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Phenotyping of groundnut (*Arachis hypogaea* L.) genotypes for physiological and yield traits under mid-season drought stress

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Abstract
Two field experiments were conducted during *Rabi* 2014-15 and 2015-16 to screen 12 peanut genotypes for physiological traits and to study the changes in gas exchange parameters under water deficit condition. The two years data on various physiological and yield traits was collected, pooled and subjected to Repeated Measures mixed Analysis of Variance (RMANOVA) at a probability level of 5 % and Principal Component analysis was carried out using SPSS 20.0software. The physiological traits viz., gas exchange parameters, SCMR, SLA, RWC, RI and CSI of peanut leaves significantly differed among irrigation treatments and genotypes. From the PCs, it was clear that among all the twelve variables, photosynthetic rate, transpiration rate and pod yield are the major source of variation both in T1 and T2 treatments. Our results suggest that the genotypes TCGS 1345 followed by TCGS 1343 are promising genotypes which maintained least deviation on physiological traits and recorded high pod yields under water deficit condition.

Keywords: Physiological traits, gas exchange parameters, irrigation, peanut,

Introduction
Globally, peanut occupies an area of 26.4 m ha with a production of 37.1 m metric tonnes and productivity of 1400 kg ha^{-1} (FAOSTAT, 2015-2016). It is mainly grown in states like Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra. In India, peanut occupies an area of 45.78 lakh ha with production of 60.48 lakh tonnes and productivity of 1321 kg ha^{-1} in *kharif*. In *rabi-summer* it is being grown in 7.59 lakh ha with production of 14.14 lakh tonnes with productivity of 1861 kg ha^{-1}. In Andhra Pradesh, in *kharif*, it is cultivated in an area of 9.3 lakh ha with production of 3.9 lakh tonnes and productivity of 419 kg ha^{-1} while in *Rabi*, cultivated in 0.80 lakh ha with production of 2.12 lakh tonnes and productivity of 2650 kg ha^{-1} (Indiastat.com, 2016-17).
In Andhra Pradesh, it is mostly grown under rainfed situation in Anantapur, Chittoor, Kurnool and Kadapa districts.In India, groundnut is mainly grown in states of Gujarat, Andhra Pradesh, Tamilnadu, Karnataka and Maharashtra, mainly growing under rainfed (kharif) conditions. An area of about 70 percent and 75 percent of the production has been concentrated in the four states of Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. Andhra Pradesh occupies second place in peanut production, but, the productivity is very low under rainfed conditions (419 kg/ha.) compared to irrigated conditions (2650 kg/ha.). Low rainfall and prolonged dry spells during the crop growth period are the main reasons that cripple the peanut productivity.
The farmers of the dry land areas are growing a crop either on rainwater in kharif or on conserved soil moisture during the winter. Most of the crop varieties grown have low genetic potential for yield under low moisture scenario. Many measures have been laid out for selecting a crop variety for dry lands. The ability to produce better yield under limited soil moisture conditions is the most desirable criteria. In other words, crop varieties for dry land areas should be of short duration, drought resistant or tolerant and high yielding which can be harvested with in rainfall periods and have sufficient residual moisture in soil profile for post-monsoon cropping.
The drought patterns can be grouped in to three types i.e., early season, mid-season and end of season drought respectively. Mid-season drought affects the most vulnerable stages (pegging, pod and seed development) of plant growth in peanut (Nigam *et al*., 2003) [23]. Nageswara Rao *et al.*, 1989 [24] observed a poor relationship between the yield potential under adequate water availability and the sensitivity of genotypes to mid-season drought and suggested the

possibility of identifying genotypes with high yield potential and relatively low sensitivity to mid-season droughts.
Drought affects plant growth, photosynthetic activity, membrane integrity, osmotic adjustment, water relations and ultimately low yields were noted. Hence, the study was aimed to sort the changes in physiological efficiency and to screen the peanut genotypes for high yields under water deficit condition to increase production of peanut in rainfed /water deficit soils.

