Madras Agric. J., 103 (10-12): 309-313, December 2016
https://doi.org/10.29321/MAJ.10.001040

Physiological and Yield Responses of Groundnut (*Arachis hypogaea* L.) Genotypes to Drought

P. Maheswari*, M.K. Kalarani, A. Senthil and S. Sowmiyapriya
Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore

Groundnut (*Arachis hypogaea* L.) is an important oil seed crop mainly grown as rainfed crop. Due to erratic rainfall and frequent drought during the crop growth period, groundnut yields are generally low and unstable under rainfed conditions. Drought during critical crop growth stages is crucial for yield in groundnut varieties. But tolerant genotypes may give better yield due to maintenance of physiological responses that were triggered during drought. The experiment was conducted in the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during 2015-2016 to study physiological characters responsible for improving yield of different groundnut genotypes *viz.,* CO 7, COGn 4, TMV 7 and TMVGn 13 under water stress at different flowering phases *viz*., pre flowering drought (PFD) during 15- 30 DAS, flowering drought (FD) during 35-50 DAS and post flowering drought (PoFD) during 75-90 DAS by withholding irrigation and control was also maintained with watering up to field capacity for comparison. Observations on various physiological parameters *viz.,* leaf area, root length, relative water content, osmotic potential and leaf gas exchange parameters including*,* photosynthetic rate, transpiration rate and stomatal conductance were studied during stress and recovery period. Among the treatments, the plants under PFD performed better in recording higher value of physiological parameters under stress and recovered quickly. The variety, CO7 was found to perform well under all stages of stress followed by TMV 7, TMVGn 13 and COGn 4 with respect to physiological parameters and yield.

Key words: Leaf area, Root length, Relative water content, Osmotic potential, Gas exchange parameters

Groundnut, the king of oil seeds is one of the important legume crops of tropical and semiarid tropical countries including India, where it provides a major source of oil, carbohydrates and proteins. The area under rainfed groundnut in Tamil Nadu is 2.50 lakh hectares with a production of 3.50 lakh tones during *Kharif* 2012-13 (www.agritech.tnau.ac.in). Drought is the major environmental factor contributing to the reduced agricultural productivity and food safety worldwide. Severity of drought depends on the stage of crop development, the duration of stress period and the magnitude of drought. Drought affects membrane lipids, photosynthetic responses (Lauriano *et al*., 2000). The crop suffers by dry spells during critical pheno-phases like vegetative, flowering and post flowering stages affecting the physiological parameters severely and also yield substantially (Pallas *et al*. 1979 and 1988; Nautiyal *et al*. 1999). With this background, the present investigation was taken up to find out the physiological responses for improving yield characters under different stages of water stress.

Materials and Methods

A pot culture study was conducted in Rain Out Shelter (ROS), Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during *Kharif* , 2015. Red sandy loam soil was used for pot culture experiment. Soil mixture was prepared by using red soil, sand and vermicompost in the ratio of 3:1:1. Four groundnut bunch genotypes *viz.,*CO 7 (Drought resistant check), COGn 4 (Drought susceptible check) TMV 7 and TMVGn 13 (Farmers popularly grown varieties) were used with four treatments of control, Pre Flowering Drought (PFD), Flowering Drought (FD) and Post Flowering Drought (PoFD). Uniform watering was given up to 15 days to all treatments. Thereafter, watering was given up at every third day to control pots, to maintain the normal soil moisture percentage. Watering was with held 15-30 days for PFD, 35-50 days for FD, 75-90 days after sowing (DAS) for PoFD. Soil moisture content was observed once in two days by using ML2 Theta Probe moisture meter (Delta T. Sensor type). The experiment was laid out in Factorial Completely Randomized Design (FCRD) with three replications. Observations on various physiological parameters were taken during stress and after recovery period.

