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Studies on genetic variability, heritability and genetic advance in groundnut (*Arachis hypogeae* L.) genotypes under normal and moister stress condition in vegetative stage

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Abstract
The present investigation was carried out in 49 groundnut genotypes to assess the nature and extent of genetic variability, heritability and genetic advance under normal and moisture stress condition in three replications in a completely randomized design in the vegetative phases. The observations on plant height, root length, root to shoot ratio, SPAD chlorophyll meter reading, relative water content, membrane stability index, number of days for flower initiation, percentage of wilted plants and percentage of recovered plants after re-watering were recorded to understand the drought tolerance ability of the genotypes. The results of the analysis of variance for all the characters studied were found to be highly significant in both the conditions indicating that the availability of enormous variability. High heritability coupled with high genetic advance was recorded for majority of the traits. It indicates that the lesser influence of environment on the expression those traits and also shows that predominance of genetic factor controlling variability. Hence, early generation selection in this gene pool would be effective for the improvement of drought tolerance of groundnut.

Keywords: Genetic variability, heritability, genetic advance, PCV, GCV

Introduction
Groundnut (*Arachis hypogaea* L.) has emerged as an economically important crop due to its major share in vegetable oil production of India. India is the second major producer of groundnut in the world next to China. In India, groundnut takes up an area of 4.77 m. ha with a production of 4.69 m. tones recorded a mean productivity of 984 kg ha^{-1} (www.agricoop.com). In Karnataka, the Kharif (rainy) season groundnut crop is generally grown under rain-fed condition which is significantly affects inter-year production deviation. There moisture stress or drought during vegetative and reproductive phases is one of the major production constraint in groundnut production in Karnataka. Therefore, the recognition of drought tolerant cultivars is necessary to sustain and to improve production of groundnut. There are a few reports available on the response of groundnut cultivars to moisture stress tolerance. Phenotyping is a key criterion for screening breeding materials based on drought adaptive physiological and morphological traits including yield and its components (Monneveux *et al*., 2012) [1].
However, drought tolerance screening under field conditions requires lot of resources like rain-free environment, land, labour etc. Further, it also depends on the environmental interactions (Genotype × Environment) that modify phenotypic expression of a genotype. Hence, the study of effect of drought stress in pot culture in vegetative stage is one of the viable alternative methods for drought tolerance field screening. Several authors proved that screening for drought tolerance by pot culture under shade net conditions was a reliable method in many crops (Yohannes, 2014) [2]. So, the use of genetics and plant breeding features to improve drought tolerance is an important part of the solution to stabilize world groundnut production. Though, the crop improvement for water stress tolerance requires persistent efforts chiefly, through the knowledge of genetic mechanism governing heritable traits.
The Genetic effect of heritable traits guides plant breeder to understand the pattern of inheritance of number of plant traits. Any crop improvement programme is chiefly depends on the information on genetic variability, heritability and genetic advance which help to outline the crop improvement program. Hence, screening of the germplasm lines for drought tolerance is the initial step in developing cultivars which possess both high yield and drought tolerance. So, the present work was carried out to know the nature and extent of genetic variability, heritability and genetic advance of traits involved in drought tolerance.

Material and Methods

The research materials used in the study comprise of 49 genotypes of groundnut. They were screened under drought stress and normal (non-stress) environment (Figure 1). Forty nine genotypes were included for pot culture experiment. Seeds were treated with Chlorpyriphos 20 EC at 15 ml per Kg of seeds and afterward by *Thiram* @ 2.5 g per Kg of seeds and after that sown in pots with two seedlings per pot in two replications for both treatment and control. Each pot containing a mixture of well decomposed farm yard manure (FYM), sand and soil in the ratio 1: 1: 2 were kept under shade net. Soil moisture tension was monitored using a tensiometer. Once the soil moisture tension reaches 40 – 50 centibars, water was applied. As per this schedule, the plants in the pot culture study were watered in both treatment and control pots till 45 days after sowing. Then, the water stress was imposed in the treatment pots for 15 days (on 10th day of water stress, soil moisture tension in tensiometer reaches the maximum level of 85 centibars), while normal watering was given to control pots. The observations were recorded in both moisture stressed and non-stressed plants. After 15 days of moisture stress, the treatment pots were re-watered for analyzing the recovery of various genotypes from water stress. Observations on Plant height, Root length, Total Chlorophyll content, Number of days to flower initiation and Percentage of plants recovered from wilting after re-watering were recorded. Further, Percentage of wilted plants, Root to shoot ratio, Relative water content (RWC) of leaf tissue and Membrane damage or Membrane Stability Index were computed to have a better understanding on their drought tolerance ability.