Materials and Methods
Two field experiments were conducted at the research farm of Regional Agricultural Research Station, Tirupati, Andhra Pradesh, India during rabi 2014-15 and 2015-16 using 12 peanut genotypes procured from Department of Genetics and Plant Breeding, Regional Agricultural Research Station, Tirupati, Andhra Pradesh, India. The experiment was laid in a split plot design taking two irrigation treatments viz. control (T1), and water deficit (T2) as main treatments, and 12 genotypes as sub treatments. The peanut genotypes were sown in 3 replications during second fortnight of December' 2014.-15 and 2015-16. The water deficit condition was created under rain out shelters by with-holding irrigation from pegging to pod and seed development i.e. 40-90 DAS (midseason drought) while adequate moisture was maintained in the control.
The SPAD Chlorophyll meter Reading (SCMR), Specific Leaf Area (SLA), Relative Water Content (RWC), Relative leaf Injury (RI) per cent, Chlorophyll Stability Index (CSI), actual quantum yield of PSII (Fv'/Fm'), Stomatal Conductance (gs), Transpiration Rate (E), and Photosynthetic Rate (PN) were recorded in 5 plants for the third leaf from the top of the main stem at the end of the stress period i.e., 85-90 DAS in control and water deficit condition.
To determine soil moisture content (SMC) by gravimetric method, soil samples were drawn from the upper layer (0–15 cm) and lower layer (15–30 cm) soil depths. SCMR was measured using Minolta SPAD 502m (Tokyo, Japan) for the third fully expanded leaf from the top of the main stem. Leaf area was measured using LI-3100 leaf area meter and the leaf samples were oven dried at temperature 800C at least 48 h to determine leaf dry weight. Then SLA was calculated using the formula SLA=leaf area (cm2)/leaf dry weight (g). The leaf samples were collected and weighed to record RWC. After recording fresh weight, the leaf samples were soaked for 4 h and turgid weight was recorded as described by Barrs and Weatherly (1962) using the formula

RWC (%) = [(FW– DW)/(TW– DW)]*100,
Where, FW fresh weight, DW dry weight and TW is turgid weight.

Chlorophyll was extracted from fresh leaf tissue by soaking in DMSO (Dimethyl sulphoxide), then the absorbency was determined at 645 and 663 nm with UV spectrophotometer and chlorophyll content was determined following the method of Arnon (1949). The CSI was determined according Sairam *et al*., (1997) and calculated as

CSI = (Total chlorophyll under water deficit/Total chlorophyll under control) x100.

RI % was estimated by incubating one gram of leaf sample in 10 ml of distilled water and kept for shaking for 3 h. Then the initial light absorbance (Ia) values were recorded at 273 nm using UV spectrophotometer. The same sample after incubation was kept in boiling water bath for 30 min and the final absorbance values (Fa) were recorded at 273 nm as described by Leopold *et al*., 1981. The relative leaf injury was calculated using the formula RI (%) = (Ia/Fa) x100.
The gas exchange parameters viz., Fv'/Fm', PN, gs, E, WUE were recorded between 08:00 and 10:00 h by LI-COR 6400, Portable Photosynthesis system (LI-COR Inc. Lincon, NE, USA) with modulated fluorescence measurement as described by Maxwell and Johnson (2000). The WUE was calculated as the ratio of PN to E. In order to measure the yield, 10 plants were selected randomly after maturity and yield per plant was obtained from the average of these plants yield.
The two years data was collected, pooled and subjected to repeated measures mixed analysis of variance at a probability level of 5 % and Principal Component (PC) analysis was carried out using SPSS 13.0 statistical software.

Results and Discussion
The Soil moisture content (SMC) varied in control (T1) and simulated mid-season moisture stress (T2) treatments. At 40 DAS (at the start of moisture stress period), SMC maintained in the range of 17.6 to 19.5 % at 0-15 and 15-30 cm soil depth in both T1 and T2 treatments whereas at 90 DAS (at the end of stress period), SMC was 18.9 and 19.7 % at 0-15 and 15-30 cm soil depth in T1 and it reduced to 7.2 and 8.7 % at 0-15 and 15-30 cm soil depth. The Relative Water Content (RWC) of peanut leaves decreased by 20.6 % in T2 compared to T1 treatment. The interaction was significant with the highest RWC in TCGS 1342 (89.2 %) in T1 and in TCGS 1345 (73.7 %) which is on par with TCGS 1343 (71.5 %) in T2 treatment (table 1). Relative water content (RWC) reflecting the metabolic activity in tissues, is a measure of plant water status and used as an index for dehydration tolerance. A decrease in RWC with increase in drought stress has been noted in wide variety of plants as reported by Nayyar and Gupta (2006) [22]. RWC was affected by the interaction of water deficit severity, duration of the drought event and species (Yang and Miao, 2010) [29]. The significant reduction of RWC in this study in T2 was due to variation in soil water availability of two irrigation treatments which is in agreement with the results of Kalariya *et al*. 2015 [16]. The genotypic variation of RWC depends on the moisture regime and also genetic background (Daniele *et al*. 2006) [10].
Leaves also become thicker (low SLA) under moderate drought stress (Reddy and Rao, 1968) [24] and leaf expansion is more sensitive to soil water deficit than stomatal closure (Black *et al*., 1985) [5]. In the present study, water deficit reduced specific leaf area and increased SCMR. The mean Soil plant analytical development chlorophyll meter reading (SCMR) of peanut leaves significantly increased to 5.5 % in T2 compared to T1 treatment. Genotypes also differed significantly with the highest SCMR in TCGS 1397 (49.9) and lowest in TCGS 1346 (44.0). The interaction was significant with the highest SCMR in TCGS 1397 (50.5) under T1 and in TCGS 1345 (51.2) which was statistically on par with TCGS 1343 (50.4) under T2 treatment (table 1). A large decline in the levels of chlorophyll a, b and total chlorophyll was observed under drought stress in different sunflower varieties (Manivannan *et al*. 2007b) [18]. The decrease in chlorophyll was attributed to the inhibition of chlorophyll synthesis which is the main cause of inactivation of photosynthesis (Kaiser *et al*. 1981) [15]. Drought stress increased SCMR and canopy temperature (Jongrung Klang *et al*. 2008) [14] and the increase would be primarily due to the

