RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
49 (3) 270-279, 2017

EFFECTS OF TERMINAL DROUGHT ON GROWTH, YIELD AND YIELD COMPONENTS IN VALENCIA PEANUT GENOTYPES

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SUMMARY

Plant development and pod yield in peanut (*Arachis hypogaea* L.) can be gravely affected by water deficits. Insufficient water during the pod formation has been reported to cause the largest reduction in pod yield in Virginia and Spanish peanut, however this information on Valencia peanut is limited. The aim of this work was to examine effects of terminal drought on growth, yield and yield components of Valencia peanut genotypes. A greenhouse experiment was conducted at the Field Crop Research Station of Khon Kaen University, Khon Kaen province during July to October 2016. A 2 × 9 factorial experiment consisting of two water levels (full irrigation and drought stress) and nine peanut genotypes was set up in a randomized complete block design (RCBD) with four replications. Two water levels were assigned in factor A and nine peanut genotypes in factor B. Plant growth data (biomass, leaf dry weight, stem dry weight and root dry weight) yield and yield components (pod yield, number of mature pods per plant, seeds number per pod and seed size) were recorded at harvest. Under full irrigation, all peanut genotypes performed better in terms of plant parts and yield traits. The PI 536121 performed better for biomass, shoot dry weight, pod dry weight and root dry weight. The results also indicated high performance of ICG 14127 for pod yield per plant and a number of mature pods per plant under terminal drought stress.

Key words: Groundnut, end season drought, water stress, yield, yield components

Key findings: Drought stress decreased biomass, pod yield, number of mature pods per plant of Valencia peanut genotypes. The ICG1412 performed well under drought conditions.

Manuscript received: March 23, 2017; Decision on manuscript: July 1, 2017; Manuscript accepted: July 27, 2017.

Communicating Editor: Naqib Ullah Khan

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an annual legume crop, most popular oilseed in the world and one of the most important crops that helps small scale producers in getting significant revenue in developing countries (Wynne and Beute, 1991; Reddy *et al*., 2003). Peanut is grown for oil and food (Arruda *et al*., 2015). Under arid and semi-arid environments, it occupies more than half of the global production area of peanut (Reddy *et al*., 2003; Furlan *et al*., 2012). In these regions, drought is the major constraint on peanut production (Wright and Nageswara Rao, 1994). Even under irrigation, peanut is frequently exposed to drought because the irrigated water is not sufficient for crop growth (Painawadee *et al*., 2009).

Drought is the most pervasive factor that causes a substantial reduction in peanut performance in terms of plant survival, growth, productivity, economic, yield and nutritional quality of seed proteins (Aminifa *et al*., 2013; Dinh *et al*., 2013). The duration and intensity of drought, and the growth stage at which the stress occurs have large effects on peanut yield reduction (Awal and Ikeda, 2002). Puangbut *et al*. (2009) reported that drought stress at the vegetative phase or pre-flowering stage had no detrimental effect on pod yield and many cases were found to increase yield. On the other hand, Girdthai *et al*. (2010) reported that water deficit stress occurring during the pod formation and seed filling phase has been observed to cause the largest reduction in peanut pod yield. Therefore, selection of varieties for high yield under drought environment is the major criterion for improving peanut productivity. However, pod yield per plant, number of mature pods per plant, and 100-seed weight are important characters for pod yield under drought stress (Aminifar *et al*., 2013; Jeyaramraja and Woldesenbet, 2014).

Similar studies indicated that drought at late season reduced pod yield in Virginia type more severely than in the Spanish type. The drought also reduced the number of pods per plant, number of seeds per pod and seed size leading to yield reduction (Wright *et al*., 1991). At present, the information on the effect of terminal drought on yield and yield components in Valencia type peanut has not been clearly investigated. To reduce yield loss from drought, development of peanut genotypes with resistance to water deficit at the end-of-the-season-stage is an important breeding goal to alleviate drought effects on peanut yield. Therefore, the present study was undertaken to examine the effects of terminal drought on growth, yield and yield components of Valencia peanut genotypes.