Percentage of wilted plants was calculated using the following formula

$$\text{Percentage of wilted plants} = \frac{\text{Number of plants wilted}}{\text{Total number of plants}} \times 100$$

Root to shoot ratio were calculated by using the formula.

$$\text{Root to shoot ratio} = \frac{\text{Length of root (cm)}}{\text{Length of shoot (cm)}}$$

RWC was calculated according to Dhopte and Manuel (2002) [3] as per the following formula which was expressed as percentage.

RWC = (FW-DW/TW-DW) ×100

Where,
FW is fresh weight, DW is dry weight and TW is turgid weight of leaf samples.

Membrane stability index (MSI) was calculated using the method described by Blum and Ebercon (1981) [4] and it was calculated using the following formula and it was expressed as percentage.

$$\text{Membrane stability Index} = \frac{EC_b - EC_a}{EC_c} \times 100$$

Where, EC_a – Electrical Conductivity (EC) of initial solution
EC_b – EC of same solution after hot water-bath at 55 °C for 30 minutes and
EC_c – EC of same solution after hot water-bath at 100 °C for 30 minutes.

The statistical analysis of the data on the individual characters was carried out on the mean values of ten random plants and analyzed by using Windostat software package (Version 9.2). The analysis of variance for each character was analyzed by adopting Completely Randomized Design as suggested by Cochran and Cox (1957) [5]. The mean, range and variance values of each character were calculated for each genotype. The coefficient of variation both at phenotypic and genotypic levels for all the characters were computed by applying the formula as suggested by Burton and Devane (1953) [6]. PCV and GCV were classified into low (0 – 10 %), moderate (11 – 20 %) and high (21 % and above) as suggested by Subramanian and Menon (1973) [7]. Heritability in broad sense for all the characters was computed by the formula suggested by Hanson *et al.* (1956) [8]. Heritability was classified into low (0 – 30 %), moderate (31 – 60 %) and high (61 % and above) as suggested by Robinson *et al.* (1949) [9]. The predicted genetic advance was estimated according to the formula given by Johnson and Robinson (1955) [10]. The genetic advance as per cent of mean was categorized into low (0 – 10 %), moderate (10.1 – 20 %) and high (> 20.1 and above) as suggested by Johnson and Robinson (1955) [10].

Results and Discussion

Analysis of variance was conducted to test the significance differences among the genotypes studied under moisture stressed and non-stressed pots. Analysis of variance revealed that the genotypes under study were differed significantly even at one *per cent* level of probability for all characters studied in both moisture stressed and non-stressed pots. This indicates existence of variability among the genotypes for various drought tolerance parameters. The mean sum of squares of all the characters is presented in the Tables 2 and 3 for moisture stressed and non-stressed pots, respectively.

The extent of the genetic variability was shown by the parameters *viz.*, mean, range, genotypic and phenotypic coefficients of variability, estimate of heritability and expected genetic advance as per cent mean were calculate for all characters is presented in the Tables 4 and 5 for moisture stressed and non-stressed pots, respectively. Comparison between phenotypic co-efficient of variation and genotypic co-efficient of variation for all the characters studied under stress and normal condition is represented in figure 1. Comparison between broad sense heritability and genetic advance over mean for all the characters studied in drought tolerance screening at seedling stage under both stress and non-stress condition is represented in figure 2.