increase in leaf thickness as a result of smaller leaves. The Specific Leaf Area (SLA) had significantly decreased to 7.4 % in T2 compared to T1 treatment. The interaction was significant with the lowest SLA in TCGS 1345 and on par with TCGS 1343 in both T1 and T2 treatments (table 1). Arunyanark *et al*. 2009 [3] recorded significant correlation between SCMR and chlorophyll density under drought and specify that, drought did not impair chlorophyll in peanut (Holbrook and Stalker, 2003) [13] and the maintenance of high chlorophyll under drought stress would be benefit to peanut. In the present study, the interaction was significant with the highest SCMR, lowest SLA and highest RWC in TCGS 1345 and on par with TCGS 1343 in both T1 and T2 treatments.

The Net photosynthetic rate (PN) was 26.5 µ moles CO2/m2/s in T1 and 17.5 µ moles CO2/m2/s in T2 at the end of stress period. Also there was significant interaction of genotypes and treatments with the highest PN in TCGS 1343 under T1 and in TCGS 1345 which is on par with TCGS 1343 in T2 (table 1). There was decrease in stomatal conductance (gs) and transpiration rate (E) by 35.7 % and 50.3 % respectively in T2 compared to T1 treatment. The interaction was significant with the highest gs in TCGS 1343 (0.42 moles H2O/m2/s) in T1 and in TCGS 1345 (0.24 moles H2O/m2/s) which is on par with TCGS 1343 (0.22 moles H2O/m2/s) in T2 treatment. Also there was significant interaction of genotypes and treatments with the highest E in TCGS 1343 and TCGS 1399 (8.62 m moles H2O/m2/s) under T1 and in TCGS 1345 (4.69 m moles H2O/m2/s) which is on par with TCGS 1343 (4.62 m moles H2O/m2/s) in T2 treatment. The actual efficiency of photosynthesis (Fv'/Fm') was 0.574 in T1 and 0.479 in T2 during 75 to 80 DAS. Highest Fv'/Fm' recorded in TCGS 1398 in T1 and in TCGS 1349 in T2 treatment (table 2). Highest water use efficiency (WUE) recorded in TCGS 1342. Drought stress severely hampered the gas exchange parameters (PN, gs, E, Fv'/Fm' and WUE) of crop plants and this could be due to decrease in leaf area, reduced photosynthetic rate, premature leaf senescence and oxidation of chloroplasts lipids (Menconi *et al*. 1995) [20]. Subramaniam and Maheswari, (1990) reported that leaf water potential, transpiration rate and photosynthetic rate decreased increasingly with increasing duration of water stress indicating that plants under mild water stress were delaying tissue dehydration. A water deficit in plant tissues under drought stress leads to a significant inhibition of photosynthetic rate due to reduction in stomatal conductance. The plant reacts to water deficit with a rapid closure of stomata to avoid further loss of water through transpiration. The photosynthesis plays a significant role in both biomass accumulation and productivity in identifying the efficient genotypes and to understand the physiological traits of productivity both under control and stress conditions. Acclimation to different environments by crop plants is directly or indirectly associated with their capacity to adapt at the level of photosynthesis, which in turn affects biochemical and physiological parameters and, finally affects the growth and yield of the whole plant (Chandra, 2003) [7]. Therefore, the ability to maintain the functionality of the photosynthetic machinery under water stress is of major importance in drought tolerance. The present study shows that drought did not significantly affect the chlorophyll fluorescence parameter in peanut.

