ISSN 1819-1894

Asian Journal of Agricultural Research

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Asian Journal of Agricultural Research 7 (1): 35-42, 2013
ISSN 1819-1894 / DOI: 10.3923/ajar.2013.35.42

Screening for Drought Tolerant Groundnut (*Arachis hypogaea* L.) Lines Suitable for Rainfed Alfisol

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ABSTRACT

The occurrence of intermittent dryness in rain-dependent cultivation and soil surface crusting in alfisol are the major hindrances in enhancing groundnut productivity. Twenty nine peanut lines were field screened for drought tolerance at Dryland Agricultural Research Station, Chettinad. The Drought Susceptibility Index (DSI), Drought Tolerance Efficiency (DTE), Stress Tolerance Index (STI) for pod yield per plant and percent change of performance in yield attributes under moisture stress were considered as measures of drought tolerance. The intermittent dry spells delayed the flowering and maturity in groundnut. The soil moisture stress resulted in reduction of plant height, number of matured pods per plant and pod yield per plant. Genotypes recorded high pod yield per plant were ICGV 07240, ICGV 07241, ICGV 07245, ICGV 07247 and VRI (Gn) 7. But these genotypes were sensitive to drought as indicated by high DSI and less DTE. Drought tolerant peanut lines ICGV 07219, ICGV 07262 and ICGV 07268 have shown consistence in the pod yield performance with less DSI and high DTE. The identified genotypes can be evaluated in varied rain-fed environments to exploit their drought tolerance and yield potentials. The validated lines can be utilized as peanut cultivars for rain-fed or drought prone environments under changing climate.

Key words: Groundnut, drought tolerance, drought susceptibility, stress tolerance

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is grown in approximately 37 million acres worldwide and is the third major oilseed crop. India stands first in area and second in production of groundnut, but the productivity is very less than other groundnut growing countries. In India, around 90% of peanut production was concentrated in States of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra, mainly grown during the kharif (rainy) season. The rain-dependent cultivation is one of the most important reasons for very low productivity (937 kg ha^{-1}) compared to the world average of 1332 kg ha^{-1} (Lal *et al*., 2006; Chenault *et al*., 2008). Low rainfall and prolonged dry spells during the crop growth period are the main reason that cripples the groundnut productivity. The arid and semi-arid regions are highly prone to extremes of temperature, severe and frequent drought, low relative humidity and high wind velocity. The drought varies with timing, intensity and duration. Nigam *et al*. (2005) suggested that physiological trait-based selection approach did not show a consistent superiority over the empirical method of drought resistance breeding in producing higher kernel yield in groundnut. The Stress Susceptibility Index (SSI) measures the yield stability that apprehends the changes in both potential and actual yields in variable environments (Fischer and Maurer, 1978). If SSI is more and less than 1, it indicates above and below-average susceptibility to drought stress, respectively (Guttieri *et al.*, 2001). The Stress Tolerance Index (STI) is used to identify genotypes that produce high yield under both stressed and non-stressed conditions (Fernandez, 1992). The Geometric Mean Productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Ramirez-Vallejo and Kelly, 1998). The drought tolerant genotypes should have high drought tolerance efficiency and stress tolerance index, least drought susceptibility index and minimum reduction in kernel yield due to moisture stress. The basic advantage in selecting yield as the selection criterion is that it integrates all the additive traits of many underlying mechanisms of drought tolerance (Kambiranda *et al.*, 2011). Early maturing, disease and drought tolerant cultures have great promise in providing production in semi-arid regions of tropical Africa and Asia (Reddy *et al.*, 2003). Hence, this study was initiated to identify suitable drought tolerant groundnut types that withstand intermittent short-term moisture stress in rain-fed alfisol of semi-arid tropical region.

MATERIALS AND METHODS

Plant materials: The advanced breeding lines were received from International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru; Regional Agricultural Research Station, Tirupati (RARS-T) and the varieties namely TMV 7, TMV (Gn) 13, VRI (Gn) 6 and VRI (Gn) 7 released from Tamil Nadu Agricultural University (TNAU) were included as genetic materials for this study.