MATERIALS AND METHODS

The pot experiment was conducted in an open-sided greenhouse during July to October 2016 under high humidity and high temperature conditions at the Field Crop Research Station of Khon Kaen University, located in Khon Kaen province (latitude 16º28´ ºN, longitude 102º 48´ºE, and 200 m above mean sea level (msl).

Experimental procedures and plant material

Nine peanut genotypes comprising eight Valencia type (ICG 10092, ICG 10890, ICG 14127, ICG 6888, KK4, PI 536121, ICG 14106 and PI 365564) and one Spanish type (ICGV 98324) were used in this study. ICGV 98324 was used as a drought resistant check. According to Koolachart *et al*. (2013), ICGV 98324 has high root length density in deeper soil layer, high water use efficiency (WUE) and high relative water content (RWC). This genotype was procured from the International Crops Research Institute for the Semi-arid Tropics **(**ICRISAT) where it was identified as a drought resistant genotype as it produced high total biomass and pod yield in screening tests under drought conditions (Nageswara Rao *et al*., 1992; Nigam *et al*., 2002, 2005).

The 2×9 factorial experiment in a randomized complete block design (RCBD) with four replications was conducted, and two soil moisture levels consisting of full irrigation (FI) and drought stress at 60 days after emergence (DAE) until harvest were assigned as factor A, and 9 peanut genotypes as factor B.

Pot and soil preparation

The peanut seed was grown in 360 cylindrical pots with inner diameter 24 cm and 70 cm in height. The experimental unit consisted of 5 pots and there were 90 pots in each replication. Soil samples were taken from the field at 2 points at the depths of 0–5 cm, 25–30 cm and 45–50 cm and oven dried at 105°C for 72 h. The dry soil samples were weighted and calculated the bulk density. The soil was sun dried, and, after drying, two soil samples were taken for laboratory analysis to determine the physical and chemical proprieties.

The dry soil was exposed to the sun to ensure that it was dry and had uniform soil moisture before the soil was loaded into the containers. The pot was filled with dry soil of 42 kg to 10 cm from the top, which resulted in a soil volume of 0.029 m^3 for each pot. Soil was separated into four layers with the same volume (10.5kg) to create uniformity (1.55g/cm^3) of bulk density. After filling the soil, the pot was covered with a white plastic bag to protect them from the rain before planting.

Plant material preparation

Seed in this experiment was obtained from seed multiplication plot previously planted at the Field Crop Research Station of Khon Kaen University, located in Khon Kaen province, Thailand. Before planting, the seed was treated with captan (3a, 4, 7, 7a-tetrahydro-2[(trichloromethyl) Thio]-1H-isoindole-1, 3 (2H)-Dione) at the rate of 5 g per kg seed to control seed rot caused by *Aspergillus niger*.

Crop management

Four seeds were planted in each pot and the seedlings were then thinned to two plants per pot at 14 DAE. Rhizobium inoculation with a water diluted commercial peat-based inoculum of *Bradyrhizobium* (mixture of strains THA 201 and THA 205; Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand) was applied to the soil in containers at the rate of 5 g per pot just after planting. In each pot, potassium fertilizer as muriate of potash (KCl) at the rate of 0.39 g per pot was applied at 7 DAE. Gypsum ($CaSO_4$) at the rate of 1.43 g per pot was incorporated into the soil at 30 DAE to supply calcium for development of pod and seed. Carbofuran (2, 3-dihydro-2, 2- dimethylbenofuran-7-ylmethylcarbamate 3% granular) was applied to the soil prior planting and at the pod setting stage to control soil insects. Pests and diseases were controlled by weekly applications of carbosulfan [2,3-dihydro-2,2-imethylbenzofuran-7-yl methylbamate 20% w v⁻¹water soluble concentrate] at 2.5 L per ha, methomyl [S-methyl-N(methylcarbomoyl) oxy thioacetimidate 40% soluble powder] at 1.0 kg per ha and carboxin [5, 6-dihydro-2methyl-1, 4-oxath-ine-3-carboxanilide 75% wet able powder] at 1.68 kg per ha. The experiment was conducted in the pot under greenhouse condition and weeds were controlled by hands.