Physiological parameters

Leaf area was measured by using leaf area meter (LICOR Model 3100) and expressed as cm^2 $plant^{-1}$**.** Root traits *viz.,* root length (cm) and root volumes (cc) were measured. The relative water content (RWC) was estimated according to Barr and Weatherly (1962) and expressed as per cent. Osmotic potential was estimated by using a vapour pressure osmometer (Vapro Model 5520 Wescor Inc., Logan, UT, USA). The following conversion equation was used to compute osmotic potential (in Mpa)

*Corresponding author email: mahes43.tnau@gmail.com

[(Osmolality mmol kg^{-1}) x (0.0832) x (310)] / 10000

Osmotic adjustment was calculated as the difference between the turgid potential in the well watered treatment and stress treatment (Babu *et al*. 1999). Leaf gas exchange parameters *viz*., photosynthetic rate, transpiration rate and stomatal conductance were recorded using an advanced portable photosynthesis system (LI-6400 XT, Licor Inc, Nebraska, USA). The photosynthetic rate was expressed as µmol CO_2 $m^{-2} s^{-1}$, stomatal conductance and transpiration rate expressed as mmol H_2O $m^{-2} s^{-1}$

Yield parameters

Pod yield was determined by taking pod weight of five plants randomly selected from each treatment and replication and mean value was expressed as g $plant^{-1}$. Kernel yield was determined by taking kernel weight of five plants randomly selected from each treatment and replication and mean value was expressed as g $plant^{-1}$

The data collected on different characters from pot culture experiments were statistically analyzed in a FCRD (Factorial Completely Randomized Design) as suggested by Gomez and Gomez (1992). The critical difference (CD) was computed at five per cent probability.

Results and Discussion

Leaf area

Among the different stages of drought, 68.87 per cent reduction of leaf area was observed in PoFD imposed plants over control (Table 1) and lower reduction per cent was observed in FD (19.63%) during stress. After recovery, PFD imposed plants recorded less leaf area reduction per cent (20.78 %) than FD (27.50 %) and PoFD (69.37 %). Turner (1986) reported that, even small reduction in the leaf water potential caused considerable inhibition of enlargement. Thiyagarajan *et al*. (2009) found that, leaf area for irrigated treatment was greater than water stress treatment. Leaf area reduction per cent was low in PFD imposed plants during stress and also in recovery and often had higher leaf area than other stages of water stress (Jongrungklang *et al*., 2013). These responses are in agreement with findings of Puangbut *et al*. (2009).

Root length and root volume

The root traits *viz.,* root length (cm) and root volume (cc) were recorded under control in comparison with PFD, FD and PoFD during harvest. Positive relationship was obtained between root traits and PFD. Significant difference in root length and volume was observed among the genotypes and between treatments. Irrespective of the genotypes, PFD imposed plants recorded higher mean root length (45.18 cm) and volume (5.67 cc) than control (28.52 and 4.91cc) and depicted in Fig 1. FD and PoFD imposed plants recorded minimum root length and volume of 23.35 cm and 3.89 cc and 28.15 cm and 3.34 cc respectively. Among the genotypes, COGn 4 recorded lower root length and volume in all the stress treatments. The studies of Jongrungklang *et al*. (2013) clearly revealed that, the increase in root traits of root length and volume under water deficit condition and after recovery is related to better drought tolerance. Rapid root growth into the surrounding soil would have an adaptive advantage to utilize the soil water more completely. The findings of Reddy *et al.* (2003), Thiyagarajan *et al*. (2009) and Madhusudhan and Sudhakar (2014) in groundnut are in agreement with present investigation.

Table 1. Effect of water stress on leaf area (cm^2 $plant^{-1}$) of groundnut genotypes

Genotypes	At Stress						At Recovery					
	Pre flowering drought		Flowering drought		Post flowering drought		Pre flowering drought		Flowering drought		Post flowering drought	
	Control	Stress	Control	Stress	Control	Stress	Control	Recovery	Control	Recovery	Control	Recovery
CO 7	425.8	289.7	854.1	709.3	883.1	398.4	792.2	736.5	876.9	731.2	898.9	399.4
COGn 4	451.3	119.7	525.3	361.7	825.3	117.3	752.8	325.1	880.1	366.7	841.6	116.6
TMV 7	403.8	260.5	831.7	695.2	873.2	272.1	770.3	680.4	852.3	715.1	884.7	275.5
TMVGn 13	395.4	240.6	823.3	672.4	862.3	284.3	705.2	650.7	843.7	690.3	872.6	283.3
Mean	419.1	227.6	758.6	609.6	860.9	268.0	755.1	598.1	863.2	625.8	874.4	268.7
	G	S	T	GS	ST	GT	G	S	T	GS	ST	GT
SEd	4.21	3.65	2.98	7.30	5.16	25.98	18.37	15.91	12.99	31.83	22.50	25.98
CD (0.05)	8.47	7.34	5.99	14.68	10.38	52.25	36.95	32.00	26.12	64.00	45.25	52.25