Field evaluation: The 29 groundnut strains and varieties were field screened in post-rainy season (December 2010 to April 2011) and kharif/rainy season (August to December 2011) at Dryland Agricultural Research Station, Chettinad (10°10'N, 78°47'E, 115 m aMSL). Each genotype was sown in 5 rows of 4 m length with the spacing of 30×15 cm in a replicated design. The crop was grown by adopting recommended package of practices. The experimental soil type was typical alfisol of sandy loam with the pH of 5.8. The weather data were recorded from automatic weather station is located 100 m away from the experimental field.

Statistical analysis: The observations recorded were days to 75% flowering, days to maturity, plant height (cm), number of primary branches, number of matured pods per plant and pod yield per plant (g). The effect on moisture stress on these parameters was calculated using data from rainy and post-rainy seasons. Data were analyzed using GENRES 7.01; the Least Significant Difference (LSD) was used to test the significance between genotypes mean at 95% confidence level. The response of genotypes to moisture stress was assessed by the following drought tolerance parameters for pod yield per plant:

$$\text{Mean Productivity (MP)} = \frac{(Ys+Yp)}{2} \text{ (Rosielle and Hamblin, 1981)}$$

$$\text{Drought Susceptibility Index (DSI)} = \frac{[(1\text{-Ys})/\text{Yp}]}{(\bar{\text{Y}}\text{s}/\bar{\text{Y}}\text{p})} \text{ (Fischer and Maurer, 1978)}$$

$$\text{Drought Tolerance Efficiency (DTE\%)} = \frac{\text{Ys}}{\text{Yp}} \times 100 \text{ (Ficher and wood, 1981)}$$

$$\text{Stress Tolerance Index (STI)} = \frac{(\text{Ys} \times \text{Yp})}{\bar{\text{Y}}\text{p}} \times 100 \text{ (Fernandez, 1992)}$$

where, Ys and Yp are the pod yield of genotypes under stress and non-stress conditions, respectively. $\bar{Y}s$ and $\bar{Y}p$ are the mean pod yield of all genotypes under stress and non-stress conditions, respectively. The genotypes with high value of MP, DTE, STI and value below 1 for DSI were considered as drought tolerant genotypes.

RESULTS AND DISCUSSION

Moisture stress: Drastic variation in quantity of rainfall, number of rainy days, relative humidity, leaf wetness, soil moisture availability and occurrence of dry spell was observed during crop growth period in rainy and post-rainy seasons at experimental site (Table 1). The crop was purely grown under rain-fed condition in kharif season. The weather data indicated that the relative humidity and leaf wetness were significantly less during post-rainy period. The crop encountered severe soil moisture stress in post-rainy period (9.5%) as compared to rainy season (12.9%). The quantity and distribution pattern of rainfall indicated intermittent dry spells in crop growth stages viz., 30-75 Days After Sowing (DAS) and 85-110 DAS in post-rainy crop. Three life saving sprinkler irrigations were given to an amount of 20 mm for each irrigation. Only 44% of moisture was received by the crop during post-rainy period (261 mm) as compared to rainy season (598 mm). The post-rainy crop encountered the mid and terminal drought during the crop growth period. Hence in this study, the rainy and post-rainy season evaluations were considered as no moisture stress and moisture stress conditions, respectively.

Effect of moisture stress on yield parameters: The soil moisture stress on groundnut during flowering phase extended the days to 75% flowering up to six days. The initiation of flowering was not delayed but the rate of flower production was reduced by drought stress during flowering. However, the total number of flowers per plant was not affected due to an increase in the duration

Table 1: Weather parameters prevailed during the crop growing seasons

Parameters	Rainy season	Post-rainy season
Average maximum temperature (°C)	32.3	31.4
Average minimum temperature (°C)	24.2	23.3
Average relative humidity (%)	77.5	54.6
Average leaf wetness (h)	5.9	4.6
Average soil moisture at 15 cm depth (%)	12.9	9.5
Cumulative rainfall (mm)	598.0	261*
No. of rainy days	32.0	7.0
Dry spell during crop stage (DAS)	Nil	30-75; 85-110