Prior to planting, water was applied in each pot to obtain high soil moisture to facilitate uniform emergence. The amount of water that was applied was based on the water loss from the soil surface of each pot. The soil moisture for all pots was maintained at full irrigation until 60 DAE. For non-stress, soil moisture was maintained at full capacity level until harvest. For the drought stress treatment, irrigation was stopped after 60 DAE and soil moisture was allowed to decrease gradually to approximately 1/3 available water at 80 DAE and maintained at this level until harvest. Water was applied regularly to control soil moisture contents at predetermined levels. To maintain the soil moisture contents at full-irrigated and drought stressed levels, measured quantities of water losses were replenished to the respective pots after taking account of plant water requirement, which was calculated using the method described by Doorenbos and Pruitt (1992):

$$ETcrop = ETo \times Kc$$

Where, ETcrop is the crop water requirement (mm/day), ETo = evaporation of the reference plant under specified treatment calculated by pan evaporation method, and Kc = a crop water requirement coefficient for peanut, which varies depending on variety and growth stage (Doorenbos and Kassam, 1986). The water supplied to surface is the water requirement used by the crop plant.

Data collection

Weather parameters

Weather data were obtained from the nearest meteorological station located at 50 m away from the greenhouse. Maximum and minimum air temperature (ºC) evaporation (mm), relative humidity (RH %) and rainfall (mm) were recorded daily from planting until harvest.

Soil properties

The physical and chemical properties of the soil were determined before filling the pots. Soil samples were taken from 2 points at the depths of 0–5 cm, 25–30 cm and 45–50 cm, and the bulk of all soil samples was analyzed to determine the physical properties such as sand, silt and clay (%) and the chemical properties such as soil pH, electrical conductivity, cation exchange capacity, organic matter, total nitrogen, available phosphorus, exchangeable and potassium.

Soil moisture content

The soil moisture content in the pot was measured at the depth of 0–60 cm using micro auger at 75, 90 DAE and final harvest for determining the soil moisture in the pots. The soil moisture was calculated using the formula below:

Soil moisture = [(fresh weight - dry weight)/ (dry weight)] × 100%

Relative Water content (RWC)

RWC was used to evaluate the plant water status and it was measured at 10:00 – 11:30 am. The second fully expanded leaf from the top of the main stem from each pot was taken at 60, 75, 90 DAE. The samples were put into sealable plastic bags and immediately stored in ice box to prevent moisture loss. Fresh weight was measured as soon as possible once the samples were transported to the laboratory, and, then, the leaflets were immersed into distilled water for 8 h to determine saturated leaf weight. The leaflets were transferred into paper bags and oven dried at 80 ºC for 48 h or until constant dry weight. Finally, RWC was determined using the formula suggested by Turner (1986):

RWC (%) = [(fresh weight – dry weight)/ (saturated weight – dry weight)] × 100%

Biomass (BM), pod yield, yield components and shelling percentage

At final harvest, total biomass, shoot dry weight, root dry weight, pod yield and yield components were obtained from 4 plants in two pots. For the shoot, the data were recorded for stem dry weight and leave dry weight. In underground parts, pod dry weight, root dry was recorded. Fresh weights of the different plant parts were determined immediately after harvest and the samples were oven-dried at 80 ºC for 48 h or until a constant weight to determine dry weight of all plant parts. The root shoot ratio was calculated. The pods were separated for air-dried to approximately 8% moisture content and pod dry weight was determined. Pods were shelled. Yield components such as pod number per plant, seed number per pod and 100 seed weight were recorded. Seeds number per pod was averaged from mature pods obtained from plants in two pots. Weight of 100 seeds (g) was obtained from 100 seeds. Shelling percent was calculated using the following formula:

Shelling (%) = [seed weight/ pod weight] × 100.