Relative Water Content

Relative water content (RWC) represents the ability of the genotypes to retain tissue water under water stress and the genotypes retaining more tissue water are expected to perform better. RWC in the present investigations revealed that, all the stress treatments reduced RWC to a greater extent during all the stages of crop growth. During stress, compared to control, highest percent reduction was observed in PoFD (75 %) followed by FD (42%) but plants under PFD recorded lowest reduction (38 %) and data is presented in Table 2. After re-watering, plants under PFD and FD recovered immediately but PoFD has not recovered positively. Patel and Berlyn (1983) found that, the RWC of groundnut leaf declined with decrease in soil water potential from -0.05 to -2.0 MPa. Babu and Rao (1983) reported that, non stressed plants recorded more RWC and

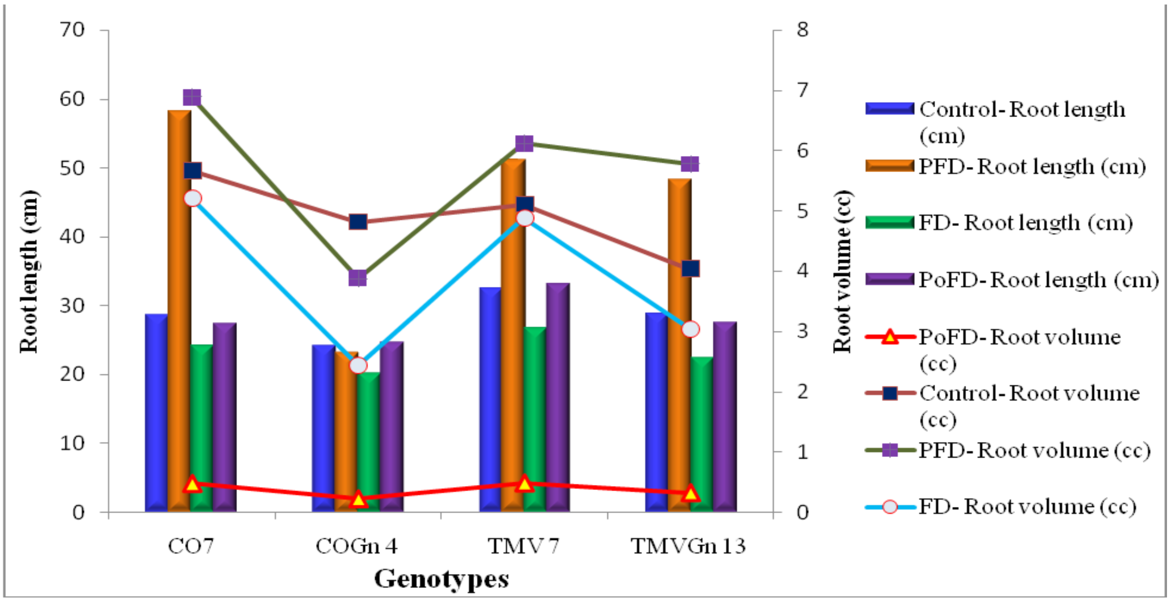

Fig.1. Effect of water stress on root length (cm) and root volume (cc) of groundnut genotypes

stressed plants have lower RWC. All the genotypes and at all the stages of drought were absolutely affected by drought and declined RWC was observed by Jongrungklang *et al*. (2013). Vurayai *et al.* (2010) found that, pod filling stage had the lowest RWC amongst the stress treatments and did not recover fully even after re watering. This may be because the plants were on their last stage of the growth and RWC is a function of many variables including plant age.

Table 2. Effect of water stress on relative water content (%) of groundnut genotypes

Genotypes	At Stress						At Recovery					
	Pre flowering drought		Flowering drought		Post flowering drought		Pre flowering drought		Flowering drought		Post flowering drought	
	Control	Stress	Control	Stress	Control	Stress	Control	Recovery	Control	Recovery	Control	Recovery
CO 7	93.92	67.17	97.51	55.32	86.77	49.97	95.44	86.38	92.12	77.39	83.47	52.47
COGn 4	90.62	43.98	96.32	28.59	81.41	18.32	93.41	71.46	90.47	31.61	69.28	19.03
TMV 7	92.51	61.38	96.77	42.32	82.17	38.71	94.79	79.80	92.76	71.82	78.51	39.97
TMVGn 13	91.33	55.71	94.38	37.97	79.56	32.11	93.34	76.11	91.78	66.34	75.92	32.98
Mean	92.10	57.06	96.25	41.05	82.48	34.78	94.25	78.44	91.78	61.79	76.80	36.11
	G	S	T	GxS	SxT	GxT	G	S	T	GxS	SxT	GxT
SEd	0.534	0.462	0.377	0.925	0.654	0.755	0.571	0.494	0.404	0.989	0.699	0.808
CD (0.05)	1.074	0.930	0.759	1.860	1.315	1.519	1.149	0.995	0.812	1.990	1.407	1.624