*Including three life saving sprinkler irrigations to a total of 60 mm of flowering (Boote and Ketring, 1990; Gowda and Hegde, 1986; Janamatti *et al.*, 1986; Meisner and Karnok, 1992), the extent of delay in flowering is a function of stress level and genotype (Blum, 2011). Number of primary branches per plant did not influenced by the moisture stress. An average reduction in plant height was recorded in water stress conditions from 30.1 to 19.2 cm (36%). The water deficit resulted in fewer and smaller leaves, which have smaller and more compact cells and greater specific leaf weight. Main axis and cotyledonary branches are shorter in water stressed groundnut plants. Soil water deficit reduces inter-nodal length more drastically than node number (Chung *et al.*, 1997). The stress during pod development stage reduced the number of matured pods from 37.4 to 25.1 (32.8%). Since the experimental soil was alfisol, even small amount of rainfall after dry spell led to surface sealing of iron and aluminum oxide clay, which resulted in rapid surface crusting problem (Palaniappan *et al.*, 2009). Peg elongation, which is turgor dependent, is delayed due to drought stress; pegs fail to penetrate effectively into air-dry soil, especially crusted soils (Boote and Ketring, 1990). The number of pods per plant is reduced due to increase in soil resistance caused by prolonged drought (Sharma and Sivakumar, 1991). Sexton *et al.* (1997) reported dry pegging delays the pod and seed development, it decreased the weight per seed from 563 to 498 mg. The post-rainy crop also experienced the moisture stress during pod development stage that delayed the maturity to an average of 13 days. As a cumulative effect of soil moisture deficit, the pod yield as an integrative trait was affected to an extent of 47.8%, that is mean reduction in pod yield per plant was recorded from 29.5 to 14.9 g.

Performance of varieties: The groundnut strains studied, JL 24 reported as drought sensitive and ICGV 91114 as drought tolerant (Kambiranda *et al.*, 2011). The drought sensitive variety, JL 24 performed equally to drought tolerant ICGV 91114, when there is no soil moisture limitation. Under moisture stress, pod yield was reduced to 59% in JL 24. Whereas, ICGV 91114 shown ability to tolerate mid and end-season drought, which was evident from less yield loss of 24%. The varieties namely Chico, TMV 7, TMV (Gn) 13 and VRI (Gn) 6 did not shown yield superiority over VRI (Gn) 7 at this location under stress. But VRI (Gn) 7 performed well under no stress (38.9 g) than moisture limited (18 g) conditions as reflected in DSI of 1.028, DTE (46.27%) and STI (24.31). The short duration varieties, TMV 7 and Chico were stable in pod yield under moisture stress with less DSI and high DTE. Hence, the four decade old Spanish bunch variety TMV 7 is widely preferred by the rain-fed farmers. However, this genotype was not having significant yield advantage over drought tolerant check and recently released varieties.

Response of groundnut genotypes to moisture stress: The Pearson coefficient of determination (R^2 = 0.1797) indicated that, there was no relation between the pod yield performance of a genotype in stress and non-stress conditions (Fig. 1). The genotypes ICGV 05155 and Narayani were highly stable with very less DSI value and high DTE but are poor yielders with 8.7 and 11.2 g of pod yield per plant, respectively (Table 2). The genotype with less DSI (<1) can be considered as drought tolerant. But low DSI values of a genotype could be due to less yield production under well-watered conditions rather than an indication of its ability to tolerate water stress. Therefore the stress genotypes defined as per DSI, need not necessarily to have high yield potential (Karaba *et al.*, 2011). Genotypes recorded significantly high mean pod yield per plant over drought tolerant check ICGV 91114 (21.5 g) were ICGV 07225(30.7 g), ICGV 07247(30.9 g), ICGV 07241 (29.9 g), ICGV 07262 (28.9 g), ICGV 07245 (28.7 g), VRI (Gn) 7 (28.5 g), ICGV 07268 (28.3 g), ICGV 07219 (27.6 g) and ICGV 07240 (24.7 g).

Table 2: Mean performance of yield, yield attributes and drought tolerant indices in groundnut