Table 1: List of groundnut genotypes studied under present investigation

Sl. No.	Genotypes	Origin	Sl. No.	Genotypes	Origin
1	Dh-241	UAS, D	26	SB-T7	UAS, B
2	Dh-235	UAS, D	27	SB-T14	UAS, B
3	Dh-234	UAS, D	28	UAS,D -2	UAS, D
4	Dh-243	UAS, D	29	UAS,D -3	UAS, D
5	Dh-245	UAS, D	30	SB-T15	UAS, B
6	Dh-246	UAS, D	31	ICGV-91114	UAS, B

7	Dh-247	UAS, D	32	VB-T31	UAS, B
8	Dh-216	UAS, D	33	SB-T12	UAS, B
9	K-6	UAS, B	34	SB-T13	UAS, B
10	K-9	UAS, B	35	KCG-2	UAS, B
11	ICGV-91115	UAS, B	36	VB-T13	UAS, B
12	Dh-101	UAS, D	37	VB	UAS, B
13	G2-52	UAS, D	38	VB-T18	UAS, B
14	GPBD-4	UAS, D	39	SB-T3	UAS, B
15	Dh-86	UAS, D	40	SB-T40	UAS, B
16	TMV-2	UAS, B	41	VB-T35	UAS, B
17	GPBD-5	UAS, D	42	SB-T2	UAS, B
18	UAS,D -1	UAS, D	43	SB-T10	UAS, B
19	R-2001-3	UAS, R	44	SB-T21	UAS, B
20	VB-T4	UAS, B	45	VB-T3	UAS, B
21	KCG-6	UAS, B	46	SB-T11	UAS, B
22	SB-T1	UAS, B	47	VB-T7	UAS, B
23	SB-T17	UAS, B	48	SB-T16	UAS, B
24	VB-T11	UAS, B	49	SB-T8	UAS, B
25	VB-T14	UAS, B			

Where,
UAS, Bangalore - University of Agricultural Sciences, Bangalore, Karnataka.
UAS, Dharwad - University of Agricultural Sciences, Dharwad, Karnataka.
UAS, Raichur - University of Agricultural Sciences, Raichur, Karnataka.
VB - Valencia Bunch
SB - Spanish Bunch

Table 2: Analysis of variance in groundnut genotypes under moisture stress in pot culture experiment

Source	d.f.	Plant height (cm)	Root length (cm)	Root to shoot ratio	SPAD chlorophyll reading	RWC (%)	MSI (%)	No. of days for flower initiation	*Per cent* of wilted plants (%)	Percentage of recovered plants after re-watering (%)
Genotypes	48	54.41**	298.56**	0.94**	34.97**	1127.43**	717.05**	20.43**	2294.01**	125.55**
Error	98	0.36	0.36	0.002	5.32	1.36	1.55	2.34	5.10	7.40
S.Em		0.42	0.42	0.04	1.63	0.83	0.88	1.08	1.60	1.92
CV%		2.55	1.09	2.01	4.94	2.15	3.56	4.58	4.76	2.82
CD@5%		1.20	1.20	0.10	4.64	2.35	2.51	3.07	4.54	5.47
CD@1%		1.60	1.60	0.13	6.18	3.13	3.34	4.10	6.05	7.29

Table 3: Analysis of variance in groundnut genotypes under normal condition in pot culture experiment

Source	d.f.	Plant height (cm)	Root length (cm)	Root to shoot ratio	SPAD chlorophyll reading	RWC (%)	MSI (%)	No. of days for flower initiation
Genotypes	48	38.61**	298.94**	0.58**	25.47**	24.42**	286.49**	20.37**
Error	98	0.36	0.36	0.001	4.00	1.45	1.04	2.58
S.Em		0.42	0.43	0.02	1.41	0.85	0.72	1.14
CV%		2.43	1.26	1.61	4.59	1.57	3.33	4.84
CD@5%		1.20	1.21	0.07	4.02	2.42	2.05	3.23
CD@1%		1.60	1.62	0.09	5.36	3.22	2.73	4.30

Where,
d.f - Degrees of freedom ** - Significance at 1 % * - Significance at 5%
RWC-Relative Water Content MSI-Membrane Stability Index

Table 4: Estimates of genetic parameters in groundnut genotypes in pot culture experiment under moisture stress condition