The mean Relative Injury (RI) of peanut leaves significantly increased to 33 % in T2 compared to T1 treatment. The interaction was significant with the lowest RI in TCGS 1342 (17.1 %) which was statistically on par with TCGS 1399, TCGS 1345, TCGS 1349 under T2 treatment. The Chlorophyll stability index (CSI) had significantly decreased (7.64 % reduction) in T2 compared to T1 treatment. The interaction was significant with the highest CSI in TCGS 1345 in both T1 and T2 treatments (table 3).Relative leaf injury per cent or leakage of solutes as a consequence of membrane damage is a common response of peanut tissue to drought stress. Variation in relative injury is mainly due to the variations in leakage of solutes caused by membrane injury. Exposure of plants to heat stress causes cellular membrane disruptions and is apparently related to temperature specific phase changes in membrane lipid bilayer (Suss and Yordanov, 1986) [68].

Genotypes also differed significantly with the highest mean pod yield in TCGS 1345 (2612.8 kg ha-1) and lowest in TCGS 1342 (903.8 kg ha-1). The interaction was significant with the highest pod yield in TCGS 1345 followed by TCGS 1343 under T2 treatment. The present study reveals that, the mean pod yield of peanut genotypes significantly decreased by 21.23 % in T2 compared to T1 treatment. Genotypes also differed significantly with the highest pod yield in TCGS 1345 (2869.7 kg ha-1) and lowest in TCGS 1342 (815.3 kg ha-1). The interaction was significant with the highest pod yield in TCGS 1345 followed by TCGS 1343 in both T1 and T2 treatments (table 3). Drought related reduction in yield and yield components of plants could be ascribed to stomatal closure in response to low soil water content, which decreased the intake of CO2 and, as a result, photosynthesis decreased (Chaves, 1991; Cornic, 2000; Flexas *et al*. 2004) [8, 9, 11]. Drought stress significantly reduced total biomass, pod dry weight, harvest index, water use efficiency and specific leaf area, but it increased SCMR and canopy temperature (Jongrungklang *et al*. 2008) [14].

In the principal component analysis, out of 12, five principal components exhibited more than one Eigen value and showed 77.32 per cent of variability in control treatment. Hence, these five were given due importance for further explanation. Table 4 presents the principal component and percentage contribution of each component to the total variation in the entries tested under control conditions. Among the genotypes, the first principal component accounted for 23.21 % of the total variation. PN contributed more to the variation (0.901), followed by E (0.872), pod yield (0.708), RWC (0.418), Fv'/Fm' (0.347), SCMR (0.110) and gs (0.036). All other characters contributed negatively to the first component (Table 4). Second principal component contributed 17.98 % of the total variation. Characters that contributed to the component include WUE which contributed the highest (0.781) followed by RWC (0.640), PN (0.294), SCMR (0.150), Fv'/Fm' (0.125), SOD (0.073) and gs (0.064). The third principal component accounted for 14.41 % of the total variation. SCMR contributed the highest (0.836) followed by CSI (0.763) and RWC (0.448) while Fv'/Fm' (0.133), PN (0.068) contributed less. Fv'/Fm' (0.673) contributed more to the variation followed by SOD (0.549) in principal component 4. E (0.186), SCMR (0.185) and pod yield (0.095) contributed low to the variation. All other characters contributed negatively to the fourth component. The fifth principal component accounted for 9.49 % of the total variation with RI (0.891) given the highest contribution followed by pod yield (0.432).

In the principal component analysis, out of 12, four principal components exhibited more than one eigen value and showed 71.57 per cent of variability in water deficit treatment. Hence, these four were given due importance for further explanation.

Under water deficit conditions, the first principal component accounted for 29.48 % of the total variation observed (Table 5). E contributed more to the variation (0.923) followed by PN (0.723), Fv'/Fm' (0.423), pod yield (0.359) than others. SOD (0.152), RWC (0.144) and SCMR (0.069) contributed least to the variation. The second component contributed 15.66 % of the total variation with the pod yield (0.702) contributing highest. Other major characters that contributed to the variation include SOD (0.695), SLA (0.267), PN (0.258), E (0.235) and Fv'/Fm' (0.148). The third principal component contributed 14.22 % of the total variation among traits. The trait gs contributed the highest (0.854) followed by RWC (0.776), PN (0.502) and WUE (0.280). The fourth principal component contributed 12.2 % to the total variation. The major characters that contributed highly to the variation include RI (0.802) and SLA (0.768) followed by CSI (0.399), gs (0.269) and WUE (0.166).