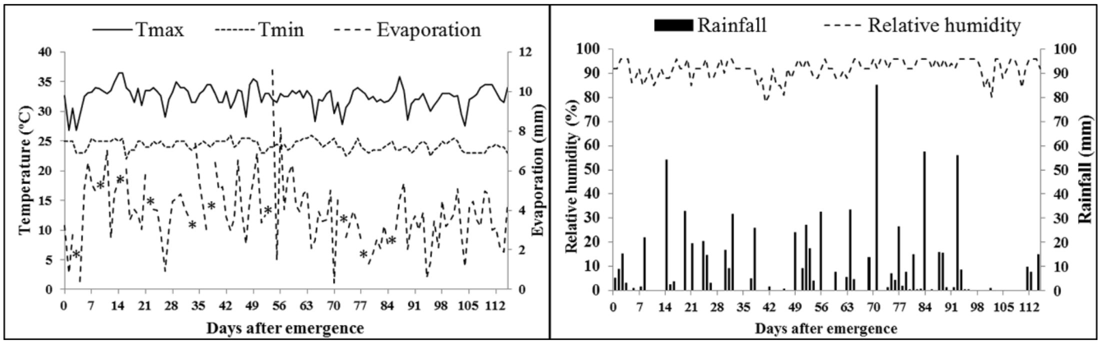
Data analysis

Analysis of variance was performed for all characters according to a 2×9 factorial experiment in a randomized complete block design (Gomez and Gomez, 1984). All calculations were accomplished using Statistix8 analytical software (Statistix8, 2003). The least significant difference (LSD) was used to detect significant differences among means at 5% probability level ($P \leq 0.05$).

RESULTS

Weather data

The means for minimum and maximum air temperatures during the crop cycle were 22–37



* = data not available

Figure 1. Maximum and minimum air temperature (ºC), evaporation (mm), relative humidity (RH %) and rainfall (mm) during the crop growth period stage of 9 peanut genotypes grown under full irrigation and drought stress.

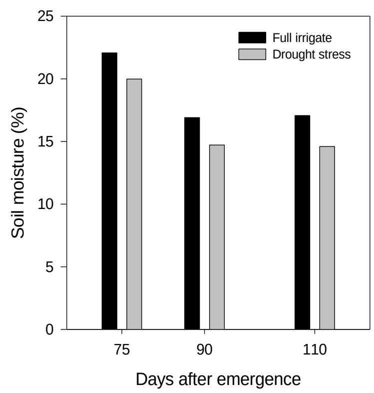


Figure 2. Soil moisture content at the 75, 90 days after emergence and at harvest (110) of 9 peanut genotypes grown under full irrigated and water stress.

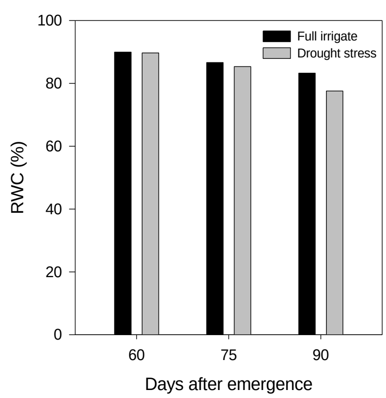


Figure 3. Relative water content (RWC) at 60, 75 and 90 days after emergence of 9 peanut genotypes grown under full irrigation capacity and water stress.

ºC (Figure 1). The values of relative humidity in this experiment ranged between 90 and 96%. The experiment was conducted in a greenhouse and rainfall did not affect the plant growth, but temperature and humidity did. The daily pan evaporation of peanut plant was 3.86 mm.