Osmotic adjustment and osmotic potential

Osmotic adjustment (OA) in plants subjected to drought stress occurs by the accumulation of high concentrations of osmotically active compounds in order to lower the osmotic potential (Rontein *et al.,* 2002). In the present investigation, higher OA with lower osmotic potential (OP) was found in PFD compared to FD and PoFD imposed plants during stress and also in recovery. CO 7 recorded highest OA values and lowest in OP values at PFD. Hide Omae (2012) reported that, OA may minimize the harmful effects of drought delay dehydrative damage in drought stressed plants by maintenance of cell turgor and physiological processes (Taiz and Zeiger, 2006). In the present study also, PFD produced more root length and root volume which can also maintain the cell turgor. This might be the reason for attaining high

OA with lower OP at PFD by CO 7 followed by TMV 7 and TMVGn 13. The present study confirms earlier findings of Rontein *et al.,* 2002 and Taiz and Zeiger, 2006 (Fig. 2). The photosynthetic rate was highly reduced under stress with the mean value of 15.28 µmol of CO_2 in PFD followed by PoFD (7.79) and FD (2.81).

Table 3. Effect of water stress on transpiration rate (mmol H_2O m^{-2} s^{-1}) of groundnut genotypes

Genotypes	At Stress						At Recovery					
	Pre flowering drought		Flowering drought		Post flowering drought		Pre flowering drought		Flowering drought		Post flowering drought	
	Control	Stress	Control	Stress	Control	Stress	Control	Recovery	Control	Recovery	Control	Recovery
CO 7	4.52	1.47	6.78	2.24	5.21	3.32	5.39	4.91	6.21	5.57	4.98	2.75
COGn 4	4.66	2.01	6.33	3.07	5.10	4.35	5.29	4.79	6.25	4.07	4.79	1.21
TMV 7	4.33	1.42	6.10	2.56	4.73	3.47	4.96	3.24	6.10	4.58	4.09	2.17
TMVGn 13	4.18	1.19	5.93	2.61	4.56	3.77	4.88	3.10	5.91	4.26	4.11	1.96
Mean	4.42	1.53	6.29	2.62	4.90	3.72	5.13	4.01	6.12	4.62	4.49	2.02
	G	S	T	GxS	SxT	GxT	G	S	T	GxS	SxT	GxT
SEd	0.033	0.020	0.017	0.058	0.041	0.047	0.024	0.029	0.017	0.041	0.029	0.034
CD (0.05)	0.067	0.041	0.034	0.117	0.083	0.096	0.048	0.059	0.034	0.083	0.059	0.068

Leaf gas exchange parameters

After re-watering, plants under PFD recorded photosynthetic rate (48.67) equal to control (47.79) and on par with each other but drastic reduction was observed under FD (33.89) and PoFD (17.93) in all the genotypes. Among the genotypes, CO 7 performed better in all the stages of stress and also in recovery. Poorest performance was observed in COGn 4 especially during stress at all the stages (Fig.3). The photosynthetic rate was highly reduced under stress in PFD followed by PoFD and FD. During recovery, PFD recorded photosynthetic rate equal to control but drastic reduction was observed under FD and PoFD in all the genotypes. Stomatal conductance also followed in same trend as that of photosynthetic rate. A decreasing trend in transpiration rate was observed during stress in tolerant and increasing trend was observed at susceptible genotypes in all the stages of drought (Table 3). During stress, 88, 40 and 40 per cent reduction was observed in transpiration rate under PFD, FD and PoFD respectively. Among the genotypes, more transpiration reduction was observed in CO 7 with the value of 1.47, 2.24, 3.32 mmol of H_2O m^{-2} s^{-1} at PFD, FD and PoFD respectively during stress condition. Plants under PFD recovered from stress completely and recorded 5.11 mmol of H_2O m^{-2} s^{-1} which was on par with control.

