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Evaluation of Peanut Cultivars Commonly Grown in Thailand under Water Limited Conditions

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Abstract: Objective of this study was to investigate whether physiological traits related to drought tolerance can correctly identify the peanut genotypes with high yield under water-limited conditions. Seven released cultivars and two drought tolerant lines were arranged in a split plot design with four replications for two years. The two water regimes (field capacity; FC and 2/3 available water; 2/3 AW.) were assigned in main plots and peanut genotypes were assigned in subplots. The data were recorded for SPAD Chlorophyll Meter Reading (SCMR), Specific Leaf Weight (SLW), biomass, pod yield, harvest index (HI), number of mature pods, shelling percentage, 100-seed weight and number of seeds per pod. SLW and SCMR could effectively identify peanut cultivars with higher pod yield under water-limited conditions. KK 60-3, KKU 72-1 and KKU 60 were identified as drought tolerant because they had SCMR and SLW, which were similar to those of ICGV 98324 and ICGV 98308. KK 60-3 had high biomass under water limited conditions because of high potential but it had poor pod yield, whereas KKU 60 had the highest pod yield and HI. KKU 60 also had the highest pod yield under well-watered conditions. The results indicated that some released cultivars had degree of drought tolerance similar to or better than that of the drought tolerant lines. The improvement of peanut cultivars for drought tolerance can be site-specific.

Key words: Harvest index, SPAD chlorophyll meter reading, specific leaf weight, surrogate trait, water regime

INTRODUCTION

Peanut production areas in Thailand are mainly in the North and the Northeast and peanut is grown as a cash crop by small-holder farmers under three major agro-ecosystems including upland rainfed conditions, lowland irrigated conditions and river bank after water recession with or without irrigation. Drought commonly occurs in any growing condition even under irrigation because insufficient water supply especially in late growing season. The released cultivars grown under diverse environments certainly are affected by drought stress at any growth stage (Jogloy *et al*., 1992). However, the responses to drought stress of certain peanut cultivars have not been investigated.

Drought concurrently occurs in most peanut production areas in the semi-arid tropics because of unpredictable rainfall and rain distribution (Nageswara Rao and Wright, 1994). Drought stress can impose to the crop at any time during crop growth, causing severe yield loss and poor seed quality (Roy *et al*., 1988). Therefore, attempts have been taken to improve peanut cultivars with tolerance to drought (Branch and Kvein, 1992). As direct selection for drought resistance is difficult, many surrogate traits have been suggested to be used as indirect selection tools. Carbon isotope discrimination (CID) was negatively correlated with water use efficiency (WUE) and low CID could be used as an indirect selection criterion for WUE (Wright and Nageswara Rao, 1994). Songsri *et al*. (2008) found that peanut genotypes with higher root length density (RLD) under drought could maintain high pod yield. However, the CID, WUE and root traits are laborious and not suitable for screening with large population size of breeding materials. Simple physiological traits are required in practical breeding programs to improve drought tolerance in peanut. Nageswara Rao and Wright (1994) found that SLA (ratio of leaf area and leaf weight) was well associated with CID. Peanut genotypes with high SLW (1/SLA) had higher transpiration efficiency (Brown and Byrd, 1996). Peanut genotypes with low SLA could maintain high RWC and normal growth under stress (Nautiyal *et al*., 2002). SLA also has negative relationships with stomatal conductance, rubisco enzyme

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in leaves and carbon exchange rate and, thus, it is possible to use SLA to evaluate drought tolerance in peanut (Upadhyaya, 2005). SPAD chlorophyll meter reading (SCMR) also knows as a user friendly and nondestructive trait for screening drought tolerance. Peanut genotypes with high SCMR could maintain higher rate of photosynthesis per unit leaf area because of SCMR had positive correlation with chlorophyll contents and chlorophyll density (Sheshshayee *et al*., 2006; Arunyanark *et al*., 2008, 2009). Therefore, SCMR and SLW might be useful in identifying peanut genotypes with drought tolerance.

Information on the degrees of drought tolerance in commercial cultivars is useful to improve drought tolerance cultivars with high yield. This study was to investigate the physiological traits related to drought tolerance and agronomics traits in elite germplasm lines and commercial released cultivars in Thailand under continuous and long-term water-limited conditions. The conditions in this experiment were referred to as drought throughout the text and the peanut genotypes that tolerated to these conditions were referred to as drought tolerant.