Code No.	Acc. No/ Variety	Source	DF	DM	PH (cm)	NPB	NMP	MP (g)	DSI	DTE (%)	STI
G1	ICGV 05155	ICRISAT	29.0	116.0	17.0	7.8	21.2	8.7	0.040	97.90	2.63
G2	ICGV 06423	ICRISAT	33.0	116.0	21.0	8.4	35.5	26.2	0.977	48.92	21.05
G3	ICGV 06424	ICRISAT	33.0	116.0	20.0	7.3	27.7	18.6	0.756	60.51	11.31
G4	ICGV 07219	ICRISAT	36.0	113.0	20.0	8.5	39.5	27.6	0.921	51.87	23.73
G5	ICGV 07220	ICRISAT	32.0	111.0	20.0	9.2	41.8	26.2	1.032	46.06	20.61
G6	ICGV 07222	ICRISAT	32.0	111.0	23.0	8.0	40.5	26.2	1.075	43.80	20.26
G7	ICGV 07225	ICRISAT	37.0	110.0	23.0	9.1	43.0	30.7	0.980	48.81	28.77
G8	ICGV 07228	ICRISAT	34.0	116.0	24.0	9.1	41.4	23.6	1.141	40.37	15.83
G9	ICGV 07240	ICRISAT	34.0	113.0	18.0	11.5	43.4	24.7	1.175	38.57	17.07
G10	ICGV 07241	ICRISAT	34.0	115.0	21.0	9.0	34.8	29.9	1.535	19.77	17.09
G11	ICGV 07245	ICRISAT	35.0	115.0	20.0	8.8	39.8	28.7	1.299	32.13	21.01
G12	ICGV 07247	ICRISAT	32.0	113.0	20.0	7.0	40.6	30.9	1.030	46.17	28.69
G13	ICGV 07262	ICRISAT	33.0	113.0	21.0	7.9	37.0	28.9	0.769	59.80	27.21
G14	ICGV 07268	ICRISAT	31.0	114.0	23.0	8.2	26.6	28.3	0.267	86.07	27.62
G15	ICGV 06237	ICRISAT	29.0	101.0	29.0	5.3	23.0	12.4	0.873	54.38	4.83
G16	ICGV 06279	ICRISAT	30.0	104.0	26.0	7.7	18.2	16.4	0.819	57.21	8.59
G17	ICGV 4544	ICRISAT	31.0	106.0	30.0	6.0	32.5	19.3	0.697	63.56	12.29
G18	ICGS 11	ICRISAT	29.0	106.0	23.0	7.5	32.9	17.6	0.732	61.75	10.10
G19	Narayani	RARS -T	32.0	104.0	34.0	4.9	13.9	11.2	0.255	86.67	4.33
G20	TPT 25	RARS -T	34.0	104.0	28.0	5.2	28.4	18.8	0.829	56.67	11.33
G21	TCGS 913	RARS -T	30.0	104.0	22.0	4.8	19.4	18.4	0.774	59.57	10.94
G22	K134	RARS -T	31.0	104.0	33.0	5.5	22.3	18.0	0.904	52.77	10.12
V1	Chico	ICRISAT	27.0	101.0	20.0	4.6	17.4	15.0	0.360	81.21	7.68
V2	TMV 7	TNAU	30.0	104.0	36.0	6.5	34.3	17.3	0.517	73.00	10.14
V3	TMV (Gn) 13	TNAU	30.0	104.0	28.0	6.5	25.2	19.3	0.144	92.50	12.85
V4	VRI (Gn) 6	TNAU	29.0	105.0	39.0	9.3	39.8	19.5	1.254	34.48	10.07
V5	VRI (Gn) 7	TNAU	35.0	118.0	25.0	7.4	40.3	28.5	1.028	46.27	24.31
DS	JL 24	RARS -T	31.0	104.0	24.0	5.4	23.1	16.9	1.132	40.83	8.17
DT	ICGV 91114	RARS -T	32.0	104.0	27.0	4.7	23.1	21.5	0.469	75.51	15.74
Statistic analyis											
Mean		-	31.8	109.3	24.6	7.4	31.9	21.9	0.822	57.06	15.57
SEM±		-	0.8	2.2	2.4	0.9	5.0	3.1	-	-	-
CD. (p<0.05)	-	2.3	3.7	7.2	2.6	8.8	9.3	-	-	-	
CV (%)		-	3.8	4.2	15.6	16.6	19.2	19.6	-	-	-

DF: Days to 75% flowering, DM: Days to maturity, PH: Plant height (cm), NPB: No. of primary branches, NMP: No. of matured pods, MP: Mean productivity (g), DSI: Drought susceptibility index, DTE: Drought tolerance efficiency, STI: Stress tolerance index

Though the genotypes ICGV 07240, ICGV 07241 and ICGV 07245 were potential to yield high, the moisture stress had more influence on pod yield performance of these genotypes as indicated by high DSI and less DTE. Moisture stress affected pegging and pod development in peanut. Pegs struggled to penetrate in crusted soils; young pods lost their turgor and shriveled that resulted in formation of small and wrinkled kernels, which in turn reduced the pod yield severely in drought sensitive genotypes. However, these genotypes performed well in non-stress situation than in stress conditions. Hence, above drought sensitive strains are suited for irrigated conditions and also be grown in assured rainfall areas.