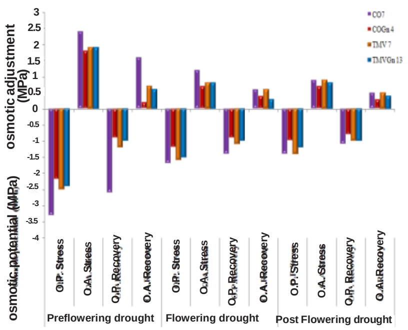

Fig. 2. Effect of different stages of water stress on osmotic potential (MPa) and osmotic adjustment (MPa) of groundnut genotypes

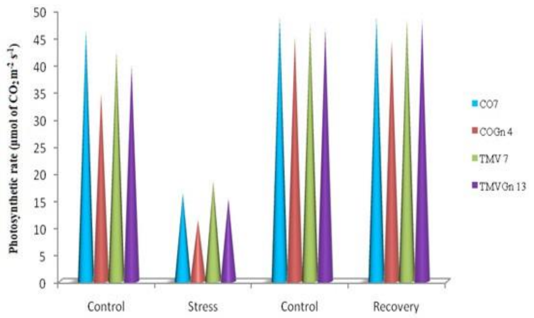

Fig. 3. Effect of water stress on Photosynthetic rate (µmol of CO_2 m^{-2} s^{-1}) of groundnut genotypes in Pre flowering drought

Among the stresses, PoFD performed very poorly to reduce the transpiration rate under water deficit conditions. COGn 4 performed poorly even after recovery compared to other genotypes. Among the stress, PoFD stressed plants not recovered even after re-watering. Reddy *et al*. (2003) reported that, canopy photosynthesis is reduced by moisture stress due to reduced stomatal conductance. Vurayai *et al*. (2010) discussed that the decreased stomatal conductance resulting in lower net carbon dioxide assimilation rate, lower intercellular carbon dioxide and lower chloroplastic carbon dioxide tension reduces photosynthetic efficiency. Plants stressed during the vegetative stage completely recovered their stomatal conductance after re-watering. Recovery of stomatal conductance may result in increased carbon dioxide diffusion into the leaves to attain higher photosynthetic rates.

Yield and yield components

The performance of groundnut genotypes on pod and kernel yield is depicted in Fig.4. FD and PoFD reduced the pod and kernel yield in all the genotypes over control. The decrease was 56.0 and 67.63 per cent under FD and 54.76 and 71.17 per cent in PoFD of pod and kernel yield respectively. All the genotypes recorded more pod and kernel yield under PFD compared to control except CoGn 4. More pod and kernel yield of 21.18 and 19.72 in CO 7, 20.11 and 14.99 in TMV 7 and 18.67and13.54 g plant $^{-1}$ in TMVGn 13 were recorded at PFD than control. With respect to pod and kernel yield, significant variation was observed within the genotypes and between the treatments. PFD showed differential responses for the increasing pod yield and improved the assimilate portion to promote more growth and development. Similar findings were also observed in the present study under PFD. The spectacular increase in physiological traits after rewatering in PFD might be the major reasons for recording higher pod and kernel yield than control. Water stress experienced during the flowering stages of groundnut significantly reduced pod yield. However, the plants with stresses during the flowering period did not regain even after rewatering (Vurayai *et. al.,* 2010). Also, they have reported that, flowering drought reduced photosynthetic efficiency and dry matter production and may have negative impact on plant growth and yield. The decrease per cent of pod and kernel yield was recorded under FD and PoFD. FD and PoFD experienced stress during flowering and pod filling stage irrespective to genotypes causes severe effects on physiological parameters. The root zone water content directly affect the plant water status, photosynthesis and hence the assimilate supply to the developing pegs to pods. However, water content in pegging and pod formation at 5cm depth could affect reproductive growth independent of root zone moisture content (Wright and Rao, 1994). These findings corroborated with the present study results. Among the genotypes, irrespective of the stress treatments, CO7 recorded more pod and kernel yield by maintaining productive physiological traits under all the stress treatments.

Conclusion

The present study clearly indicated that, groundnut genotypes *viz*., CO7, TMV7 and TMVGn13 performed well in PFD than control. The better physiological performance of genotypes under PFD might be due to two mechanisms during water deficit period. The first mechanism is that, there is an increase of root growth in lower soil layers that still have high soil moisture during drought period to maintain the plant water status and it reduce stomatal conductance, transpiration water loss and leaf area. The second mechanism is improved stomatal conductance and photosynthetic rate after rewatering.

