18.60 db	21.00 ec	23.80 fa	27.20 g	24.60 ha	18.40 ib	2.36
Plant width (n = 10) (cm)	19.40 a	18.80 ba	19.40 ca	16.20 d	12.60 e	16.20 fd	14.20 g	13.40 heg	13.2 ieg	1.32
Days to maturity	82.00 a	83.00 ba	85.20 c	93.00 d	96.80 e	96.40 fe	84.80 gbc	93.80 hd	98.80 i	1.69
Total pods/plant (No.)	92.80 a	100.00 b	94.60 c	105.80d	100.20 eb	92.80 fa	91.80 ga	89.60 h	91.20 ia	2.06
Seeds/pod (No.)	2.00 a	2.00 ba	2.20 ca	2.00 da	2.40 ec	2.00 fa	2.00 ga	2.00 ha	2.00 ia	0.302
Seed yield/plant (No.)	206.60 a	112.40 b	110.60 cb	197.20 d	192.40 ed	203.40 fad	163.80 g	167.40 h	201.2 id	12.19
Pod length (cm)	3.04 a	2.10 b	2.34 c	3.26 d	2.50 e	2.04 fb	2.90 g	2.94 hg	2.16 ib	0.133
Pod width (cm)	1.22 a	0.96 b	1.36 ca	1.12 d	0.56 e	0.96 fb	1.00 gd	1.06 hdf	0.96 g	0.165
Length of kernel (cm)	1.18 a	0.98 b	1.30 ca	1.20 da	1.28 ea	1.16 fa	1.46 gc	1.30 ha	0.96 ib	0.184
Width of kernel (cm)	0.68 a	0.58 ba	0.90 c	1.04 d	0.72 ea	0.56 fa	0.94 gc	0.40 hf	0.90 ic	0.167
Weight with shell (100 g)	101.20 a	72.80 b	110.60 c	91.40 d	83.60 e	92.00 fd	91.20 gd	90.80 hd	71.60 i	2.687
Weight without shell (100 g)	40.80 a	25.80 b	39.60 ca	30.40 d	30.00 ed	35.80 f	30.20 gd	28.20 h	26.40 i	1.311

Values are mean of nine samples. Values followed by common alphabet in a row are not significant at 5% level (using DMRT).

Table 5 Biometric parameters of different groundnut varieties during the crop season.

Attributes	VRI-2	VRI-3	VRI-4	VRI-5	VRI-6	TMV-13	ALR-1	ALR-3	CO-2	CD (P=0.05)
Days to 50% flowering	29.80a	43.20 b	43.80 cb	42.40 dc	43.40 ebd	45.40 f	46.20 gf	46.40 hf	44.2 ice	1.064
Flowering duration (days)	55.20 a	59.40 b	59.20 cb	55.40 da	56.60 ea	58.40 fb	61.20 g	62.60 hf	63.00 i	1.487
Plant height (n = 10) (cm)	24.80 a	19.40 b	20.00 cb	18.00 d	22.80 e	24.60 fa	28.80 g	24.00 ha	17.60 i	1.246
Plant width (n = 10) (cm)	19.80 a	20.20 ba	21.00 cb	16.20 d	13.20 e	15.80 fd	15.80 gd	15.40 hd	13.40 i	0.984
Days to maturity	89.40 a	87.20 b	87.80 cb	94.20 d	96.80 e	95.80 fe	84.80 g	93.80 ha	99.60 i	1.209
Total pods/plant (No.)	93.60 a	101.00 b	96.60 c	106.20 d	100.80 eb	98.00 f	95.40 gc	92.4 hbcd	93.00 ia	1.987
Seeds/pod (No.)	2.40 a	2.00 ba	1.40 c	2.00 da	2.60 e	2.00 fa	1.40 gc	1.80 h	2.00 ia	0.989
Seed yield/plant (No.)	200.40 a	194.60 b	199.00 ca	200.00 da	195.20eb	204.80f	175.00 g	184.00 h	204.8 if	1.77
Pod length (cm)	3.62a	2.56 b	2.28 cb	3.26 d	2.58 eb	2.32 fb	3.14 gd	3.16 had	2.36 ib	0.297
Pod width (cm)	1.36 a	1.20 ba	1.52 ca	1.22 da	0.68 e	1.10 fbd	1.10 gbd	1.24 h	1.06ibd	0.321
Length of kernel (cm)	1.22 a	1.20 ba	1.70 c	1.48 d	1.40 d	1.62 fc	1.82 g	1.90 h	1.20 ia	0.098
Width of kernel (cm)	0.90a	0.72 b	0.96 ca	1.06 d	0.90 ea	0.88 fa	1.00 gcd	0.60 h	0.96 ia	0.092
Weight with shell (100 g)	109.00 a	78.40 b	114.00 c	94.00 d	81.20 e	95.20 f	95.00 gf	95.00 hf	78.40 i	0.956
Weight without shell (100 g)	47.20a	30.40 b	45.40 c	35.40 d	32.80 e	41.20f	34.60 g	34.00 hg	30.40ib	0.965

Values are mean of nine samples. Values followed by common alphabet in a row are not significant at 5% level (using DMRT).