The bunch type genotypes shown high DTE namely ICGV 07219 (51.87%), ICGV 07262 (59.8%) and ICGV 07268 (86.07%) with consistent pod yield performance under stress and non-

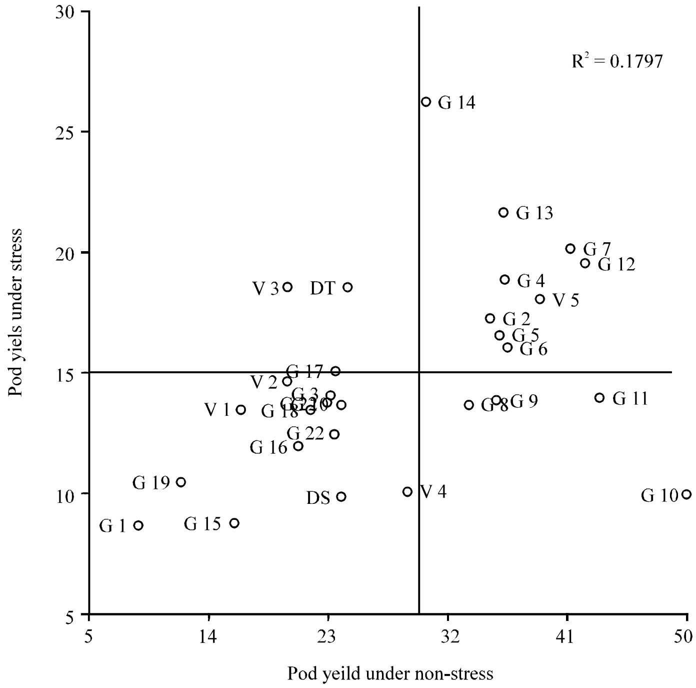

Fig. 1: Pod yield per plant under no moisture deficit and stress in groundnut genotypes (The accession number of plotted genotypes given in Table 2)

stress situation (Fig. 1), they also recorded less DSI and high STI values for drought stress indices (Table 2). Genotypes recorded moderate drought tolerance with DTE of ICGV 07225 (48.81%), VRI (Gn) 7 (46.27%) and ICGV 07247 (46.17%) with high pod yield over drought tolerant check. These results revealed that, the genotypes ICGV 07219, ICGV 07262 and ICGV 07268 have the drought tolerance ability and better pod yield potential. The drought tolerant genotypes had smaller leaflets, ability to maintain greenness till maturity and ability to adjust narrow leaflet angles during peak sunshine hours, which might be contributed to their drought tolerance ability. Arunyanark *et al.* (2008) and Sheshshayee *et al.* (2006) suggested the ability of maintaining chlorophyll density under water deficit conditions as drought resistance mechanism in peanut.

CONCLUSION

The soil moisture stress during flowering and pod development stages prolongs the flowering and maturity in groundnut. The intermittent dryness during cropping period reduced the biomass production, development of matured pods and pod yield. The genotypes ICGV 07240, ICGV 07241 and ICGV 07245 have the ability to perform well in moisture stress free situation, but they cannot tolerate intermittent dry spells. Groundnut genotypes suitable for rain-fed alfisol region should have drought tolerant ability and good peg penetration strength to overcome the surface crusting. Based on drought tolerance parameters, the bunch type groundnut genotypes ICGV 07219, ICGV 07262 and ICGV 07268 were recorded consistent pod yield in non-stress and stress situations. Further, evaluation of identified promising genotypes in varied rain-fed environments is required to exploit the drought potential of these lines for climate-smart agriculture.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Dr.S.N.Nigam, ICRISAT, Patancheru; Dr. R.P.Vasanthi and Dr.T.Muralikrishna, Regional Agricultural Research Station, Tirupathi for providing groundnut breeding lines used in this study.

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