Sl. No.	Character	Mean	Range	PCV(%)	GCV(%)	h^2(%)	GAM (%)
1	Plant height (cm)	23.39	12.60 - 33.05	22.38	22.23	98.70	45.50
2	Root length (cm)	54.74	27.30 - 82.55	22.34	22.31	99.76	45.90
3	Root to shoot ratio	2.44	1.24 - 4.08	28.11	28.04	99.49	57.61
4	SPAD chlorophyll reading	46.70	37.65 - 57.40	9.61	8.25	73.58	14.57
5	Relative water content (%)	55.19	19.39 - 86.33	39.75	39.62	99.32	81.33
6	Membrane stability index (%)	35.00	5.49 - 87.96	54.17	54.05	99.57	111.10
7	No. of days for flower initiation	33.38	30.00 - 42.00	10.11	9.01	79.47	16.55
8	Percentage of wilted plants (%)	47.45	0.00 - 100.00	71.46	71.30	99.56	146.55
9	Percentage of recovered plants after re-watering (%)	96.38	75.00-100.00	8.46	7.98	88.87	15.49

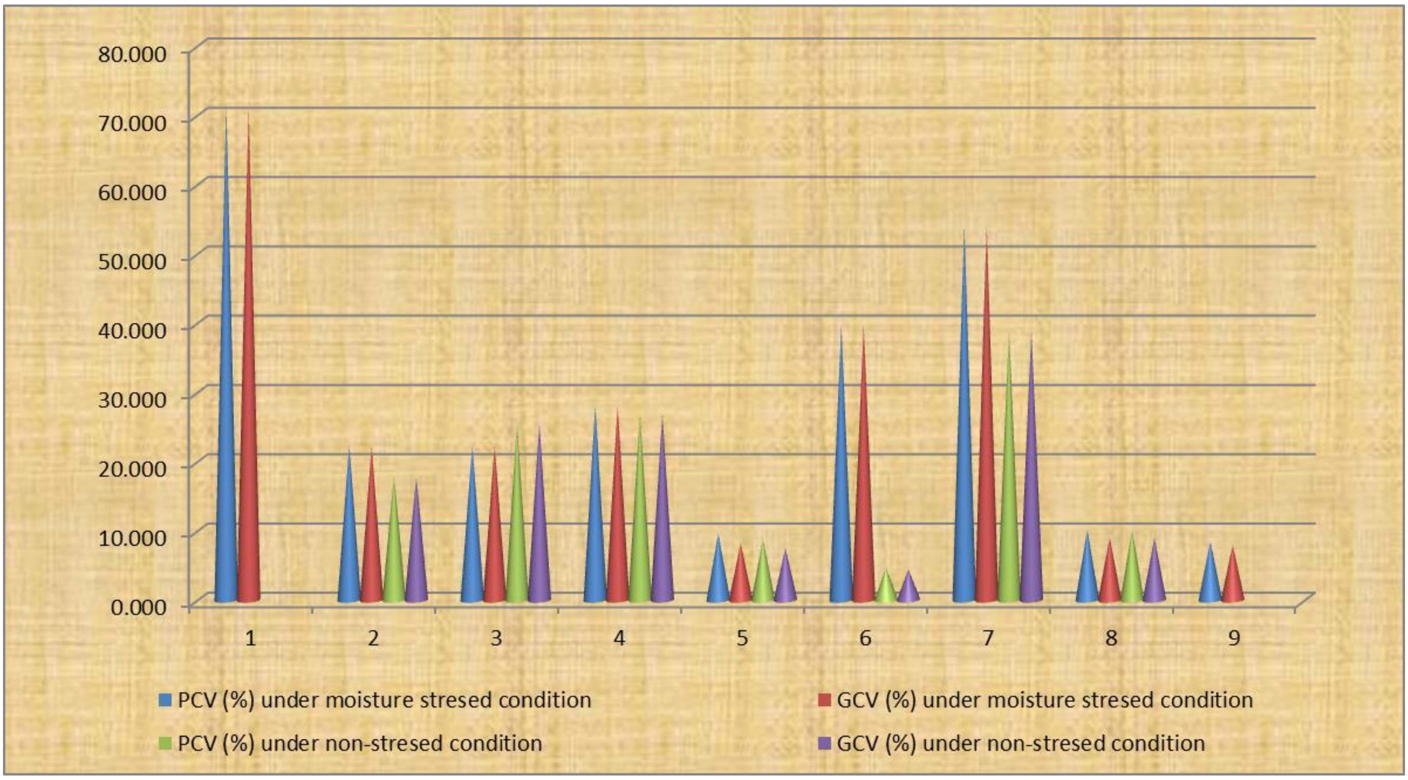
Where,
PCV – Phenotypic Coefficient of Variation
GCV – Genotypic Coefficient of Variation
h2– Broad sense heritability
GAM – Genetic Advance as per cent over Mean