Principal component (PC) analysis is a form of multivariate analysis utilized in present study, reflects the importance of the largest contributor to the total variation at each axis of differentiation. The Eigen values are often used to determine how many factors to retain. The sum of the Eigen values is usually equal to the number of variables (Sharma, 1998). It was concluded that maximum variation was present in first PC both in control and water deficit treatment. So selection of genotypes from first PC will be useful. In control and water deficit treatments, from the PCs, it was clear that among all the twelve variables, photosynthetic rate, transpiration rate and pod yield had high value which is in agreement with Chahal and Gosal (2002) [6] who showed that characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero.

The present study reveals that a good hybridization breeding program can be initiated by the selection of genotypes from the PC1 as it contributed maximum toward diversity with maximum Eigen value. Characters with high variability are expected to provide high level of gene transfer during breeding programs (Gana, 2006; Aliyu *et al*., 2000) [12, 1]. Hence, from the study, the genotypes TCGS 1345 followed by TCGS 1343 recorded high pod yields by maintaining the physiological and biochemical efficiency under water deficit condition.

Table 1: Impact of water deficit on SCMR, SLA, RWC and P_N of groundnut genotypes

S No	Genotype	SCMR			SLA (cm^2 /g)			RWC (%)			P_N (µmoles $CO_2/m^2/s$)		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS - 1342	46.1	48.0	47.1^{c}	147.5	145.2	146.4^{b}	89.2	70.7	79.9^{a}	29.6	17.2	23.4^{c}
2	TCGS - 1343	46.6	50.4	48.5^{b}	148.9	145.6	147.2^{b}	84.7	71.5	78.1^{b}	33.1	20.3	26.7^{a}
3	TCGS - 1345	44.3	51.2	47.7^{c}	162.1	143.8	152.9^{c}	82.9	73.7	78.3^{b}	27.0	22.6	24.8^{b}
4	TCGS - 1346	41.8	46.3	44.0^{f}	152.8	150.1	151.4^{c}	81.9	67.5	74.7^{c}	29.3	19.9	24.6^{b}
5	TCGS - 1349	45.3	48.9	47.1^{c}	161.5	160.9	161.2^{e}	87.7	69.8	78.7^{b}	30.8	18.9	24.8^{b}
6	TCGS - 1397	50.5	49.2	49.9^{a}	160.0	132.1	146.1^{b}	84.2	65.4	74.8^{c}	24.0	14.9	19.4f
7	TCGS - 1398	46.6	47.8	47.2^{c}	151.5	138.6	145.0^{a}	82.2	62.8	72.5^{d}	21.7	16.3	19.0^{f}
8	TCGS - 1399	42.5	46.7	44.6^{f}	152.2	135.1	143.6^{a}	83.3	62.2	72.8^{d}	28.1	18.4	23.3^{c}
9	TCGS - 1426	44.6	45.7	45.1^{e}	179.0	162.9	171.0^{f}	82.0	61.8	71.9^{d}	22.8	15.3	19.1^{f}
10	TCGS - 1429	47.8	47.8	47.8^{c}	152.8	142.9	147.8^{b}	80.3	68.6	74.4^{c}	26.3	17.9	22.1d
11	Kadiri - 6	45.2	46.2	45.7^{e}	164.4	148.3	156.3^{d}	83.5	59.2	71.3^{e}	20.1	13.0	16.5^{g}
12	Dharani	44.7	47.8	46.2^{d}	157.6	153.5	155.5^{d}	79.9	62.0	71.0^{e}	25.6	15.3	20.5^{e}
	mean	45.5	48.0		157.5	146.6		83.5	66.3		26.5	17.5	
	Summary of repeated measures mixed ANOVA												
		F-value	p-value		F-value	p-value		F-value	p-value		F-value	p-value	
	Treatment	259.6*	0.03(<0.05)		27.7*	0.03(<0.05)		511.1*	0.03(<0.05)		294.7*	0.02(<0.05)	
	Genotype	25.5*	0.03(<0.05)		17.8*	0.02(<0.05)		6.2*	0.03(<0.05)		11.9*	0.02(<0.05)	
	Treatment x Genotype	4.2*	0.03(<0.05)		6.7*	0.02(<0.05)		2.6*	0.03(<0.05)		2.2*	0.03(<0.05)	

* Significant at 5% level same alphabets indicates insignificant difference among genotypes (DMRT)

Table 2: Impact of water deficit on g_s, E, WUE and Fv'/Fm' of groundnut genotypes