Soil physical and chemical properties

The soil used in this experiment is Yasothon soil series, which is characterized as a sandy loam soil with pH of 5.62, Ec of 0.081 dS per m, low organic matter, low nitrogen, high phosphorus and medium potassium (Table 1).

Soil moisture content

Soil moisture content was measured using micro auger. Water was replenished to the pots on the soil surface based on crop water requirement. Soil moisture content for stressed treatment reduced gradually from 75 and 90 DAE to final harvest (110 DAE) (Figure 2).

Relative water content (RWC)

Stressed and well-irrigated treatments were similar for RWC at 60 and 75 DAE (Figure 3). The water treatments were clearly different at 90 DAE as RWC was greatly reduced in stressed plants. Non-stressed peanut had higher RWC than that of the drought stressed peanut.

Biomass production

The interactions between peanut genotype and water regime were not significant for total biomass, leaf dry weight, stem dry weight, pod dry weight, root dry weight and root/shoot ratio (data not reported). The means of the peanut varieties were averaged from two water regimes. Water regimes were significantly different ($P \leq 0.05$) for biomass production (Table 2). Full-irrigated treatment (30.08 g/plant) was significantly higher than stressed treatment (26.16 g/plant). In this study, peanut genotypes also differed for biomass production ranging from 25.09 g/plant to 34.29 g/plant. PI 536121 produced maximum value (34.29 g/plant), whereas KK4 produced minimum value (25.09 g/plant).

Leaf dry weight (LDW)

Water regimes were significantly different ($P \leq 0.05$) for leaf dry weight, ranging from 5.65 g/plant for drought stress to 7.86 g/plant for full irrigation (Table 2). Peanut genotypes were also significantly different ($P \leq 0.05$) for LDW. PI 536121 had the highest leaf dry weight (9.99 g/plant), whereas KK4 had the lowest LDW (4.76 g/plant).

Stem dry weight (SDW)

Water regimes were not significantly different for stem dry weight, but peanut genotypes were significantly different ($P \leq 0.05$) for this trait (Table 2). PI 536121 had the highest stem dry weight (16.67 g/plant), whereas the ICGV 14127 had the lowest stem dry weight (11.39 g/plant).

Root dry weight (RDW)

Peanut plants grown under two water regimes were not significantly different for root dry weight (Table 2). Peanut genotypes were significantly different ($P \leq 0.05$) for this trait and root dry weights among peanut genotypes ranged from 3.70–5.90 g/plant. PI 5336121 showed high RDW (5.90 g/plant), while ICG10092 had lowest RDW (3.70 g/plant).

Root/shoot ratio

Peanut plants grown under well-irrigated and drought conditions were not significantly different for root/shoot ratio (Table 2), and peanut genotypes were not significantly different for this trait.

Pod yield (PY)

The interaction between genotype and water regime was not significant for pod yield (data not reported). Means of peanut genotypes were averaged from two water regimes. Water regimes and genotypes were significantly different ($P \leq 0.05$) for pod yield.Peanut has grown under irrigation gave a significantly higher pod yield (3.77 g/plant) than did peanut grown under drought (2.52 g/plant) (Table 3).

Table 1. Chemical and physical properties of the soil in pot experiment at Field Crop Research Station at KhonKaen University.

Soil sample						
pH (1:1 H20)	EC (1:5 H_2O) (dS m^{-1}) at 25° C	CEC C mol kg^{-1}	Organic Matter (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (mg kg^{-1})
5.62	0.081	10.27	0.758	0.036	11.85	53.54
Particle size (USDA system)						
% Sand (2.0–0.05 mm)		% Silt (0.05–0.002mm)		% Clay (<0.002 mm)	Texture Class	
69.93		18.07		12	Sandy loam	

Table 2. Biomass, leaf dry weight, stem dry weight, root dry weight and root/shoot ratio of 9 peanut genotypes grown under two water regimes.