Table 5: Estimates genetic parameters in groundnut genotypes in pot culture experiment under normal condition

Sl. No.	Character	Mean	Range	PCV (%)	GCV (%)	h^2 (%)	GAM (%)
1	Plant height (cm)	24.52	13.85-34.35	18.00	17.83	98.18	36.40
2	Root length (cm)	47.96	30.40-81.40	25.51	25.48	99.76	52.42
3	Root to shoot ratio	2.00	0.99-3.71	26.98	26.93	99.64	55.38
4	SPAD chlorophyll reading	43.60	36.60-51.45	8.81	7.52	72.89	13.22
5	Relative water content (%)	76.44	65.81-84.62	4.71	4.43	2.06	8.61
6	Membrane stability index (%)	30.66	4.60-55.83	39.11	38.97	99.28	79.98
7	No. of days for flower initiation	33.17	30.00-42.00	10.21	8.99	77.50	16.30

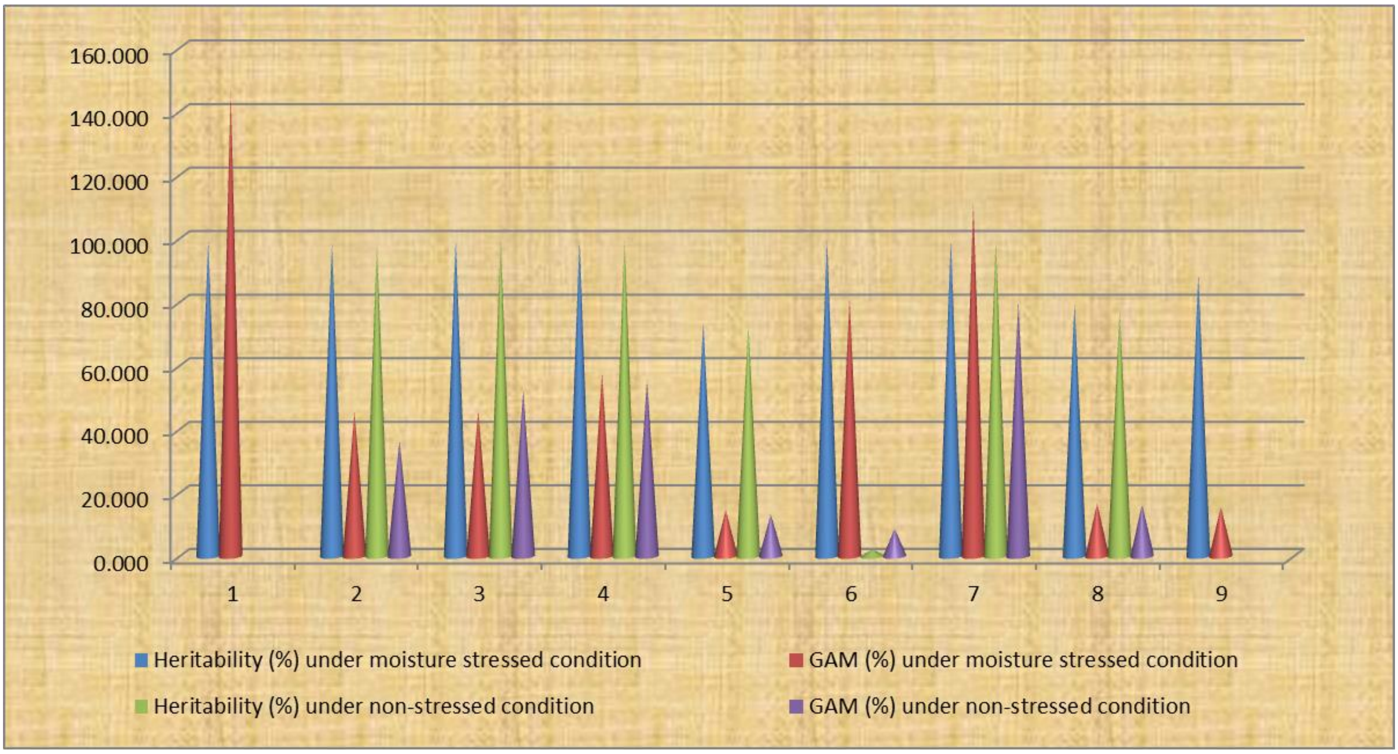
Where,
PCV – Phenotypic coefficient of variation
GCV – Genotypic coefficient of variation
h2– Broad sense Heritability
GAM – Genetic advance as per cent over mean