S No	Genotype	g_s (moles $H_2O/m^2/s$)			E (m mole $H_2O/m^2/s$)			WUE			Fv'/Fm'		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS - 1342	0.33	0.16	0.24^{d}	7.66	2.62	5.14^{b}	3.87	6.55	5.21^{a}	0.623	0.439	0.531^{a}
2	TCGS - 1343	0.42	0.22	0.32^{a}	8.62	4.62	6.62^{a}	3.84	4.40	4.12^{b}	0.564	0.546	0.555^{a}
3	TCGS - 1345	0.27	0.24	0.25^{c}	6.10	4.69	5.40^{b}	4.42	4.82	4.62^{b}	0.582	0.526	0.554^{a}
4	TCGS - 1346	0.34	0.19	0.26^{c}	7.80	3.89	5.85^{b}	3.76	5.12	4.44^{b}	0.597	0.572	0.585^{a}
5	TCGS - 1349	0.39	0.18	0.29^{b}	8.28	3.74	6.01^{a}	3.71	5.05	4.38^{b}	0.623	0.588	0.606^{a}
6	TCGS - 1397	0.25	0.17	0.21^{e}	6.65	2.64	4.65^{c}	3.61	5.63	4.62^{b}	0.551	0.501	0.526^{a}
7	TCGS - 1398	0.20	0.16	0.18^{f}	6.02	4.12	5.07^{b}	3.60	3.97	3.78^{c}	0.648	0.347	0.542^{a}
8	TCGS - 1399	0.28	0.18	0.23^{d}	8.62	4.22	6.42^{a}	3.26	4.36	3.81^{c}	0.593	0.402	0.498^{b}
9	TCGS - 1426	0.22	0.15	0.19^{f}	7.11	3.38	5.25^{b}	3.21	4.53	3.87^{c}	0.532	0.382	0.457^{b}
10	TCGS - 1429	0.27	0.17	0.22^{e}	7.93	3.74	5.84^{b}	3.32	4.78	4.05^{b}	0.557	0.495	0.526^{a}
11	Kadiri - 6	0.23	0.14	0.19^{f}	5.65	2.59	4.12^{c}	3.55	5.03	4.29^{b}	0.463	0.292	0.378^{c}
12	Dharani	0.20	0.18	0.19^{f}	6.31	2.88	4.60^{c}	4.06	5.30	4.68^{b}	0.470	0.419	0.445^{b}
	mean	0.28	0.18		7.23	3.59		3.68	4.96		0.574	0.459	
		Summary of repeated measures mixed ANOVA											
		F-value	p-value		F-value	p-value		F-value	p-value		F-value	p-value	
	Treatment	176.0*	0.03(<0.05)		538.5*	0.02(<0.05)		406.3*	0.04(<0.05)		205.3*	0.02(<0.05)	
	Genotype	45.7*	0.03(<0.05)		13.6*	0.02(<0.05)		28.2*	0.04(<0.05)		22.4#	0.06(<0.10)	
	Treatment x Genotype	2.3*	0.03(<0.05)		5.72*	0.02(<0.05)		29.8*	0.04(<0.05)		4.12*	0.03(<0.05)	

* Significant at 5% level # significant at 10% level

Same alphabet indicates insignificant difference among genotypes (DMRT)

Table 3: Impact of water deficit on RI, CSI and pod yield of groundnut genotypes

S. No	Genotype	RI (%)			CSI (%)			Pod yield (kg/ha.)		
		T1	T2	Mean	T1	T2	Mean	T1	T2	Mean
1	TCGS - 1342	12.6	17.1	14.9[a]	81.2	76.3	78.8[d]	992.3	815.3	903.8[i]
2	TCGS - 1343	15.3	19.4	17.4[c]	78.4	71.1	74.8[e]	2382.0	1928.3	2155.2[b]
3	TCGS - 1345	14.8	17.5	16.1[b]	91.5	85.8	88.6[a]	2869.7	2355.9	2612.8[a]
4	TCGS - 1346	13.3	23.3	18.3[d]	79.4	73.2	76.3[e]	2163.1	1761.4	1962.3[c]
5	TCGS - 1349	15.6	17.5	16.6[b]	82.0	78.2	80.1[c]	1434.4	998.3	1216.4[h]
6	TCGS - 1397	14.5	21.4	17.9[d]	89.1	82.7	85.9[b]	2034.5	1546.7	1790.6[d]
7	TCGS - 1398	13.6	20.0	16.8[b]	84.6	77.1	80.9[c]	1956.1	1172.5	1564.3[e]
8	TCGS - 1399	13.8	17.4	15.6[a]	78.1	71.4	74.8[e]	2519.5	1795.0	2157.3[b]
9	TCGS - 1426	14.8	19.3	17.0[c]	78.4	72.5	75.5[e]	2086.4	1876.7	1981.6[c]
10	TCGS - 1429	19.0	22.6	20.8[e]	88.7	82.8	85.7[b]	1570.0	1320.3	1445.2[f]
11	Kadiri - 6	16.9	20.3	18.6[d]	86.5	81.2	83.8[b]	998.6	875.8	937.2[i]
12	Dharani	13.7	20.5	17.1[c]	87.1	76.5	81.8[c]	1462.2	1250.8	1356.5[g]
	mean	14.8	19.7		83.8	77.4		1872.4	1474.8	
		Summary of repeated measures mixed ANOVA								
		F-value	p-value		F-value	p-value		F-value	p-value	
	Treatment	254.3*	0.03(<0.05)		18.1*	0.04(<0.05)		6.2*	0.02(<0.05)	
	Genotype	8.5*	0.03(<0.05)		14.5*	0.04(<0.05)		27.1*	0.02(<0.05)	
	Treatment x Genotype	4.5*	0.03(<0.05)		1.9#	0.06(<0.10)		3.9*	0.02(<0.05)	