Treatments	Biomass (g $plant^{-1}$)	Leaf dry weight (g $plant^{-1}$)	Stem dry weight (g $plant^{-1}$)	Root dry weight (g $plant^{-1}$)	Root/shoot ratio
Water Regime					
Irrigated	30.08 a[1]	7.86 a	13.84 a	4.61 a	0.23 a
Drought Stress	26.16 b	5.65 b	13.49 a	4.50 a	0.22 a
Varieties					
ICG10092	25.25 c	5.02 de	12.03 c	3.70 c	0.22a
ICG 10890	28.37 b	6.17 b–e	14.76 ab	4.60 bc	0.22 a
ICG14127	27.46 bc	5.84 cde	11.39 c	3.76 c	0.23 a
ICG6888	27.85 bc	6.55 bcd	14.74 ab	4.47 bc	0.21 a
PI536121	34.29 a	9.99 a	16.67 a	5.90 a	0.23 a
KK4	25.09 c	4.76 e	12.81 bc	4.68 bc	0.24 a
ICG14106	26.49 bc	7.39 bc	12.19 c	4.16 bc	0.21 a
PI365564	27.64 bc	7.81 b	13.07 bc	4.63 bc	0.23 a
ICGV 98324	29.74 b	7.23 bc	15.33 a	5.06 ab	0.24 a
CV %	17.35	24.9	15.13	24.42	39.47

[1]Means with the same letter(s) in each column of each factor are not significantly different by LSD at $P \leq 0.05$.

Peanut genotypes were also significantly different ($P \leq 0.01$) for this trait. ICG14127 had the highest pod yield (6.47 g/plant) followed by ICG10092 (4.50 g/ plant), while PI 536121 had the lowest pod yield (1.73 g/ plant).

Shelling percentage

Peanut plants grown under well-irrigated and drought stress conditions were not significantly different for shelling percentage (Table 3). Peanut genotypes were significantly different ($P \leq 0.05$) for shelling percentage ranging from 55.07% (PI 536121) to 70.45% (ICG 14127).

Number of mature pod per plant

Peanut plants grown under well-irrigated and drought conditions were significantly different ($P \leq 0.05$) for number of mature pods per plant (Table 3). Peanut plants grown under well-irrigated condition had 11.3 pods per plant which was significantly higher than 7.2 pods per plant grown under drought stressed conditions. Peanut genotypes were significantly different ($P \leq 0.05$) for this trait. ICG 14127 had the highest number of mature pod (15.75), whereas PI 536121 had the lowest number of mature pod per plant (5.6).

Seed number per pod

The peanut plants grown under well-irrigated and drought stress conditions were not

Table 3. Pod yield (PY), shelling percentage, number of mature pod per plant, seed number of per pod and seed size of 9 peanut genotypes grown under two water regimes.

Treatments	Pod yield (g plant^{-1})	Shelling (%)	Number of Mature pods plant^{-1}	Seeds number of pod	Seed Size (g 100 seeds^{-1})
Water Regime					
Irrigated	3.77 a[1]	65.59 a	11.33 a	1.68 a	28.32 a
Drought Stress	2.52 b	60.54 a	7.19 b	1.52 a	28.05 a
Varieties					
ICG10092	4.50 b	67.63 abc	13.5 a	1.72 ab	31.47 a
ICG 10890	2.84 cd	62.78 abc	7.56 bcd	1.78 ab	26.83 ab
ICG14127	6.47 a	70.45a	15.75 a	1.99 a	31.76 a
ICG6888	2.09 d	58.65 abc	7.19 cb	1.64 ab	30.12 a
PI536121	1.73 d	55.02 c	5.63 d	1.71 ab	28.14ab
KK4	3.65 bc	68.82 abc	8.94 bc	1.44 bc	27.41 ab
ICG14106	2.75 cd	69.30 ab	7.81 bcd	1.55 abc	27.67 ab
PI365564	2.13 d	59.29 abc	7.00 cb	1.51 bc	26.10 ab
ICGV 98324	2.12 d	55.63 bc	10.00 b	1.15 c	24.14 b
CV %	32.1	22.23	29.38	19.73	18.12

[1]Means with the same letter(s) in each column of each factor are not significantly different by LSD at $P \leq 0.05$.

significantly different for seed number per pod, but Valencia peanut genotypes showed significantly different ($P \leq 0.05$) for this trait. ICG 14127 showed the highest seeds number per pod (1.90 g/pod), while ICGV 98324 had the lowest seeds number per pod (1.15g/pod).