Plate 1: Comparison of groundnut genotypes under moisture stress and normal watering in pot culture experiment under shade-net



Where, 1. Percentage of wilted plants
2. Plant height (cm)
3. Root length (cm)
4. Root to shoot ratio
5. SPAD chlorophyll reading
6. Relative water content
7. Membrane stability index
8. No. of days for flower initiation
9. Percentage of recovered plants after re-watering

Fig 1: Comparison between phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for all the characters studied in drought tolerance screening at seedling stage under both moisture stress and non-stress conditions



Where, 1. Percentage of wilted plants 4. Root to shoot ratio 7. Membrane stability index
2. Plant height (cm) 5. SPAD chlorophyll reading 8. No. of days for flower initiation
3. Root length (cm) 6. Relative water content 9. Percentage of recovered plants after re-watering

Fig 2: Comparison between broad sense heritability and genetic advance over mean (GAM) for all the characters studied in drought tolerance screening at seedling stage under both stress and non-stress condition

Plant height (60 DAS)

The mean plant height at 60 days after sowing (DAS) recorded in moisture stressed pots was 23.39 cm with a range of 12.60 to 33.05 cm. While the mean plant height in non-moisture stressed pots was 24.52 cm with a range of 13.85 to 34.35 cm. The genotypic and phenotypic coefficients of variation were high (under moisture stress) to moderate (without moisture stress) for this trait. In addition, this trait exhibited high heritability coupled with high genetic advance over mean. Similar results have been reported by Rao (2016) [11], Venkateswarlu (2007) [12], Ravi (2005) [13].

Root length (60 DAS)

The root length in moisture stressed pots was in the range of 27.30 to 82.55 cm with a mean of 54.74 cm. In case of non-moisture stressed pots, the root length ranged from 30.40 to 81.40 cm with a mean of 47.96cm. This trait showed high genotypic and phenotypic coefficients of variability in both moisture stressed and non-stressed condition. It also exhibited high heritability with high genetic advance over mean indicating the additive nature of genetic variation for this trait and the trait can be easily fixed in the genotypes by selection in the early generations which helps the breeder developing improved drought tolerant genotypes in groundnut. Choyal (2013) [14] reported high heritability but moderate GCV and PCV for this trait.

Root to shoot ratio (60 DAS)

In moisture stressed pots, root to shoot ratio ranged from 1.24 to 4.08 cm with a mean of 2.44 cm. In non-moisture stressed pots, root to shoot ratio ranged from 0.99 to 3.71 cm with a mean of 2.00 cm. This trait exhibited high genotypic and phenotypic coefficients of variability in both moisture stressed and normal condition. It also exhibited high heritability with high genetic advance over mean. Since root to shoot ratio depends on the root length, it also followed the similar trend with respect to heritability and genetic advance over per cent mean. These finding were in line with that of the finding of Gobu *et al.* (2017) [15]. In addition to root length, the root to shoot ratio can also be utilized for selection in early generation as this trait can also be fixed because of its additive nature of genetic variance. Choyal (2013) [14] reported high GCV and PCV along with high heritability for this trait.