* Significant at 5% level # significant at 10% level
Same alphabet indicates insignificant difference among genotypes (DMRT)

Table 4: Principal component (PCs) for 11 physio - biochemical and yield traits in 12 groundnut genotypes with eigen values and cumulative per cent of variation in control

Traits	PC1	PC2	PC3	PC4	PC5
SCMR	0.110	0.150	0.836	0.185	0.093
SLA	-0.114	-0.858	-0.026	-0.156	0.019
RWC	0.418	0.640	0.448	-0.107	-0.093
P_N	0.901	0.294	0.068	-0.125	-0.082
g_s	0.036	0.064	-0.086	-0.822	-0.279
E	0.872	-0.073	-0.116	0.186	-0.143
WUE	-0.370	0.781	-0.289	-0.064	-0.044
Fv'/Fm'	0.347	0.125	0.133	0.673	-0.225
RI	-0.083	-0.024	-0.003	-0.017	0.891
CSI	-0.255	-0.234	0.763	-0.122	-0.091
PY	0.708	-0.350	-0.027	0.095	0.432
Eigen value	2.785	2.158	1.729	1.469	1.139
% of variance	23.21	17.98	14.41	12.24	9.49
Cumulative %	23.21	41.19	55.60	67.84	77.32

Table 5: Principal component (PCs) for 11 physio - biochemical and yield traits in 12 groundnut genotypes with eigen values and cumulative per cent of variation in water deficit

Traits	PC1	PC2	PC3	PC4
SCMR	0.069	-0.890	0.022	-0.029
SLA	-0.010	0.267	-0.083	0.768
RWC	0.144	-0.081	0.776	-0.257
P_N	0.723	0.258	0.502	0.072
g_s	-0.177	0.088	0.854	0.269
E	0.923	0.235	0.118	0.018
WUE	-0.848	0.088	0.280	0.166
Fv'/Fm'	0.423	0.148	-0.059	-0.402
RI	-0.019	-0.359	0.106	0.802
CSI	-0.363	-0.490	-0.201	0.399
PY	0.359	0.702	-0.292	0.052
Eigen value	3.538	1.880	1.707	1.464
% of variance	29.48	15.66	14.22	12.20
Cumulative %	29.48	45.15	59.37	71.57

References

1. Aliyu B, Akoroda MO, Padulosi S. Variation within Vignareticulata Hooke FII Nigerian Journal of Genetic spp, 2000, 1-8.
2. Arnon DI. Copper enzymes in isolated chloroplasts polyphenol oxidases in Beta vulgaris. Plant Physiology. 1949; 24:1-15.
3. Arunyanark A, Jogloy S, Akkasaeng C, Vorasoot N, Kesmala T, Nageswararao RC, *et al*. Chlorophyll stability is an indicator of drought tolerance in peanut. Journal of Agronomy and Crop Science. 2008; 194:113-125.
4. Barrs HD, Weatherley PE. A re-examination of the relative turgidity technique for estimating water deficit in leaves. Australian Journal of Biological Sciences. 1962; 15:413-428.
5. Black CR, Tang DY, Ong CK, Solon A, Simmonds LP. Effects of soil moisture on water relations and water use of groundnut stands. New Phytologist. 2000; 100:313-328.
6. Chahal GS, and Gosal SS. Principles and procedures of plant breeding, biotechnology and conventional approaches. Narosa Publishing House. Inc., New Delhi, India, 2002.
7. Chandra S. Effects of leaf age on transpiration and energy exchange of Ficusglomerata, a multipurpose tress species of Central Himalayas. Physiology and Molecular Biology of Plants. 2003; 9:255-260.
8. Chaves MM. Effects of water deficits on assimilation. Journal of Experimental Botany. 1991; 42:1-16.
9. Cornic G. Drought stress inhibits photosynthesis by decreasing stomatal aperture – not by affecting ATP synthesis. Trends in Plant Science. 2000; 5:187-188.
10. Daniele C, Omar D, Jean LK, Serge B. Genotypes variations in fluorescence parameters among closely related groundnut (*Arachis hypogaea* L.) lines and their potential for drought screening programs. Field crop Research. 2006; 96:296-306.
11. Flexas J, Bota J, Loreto F, Cornic G, Sharkey TD. Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants. Plant Biology. 2004; 6:1-11.
12. Gana AS. Variability studies of the response of rice varieties to biotic and abiotic stresses. Unpublished Ph.D Thesis, University of Ilorin, 2006.
13. Holbrook CC, Stalker HT. Peanut breeding and genetic resources. Plant Breeding Reviews. 2003; 22:297-356.