References

Babu, V.R. and Rao, D.V.M. 1983. Water stress adaptations in the groundnut (*Arachis hypogaea L.*) foliar characteristics and adaptations to moisture stress. *Plant Physiol and Biochem*, **10**: 64–80.

Babu, R.C., Pathan, M.S., Blum, A. and Nguyen, H.T. 1999. Comparision of measurement methods of osmotic adjustment in rice cultivars. *Crop Sci*. **39**: 150-158.

Barr, H.D. and P.E. Weatherley. 1962. Are-examination of the relative turgidity technique for estimating water deficit in leaves. Australian Journal of Biological Science, 15: 413– 428.

Gomez, K.A. and A.A. Gomez. 1992. Statistical procedure for agricultural research. New York, Wiley Inter-Science Publications.

Hide Omae. 2012. Adaptation to High Temperature and Water Deficit in the Common Bean (*Phaseolus vulgaris* L.) during the Reproductive Period. *J. of Bot.,* **40**: 213–216.

Jongrungklang, N., Toomsan, B., Vorasoot, N., Jogloy, S., Boote, K.J., Hoogenboom, G. and Patanothai, T. 2013. Drought tolerance mechanisms for yield responses to pre-flowering drought stress of diverse peanut genotypes. *Field Crops Res.,* **144**: 34-42.

Lauriano, J.A., Lidon, F.C., Carvalho, C.A., Campos, P.S. and Matos, M.D.C. 2000. Drought effects on membrane lipids and photosynthetic activity in different peanut cultivars. *Photosyn., (Prague)*, **38**: 7-12.

Madhusudhan, K.V. and Sudhakar, C. 2014. Morphological responses of a high yielding groundnut cultivar (*Arachis hypogaea* L. cv. K-134) under water stress. *Indian J. Pharm and Biol. Res*, **2(1)**: 35-38.

Nageswara Rao, R.C., Williams, J.H., Sivakumar, M.V.K. and Wandia, K.D.R. 1988. Effect of water deficit at different growth phase of peanut. II yield response. *Agron. J.,* **80**: 431-438.

Nautiyal, P.C., Ravindra, V. Zala, P.V. and Joshi, Y.C. 1999. Enhancement of yield in groundnut following the imposition of transient soil-moisture stress during the vegetative phase. *Experi. Agric.,* **35**: 371-385.

Pallas, J.E., Stansell, J.R. and Koske, T.J. 1979. Effects of drought in florunner peanuts. *Agron. J.*, **71**: 853-857.

Patel, K.R. and G.P. Berlyn. 1983. Cytochemical investigations on multiple bud formation in tissue cultures of Pinus coulteri. **Canada Journal of Botany, 61:** 575-585.

Puangbut, D., Jogloy, S., Vorasoot, N., Akkasaeng, C., Kesmala, T. and Patanothai, A. 2009. Variabilty in yield responses of peanut (*Arachis hypogaea* L.) genotypes under early season drought. *Asian J. Plant Sci.,* **8(4)**: 254-264.

Reddy, T.Y., Reddy, V.R. and Anbumozhi, V. 2003. Physiological responses of groundnut (*Arachis hypogaea* L.) to drought stress and its amelioration: a critical review. *Plant Growth Regul.,* **41**: 75-88.

Rontein, D., Basset, G. and Hanson, A.D. 2002. Metabolic engineering of osmoprotectant accumulation in plants. *Metabolic Engineering,* **4**: 49-56.

Taiz, L. and E. Zeiger. 2006. Stress physiology. **In:** Taiz, L., E. Zeiger, (Eds.), Plant Physiology., 4th edn. Sinauer Associates, Inc., Sunderland, MA, 671–681.

Thiyagarajan, G., Rajakumar, D., Kumaraperumal, R. and Manikandan, M. 2009. Physiological response of groundnut to moisture stress. *Agricul. Rev.,* **30 (3)**: 192-198.

Turner, N.C. 1986. Adaptation to water deficits: a changing perspective. Australian Journal of Plant Physiology, **3:** 175–190.

Vurayai, R., V. Emongor and B. Moseki. 2010. Physiological Responses of Bambara Groundnut (*Vigna subterranea* L. *Verdc*) to Short Periods of Water Stress During Different Developmental Stages. *Asian Journal of Agricultural Sciences,* **3(1):** 37-43.

Wright, G.C. and R.C. Nageswara Rao. 1994. Peanut water relations. In: Smartt J (ed) The groundnut crop, Chapman & Hall publishing.

Received after revision : December 28, 2016; Accepted : December 30, 2016