SPAD chlorophyll meter reading

The SPAD chlorophyll meter reading (SCMR) in moisture stressed pots ranged from 37.65 to 57.40 with a mean of 46.69. In non-moisture stressed pots, the SCMR was in the range of 36.60 to 51.45 with a mean of 43.60. This trait showed lower genotypic and phenotypic coefficients of variation in both stressed and normal condition. It also exhibited high heritability with moderate genetic advance over mean indicating the possibility to improve this trait by proper selection methods. Similar results were reported by Ravi (2005) [13] and Bhavya *et al.* (2017) [16]. But Rao (2016) [11] reported moderate GCV and PCV for this trait.

Relative water content

The relative water content in moisture stressed pots ranged from 19.39 and 86.33 *per cent* with a mean of 55.19 *per cent*. In non-moisture stressed pots, the mean relative water content recorded was 76.44 *per cent* with a range of 65.81 to 84.62 *per cent*. This trait showed high genotypic and phenotypic coefficients of variation in moisture stressed condition and low genotypic and phenotypic coefficients of variation under normal condition. It showed high heritability and high genetic advance over mean in moisture stressed condition as against their lower values under normal moisture condition. This reflects that, this trait can be used to select drought tolerant genotypes only under stress environments (imposed or natural moisture stress) but not under normal environments. Savita *et al.* (2014) [17], and Srivalli and Nadaf (2016) [18] reported Moderate to low GCV and PCV for RWC. However Govardhan *et al.* (2018) [19] reported low GCV and PCV for RWC.

Membrane stability index

In moisture stressed pots, the mean value of membrane stability index was 35.00 with a range of 5.49 to 87.96. The membrane stability index in non-moisture stressed pots was in the range of 4.60 to 55.83with a mean of 30.66. This trait exhibited high genotypic and phenotypic coefficients of variation in both stressed and non-stressed condition. It also had high heritability with high genetic advance over mean in both the conditions indicating its utility as a parameter for selecting genotypes for drought tolerance. Similar results were reported by Uday *et al.* (2015) [20] and Iqra *et al.* (2017) [21].

Number of days for flower initiation

In moisture stressed pots, the range for number of days for flower initiation was between 30.00 to 42.00 days with a mean of 33.38 days. In non-moisture stressed pots, it ranged from 30.00 to 42.00 days with a mean of 33.17 days. This trait exhibited moderate phenotypic and genotypic coefficients of variability in moisture stressed condition as against their higher values under normal moisture condition. It had high heritability and high genetic advance over mean in both moisture stressed and normal condition.

Percentage of wilted plants

In moistures stressed pots, the percentage of wilted plants ranged from 0 to 100 with a mean of 47.45 *per cent*. Percentage of wilted plants in moisture stressed condition was in the range of 0 to 100 *per cent* with a mean of 47.44 *per cent* which indicates that, half of the genotypes under study have poor drought tolerance ability. The high phenotypic and genotypic coefficients of variation, high heritability coupled with high genetic advance over mean for the trait further shows the importance of this trait and selection based on this character will be more useful in identifying genotypes for drought tolerance.

Percentage of recovered plants after re-watering

In moisture stressed pots, the recovery *per cent* of plants after re-watering ranged from 75 to 100 *per cent* with a mean of 96.38 *per cent*. Percentage of recovered plants after re-watering the wilted plants had a range of 75 to 100 with a mean of 96.378 *per cent*. This indicates that, even though groundnut is sensitive to water stress, they have comparatively better recovering capacity once the crop receives moisture as groundnut roots have better moisture absorption capacity. This trait recorded low genotypic and phenotypic coefficients of variation. But it showed a high heritability with moderate genetic advance over mean. This trait could also be used as an additional criterion for selection of groundnut genotypes for drought tolerance.

Conclusion

From all the foregoing results, it is evident that, a vast genetic variability exists among groundnut genotypes used in the present study for drought tolerance. Further, many traits considered in the pot screening have recorded high heritability with moderate to high genetic advance indicating the reliability of selection for these traits in identifying the drought tolerant genotypes. Further, these genotypes can be additionally screened by field evaluation methods to validate drought resistant genotypes. This would further help in identifying genotypes having better drought tolerance characteristics which may be of great use in breeding for drought tolerance in groundnut. Alternatively such lines can be effectively utilized in the breeding programs aimed at developing drought tolerant cultivars.

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