14. Jongrungklang N, Toomson B, Vorasoot N, Jogloy S, Kesmala T, Patanothai A. Identification of peanut genotypes with high water use efficiency under drought stress conditions from peanut germplasm of diverse origin. Asian Journal of Plant Sciences. 2008; 7(7):628-638
15. Kaiser WM, Kaiser G, Schoner S, Neimanis S. Photosynthesis under osmotic stress. Differential recovery of photosynthetic activities of stroma enzymes, intact chloroplasts and leaf slices after exposure to high solute concentrations. Planta. 1981; 153:430-435.
16. Kalariya KA, Amrit Lal Singh, Nisha Goswami, Deepti Mehta, Mahesh Kumar Mahatma, Ajay BC, Photosynthetic characters of peanut genotypes under excess and deficit irrigation during summer. Physiology and Molecular Biology of Plants. 2015; 21(3):317-327.
17. Leopold AC, Musgrave ME, Williams KM. Solute leakage resulting from leaf desiccation. Plant Physiology. 1981; 68:1222-1225.
18. Manivannan P, Jaleel CA, Sankar B, Kishore kumar A, Somusundaram R, Alagu Lakshmanan GM, Panneerselvam R. Growth, biochemical modifications and proline metabolism in Helianthus annuus L. as induced by drought stress. Colloids and Surfaces B: Biointerfaces. 2007b; 59:141-149.
19. Maxwell K, Johnson GN. Chlorophyll fluorescence – a practical guide. Journal of Experimental Botany. 2000; 51(345):659-668.
20. Menconi M, Sgherri CLM, Pinzino C, Navari-Izzo F. Activated oxygen production and detoxification in wheat plants subjected to a water deficit programme. Journal of Experimental Botany. 1995; 46:1123-1130.
21. Nageswara Rao RC, Williams JH, Murari Singh. Genotypic sensitivity to drought and yield potential of peanut. Agronomy Journal. 1989; 81:887-893.
22. Nayyar H, Gupta D. Differential sensitivity of C3 and C4 plants to water deficit stress: association with oxidative stress and antioxidants. Environmental and Experimental Botany. 2006; 58:106-113.
23. Nigam SN, Nageswara Rao RC, Graeme C Wright. Breeding for increased water use efficiency in groundnut. Mangal rai, Harvir Singh, Hedge DM (Eds) Thematic papers. National seminar on stress management in oilseeds for attaining self-reliance in vegetable oils, ISOR, January 28-30, Hyderabad, 2003.
24. Reddy AJ, Rao IM. Influence of induced water stress on chlorophyll components of proximal and distal leaflets of groundnut plants. Current Science. 1968; 5(3):118–121.
25. Sairam RK, Deshmukh PS, Shukla DS. Tolerance of drought and temperature stress in relation to increased antioxidant enzyme activity in wheat. Journal of Agronomy and Crop Science. 1997; 178:171-178.
26. Sharma JR. Statistical and biometrical techniques in plant breeding. New Age International Limited Publishers, New Delhi, India, 1998, 432,
27. Subramaniam VB, Maheswari M. Physiological responses of groundnut to water stress. Indian Journal Plant Physiology. 1990; 33:130-155.
28. Suss KH, Yordanov I. Biosynthetic cause of *in vivo* acquired thermotolerance of photosynthetic light reactions and metabolic responses of chloroplasts to heat stress. Plant Physiology. 1986; 81:192-199.
29. Yang F, Miao LF. Adaptive responses to progressive drought stress in two poplar species originating from different altitudes. Silva Fennica. 2010; 44:23-37.