Table 6 Mean values of biometric parameters in drought tolerant (DT) and susceptible (DS) peanut varieties during drought and crop seasons.

Attributes	Drought season		Crop season		Irrespective of season		Irrespective of DT or DS type	
	DT types (Mean of 4 varieties) Column 1	DS types (Mean of 5 varieties) Column 2	DT types (Mean of 4 varieties) Column 3	DS types (Mean of 5 varieties) Column 4	DT types (Mean of columns 1 and 3)	DS types (Mean of columns 2 and 4)	Drought season (Mean of columns 1 and 2)	Crop season (Mean of columns 3 and 4)
Days to 50% flowering	43.3	47.76	40.45	44.6	41.875	46.18	45.53	42.52
Flowering duration (days)	52.25	55.84	57.1	60.52	54.68	58.18	54.05	58.81
Plant height (n = 10) (cm)	22.68	20.84	23.6	21.12	23.14	20.98	21.76	22.36
Plant width (n = 10) (cm)	15.6	16.2	16.25	17.16	15.93	16.68	15.9	16.71
Days to maturity	89.15	91.44	91.3	92.84	90.23	92.14	90.30	92.07
Total pods/plant (No.)	75.15	93.64	99	96.2	87.08	94.92	84.40	97.6
Seeds/pod (No.)	2.1	2.04	2.1	1.84	2.1	1.94	2.04	1.97
Seed yield/plant (No.)	190	159	192.65	179.44	191.33	169.2	174.5	186.1
Pod yield (kg/ha)	2256	1882	2350	2457	2303	2170	2069	2404
Pod length (cm)	2.92	2.32	3.15	2.52	3.04	2.42	2.62	2.84
Pod width (cm)	0.98	1.06	1.09	1.22	1.033	1.14	1.0175	1.157
Length of kernel (cm)	1.205	1.14	1.205	1.524	1.205	1.332	1.17	1.37
Width of kernel (cm)	0.85	0.67	0.97	0.82	0.91	0.75	0.76	0.90
Weight with shell (100 g)	91.85	91.56	94.8	92.2	93.33	91.88	91.71	93.5
Weight without shell (100 g)	32.85	30.16	31.51	36.08	35.18	33.12	31.51	33.79

perspective, drought is ultimately defined in terms of its effects on yield, since this is the relevant issue when addressing the improvement of crop production under water-limited environments (Passioura 2007). Consequently, the timing of water deficits during the season (e.g. sowing, crop establishment, flowering, or grain filling) may have a much larger impact on yield than the intensity of drought *per se* (Pinheiro and Chaves 2011). Hence, our classification of peanut varieties into DT and DS types based on yield is well justified.

No uniqueness could be found between DT and DS types of peanut varieties with regard to seed color, pod constriction and pod beak (**Table 3**). All the 9 peanut varieties studied showed significant differences in their biometric parameters like days to 50% flowering, flowering duration, plant height, plant width, days of maturity, pod length, pod width, length of the kernel, width of the kernel, weight with the shell, weight without shell, number of pods/plant, seeds/pod and seed yield/plant (**Tables 4, 5**).

Days to 50 % flowering was found to be least for the DT variety, VRI-2 both during drought and crop seasons (**Tables 4, 5**). During drought season, DS types required highest number of days to 50 % flowering (**Table 6**). In contrast, Boote and Ketring (1990) reported that the start of

Table 7 Correlation matrix of biometric parameters and yield in different peanut varieties.

Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Days to 50% flowering (1)	1.00														
Flowering duration (days) (2)	0.22	1.00													
Plant height (n = 10) (cm) (3)	-0.02	0.14	1.00												
Plant width (n = 10) (cm) (4)	**-0.53**	-0.05	-0.13	1.00											
Days to maturity (5)	0.32	0.05	-0.25	**-0.69**	1.00										
Total pods/plant (No.) (6)	-0.10	-0.29	-0.46	0.13	0.04	1.00									
Seeds/pod (No.) (7)	-0.21	**-0.49**	-0.15	-0.26	0.31	0.16	1.00								
Seed yield/plant (No.) (8)	-0.29	-0.05	0.08	-0.19	**0.53**	0.07	-0.01	1.00							
Pod length (cm) (9)	**-0.53**	-0.09	0.38	0.06	-0.20	0.11	0.02	0.21	1.00						
Pod width (cm) (10)	-0.39	0.27	-0.04	**0.75**	-0.44	-0.13	**-0.51**	-0.04	0.29	1.00					
Length of kernel (cm) (11)	0.14	**0.49**	**0.50**	-0.01	-0.07	-0.01	**-0.50**	0.11	0.32	0.29	1.00				
Width of kernel (cm) (12)	-0.21	0.09	-0.17	0.03	0.04	0.40	-0.10	0.22	0.21	0.21	0.21	1.00			
Weight with shell (100 g) (13)	-0.34	-0.11	0.32	**0.54**	-0.38	-0.15	-0.24	-0.01	0.37	**0.70**	**0.48**	0.20	1.00		
Weight without shell (100 g) (14)	**-0.57**	-0.07	0.27	**0.60**	-0.24	-0.08	-0.10	0.24	0.24	**0.64**	0.37	0.26	**0.87**	1.00	
Pod yield (Kg/ha) (15)	-0.41	0.06	-0.11	-0.13	**0.50**	0.13	0.10	**0.76**	0.13	0.07	0.11	**0.52**	0.08	0.39	1.00