Seed size (100 seed weight)

Peanut plants grown under well-irrigated and drought conditions were not significantly different for seed size. Peanut genotypes were significantly different ($P \leq 0.05$) for seed size (Table 3). ICGV 98324 had a smallest seed size.

DISCUSSION

High air temperature during the growing season in the experiment could be a major factor for rapid depletion of soil moisture content in the stressed treatment. Water deficit leads to severe yield loss in peanut due largely to the reduction in number of mature pods. Drought stress occurring at pod filling stage is the most severe drought event, while drought at early growth stages had the lowest effect on pod yield (Puangbut *et al*., 2009).

In this study, peanut genotypes were significantly different for most traits under investigation. Drought stress reduced biomass production at harvest in both total biomass (13.03%) and other plant parts, whereas well-irrigated treatment had high total biomass and biomass of other plant parts because supplied water was sufficient for crop growth during the growing phase. The results showed that drought stress reduced biomass production and the differences in biomass production indicated genetic variability in the tested peanut genotypes (Nageswara Rao *et al*., 1989).

The results in our research on Valencia peanut indicated that PI 536121 had high biomass production, but it had low pod yield under drought. The results in this study were not in agreement with those in previous studies. Nageswara Rao *et al*. (1988) found high biomass production was associated with high pod yield. The difference in the results of the two studies could be due to the differences in materials (peanut types) used and the differences in experimental conditions.

Drought reduced leaf dry weight (28.12%). The differences in leaf dry weight among peanut genotypes were observed, indicating variation in these peanut genotypes for these traits. At harvest, most peanut genotypes were defoliated.

The current study demonstrated that drought reduced pod yield (33.16%) and number of mature pods per plant (36.54%). The results indicated that the reductions in the number of mature pods per plant were the main causes of yield reduction, whereas drought did not affect shelling percentage, seed number per pod and seed size. In previous studies, end of season reduced number of mature pods of peanut genotypes, and the reduction affected pod yield (Nageswara Rao *et al*., 1989). The results in this study were similar to those in previous studies in Spanish peanut. Drought reduced pod number and yield irrespective of types of peanut. The severity of the drought effect would be dependent on drought event, plant type and growth stage.

Two Valencia peanut genotypes (ICG14127 and ICG10092) had the highest pod yields of 6.47 and 4.50 g/plant, respectively, which were higher than a Spanish peanut genotype 'ICGV 98324' (2.12 g/plant). As the interaction between peanut genotype and water regime was not significant for pod yield, the high performance of these peanut genotypes was consistent across water regimes. These peanut genotypes (ICG 14127 and ICG 10092) are promising for further breeding for drought tolerance in Valencia peanut. However, further investigation is still required to validate the results of these Valencia peanut genotypes for resistance, especially in the terminal drought under field conditions.

ACKNOWLEDGEMENTS

The authors are grateful for the financial support to the Peanut Mycotoxin Innovation Lab (PMIL) Project of USA and Mozambique Agricultural Research Institute, Nampula, the Peanut Project of Dr. Amade Miliano Muitia. The grateful acknowledgments are also made to the Peanut and Jerusalem artichoke Research Group and Plant Breeding Research Center for Sustainable Agriculture. The authors gratefully acknowledge the Thailand Research Fund for providing financial support for manuscript preparation from Faculty of Agriculture, Khon Kaen University (KKU) is also duly acknowledged.

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