Values in bold are statistically significant. Values above 0.468 are significant at 5 % level. Values above 0.590 are significant at 1 % level. Values above 0.708 are significant at 0.1% level.

flowering is not delayed by drought stress. Flowering duration was found to be highest for the variety, CO-2 during the crop season (**Table 5**). In general, the DS types had the largest value for flowering duration irrespective of seasons (**Table 6**). The rate of flower production is reduced by drought stress during flowering but the total number of flowers per plant is not affected due to an increase in the duration of flowering (Meisner and Karnok 1992).

VRI-5 had the highest number of pods per plant irrespective of seasons (**Tables 4, 5**). The number of pods/plant can be low due to increases in soil resistance caused by prolonged drought (Sharma and Sivakumar 1991). However, in our present study DS types had more pods/plant; however the pod yield was higher in DT types irrespective of seasons (**Table 6**). This is due to more seeds/pod, increased pod length and increased kernel width in DT types observed in the present study. The less pod yield in DS types might also be attributed to the inefficiency of the plant in pod filling due to changes in photosynthetic rates. It has been reported that photosynthesis plays a central role in plant performance under drought (Chaves *et al.* 2009; Lawlor and Tezara 2009). The partitioning of photosynthate to pods during the pod filling stage is the most influential physiological factor in determining the groundnut yield. The decline observed in leaf net carbon uptake as a result of plant water deficits is followed by an alteration in partitioning of the photoassimilates at the whole plant level (Pinheiro and Chaves 2011). In addition to pod number and partitioning of photosynthate to pods, duration of pod filling was also found to alter the yield in a significant manner (Kathirvelan and Kalaiselvan 2007). The DT types gave wider and bigger seeds, despite the wider pods given by the DS. This might again point to the fact of defective pod filling. The DT varieties gave more seeds per plant despite fewer pods than DS. The reasons for this might be the above mentioned one as the DT types could easily uptake more nutrients even at lesser moisture conditions, which provide them a better survival and resistance to drought. The pod yield was more for the DT types in the drought season and was more for the DS types in the crop season. Irrespective of the seasons DT types gave more pod yield and irrespective of the types, more pod yield was obtained during the crop season. The increased soil moisture content during crop season might be a key factor in inducing more pod yield. Mineral uptake during pod filling also influences groundnut fruit development, yield and quality (Alva *et al.* 1989; Zharare *et al.* 2002).

The weight of seeds with/without shell was reduced during the drought season (**Table 6**). It has been reported already that seed size (100-seed weight) of Thailand peanut cultivars decrease when available water was reduced (Vorasoot *et al.* 2003).

A correlation matrix was computed to study the relationship between biometric parameters and yield in different peanut varieties (**Table 7**). Pod yield was found to have significant positive relationships with days of maturity, seed yield/plant and width of kernel. Hence, these parameters with which pod yield had positive relationships could be used as biometric markers for high yield in plant breeding and improvement programs, and hence, these parameters could be considered as yield determinants. Significant negative relationship was noticed between seeds per pod and pod width. In addition to this, many other significant positive and negative relationships were observed among different biometric parameters (**Table 7**) and the reasons for this could not be interpreted. The changes in the root–shoot ratio as well as the temporary accumulation of reserves in the stem that occur in several species under water deficits (Blum *et al.* 1994; Chaves *et al.* 2002) are accompanied by alterations in carbon and nitrogen metabolism in the different organs (Pinheiro *et al.* 2001; Carla *et al.* 2008), whose fine regulation is still largely unknown (Pinheiro and Chaves 2011).

Positive relationships were found by other workers, between drought tolerance and pod yield. Certain varieties namely BR 1, BRS 151 L7, BRS and Havana showed high pod yield and hence, tolerance to drought (Santos *et al.* 2006). The drought tolerant variety, Pratap Munghali 2 gave higher pod yield when compared to the susceptible one, JL 24, during drought season (Nagda and Dashira 2005). The relationship between pod yields and the partitioning coefficient for groundnut cultivars revealed that the groundnut pod yield was highly and positively correlated with number of branches, number of pods plant^{-1} and 100 kernels weight (Kathirvelan and Kalaiselvan 2007). The variations in biometric parameters analyzed in this study indicate that DT types can be distinguished from the DS and thus explaining their survival during the drought. The increased pod yield in DT peanut varieties during drought season may be attributed to less chlorophyll degradation as a result of osmotic adjustment (Govind *et al.* 2009).

ACKNOWLEDGEMENTS

This work was supported by UGC, New Delhi.

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