MATERIALS AND METHODS

Plant material: Nine peanut genotypes consisting of seven commercial cultivars (KK 60-3, KKU 72-1, KKU 60 (Virginia type), Tainan 9, KKU 1 (Spanish type), KK 4 and Kalasin 2 (Valencia type)) commonly grown in Thailand and two drought tolerant lines (ICGV 98308 (Virginia type) and ICGV 98324 (Spanish type)) from ICRISAT were used in the experiment. The experiment was undertaken in a split plot design with four replications for two years in the dry seasons 2005/06 and 2006/07 at the Field Crop Research Station, Faculty of Agriculture Khon Kaen University located in Khon Kaen province, Thailand (latitude 16° 28′ N, longitude 102° 48′ E, 200 m.a.s.l.). Two soil moisture levels (Field Capacity (FC) and 2/3 available soil water (2/3 AW)) were assigned in main plots and the nine peanut genotypes were assigned in subplots. Soil type is Yasothon Series (loamy sand, Ocix Paleustults) with the soil moisture of FC is 11.0 % and permanent wilting point is 4.6 % and the moisture levels for 2/3 AW would be 8.8%. The peanut lines were planted in five row plots with 3 m in length and spacing of 50 cm between rows and 20 cm between hills within a row.

Crop management: Conventional tillage was practiced for soil preparation including three ploughs. Lime (625 kg ha^{-1}) was incorporated into the soil during soil preparation. Phosphorus fertilizer as triple superphosphate (24.7 kg P ha^{-1}) and potassium fertilizer as potassium chloride (31.1 kg K ha^{-1}) were applied as a basal dose prior to planting. Seeds were treated with captan (3a, 4, 7, 7a-tetrahydro-2-[(trichloromethyl)thio]-1H-isoindole-1, 3(2H)-dione) at the rate of 5 g kg^{-1} seed before planting and seeds of the large-seeded genotypes were also treated with ethrel (2-chloroethylphosphonic acid) 48% at the rate of 2 ml L^{-1} water to break dormancy. Three to four seeds were planted per hill and the seedlings were thinned to two plants per hill at 14 days after sowing (DAS). Rhizobium was applied to the seeds by inoculating 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) on the rows of peanut plants. A pre-emergent herbicide alachlor (2-cholro-2’, 6’-diethyl-N-(methoxymethyl) acetanilide 48%, w/v, emulsifiable concentrate) was spayed at the rate of 3 L ha^{-1} at planting and manual weeding was practiced during the early growth stages of the crop. Gypsum ($CaSO_4$) was applied at the rate of 312 kg ha^{-1} at 45 DAS. Carbofuran (2, 3-dihydro-2, 2-dimethylbenzofuran-7-ylmethylcarbamate 3 % granular) was applied at the pod setting stage to control subterranean ants (*Dorylus orientalis* Westwood). Pests and diseases were controlled by weekly applications of carbosulfan [2-3-dihydro-2,2-dimethylbenzofuran-7-yl (dibutylaminothio) methylcarbamate 20% w/v, water soluble concentrate] at 2.5 L ha^{-1}, methomyl [S-methyl-N-((methylcarbamoyl) oxy) thioacetimidate 40% soluble powder] at 1.0 kg ha^{-1} and carboxin [5, 6-dihydro-2-methyl-1, 4-oxath-ine-3-carboxanilide 75 % wettable powder] at 1.68 kg ha^{-1}.

A subsoil-drip-irrigation system (Super Typhoon®, Netafim Irrigation Equipment and Drip systems, Israel), with a distance of 20 cm between emitters was installed with a spacing of 50 cm between driplines at 10 cm below the soil surface at mid-way between peanut rows and fitted with a pressure valve and a water meter to ensure uniform supply of measured amount of water to each main plot. Soil moisture was initially maintained at field capacity (102.63 mm in 60 cm depth) until 21 DAS in all treatments to support crop establishment. After 21 DAS, the 2/3 AW treatment was imposed by withholding irrigation until the soil moisture at 0-60 cm of soil depth reduced to the predetermined levels of 82.57 mm in 60 cm depth at 28 DAS and after that soil moistures were held more or less constant until harvest. In maintaining the specified soil moisture levels, water was added to the respective plots by subsurface

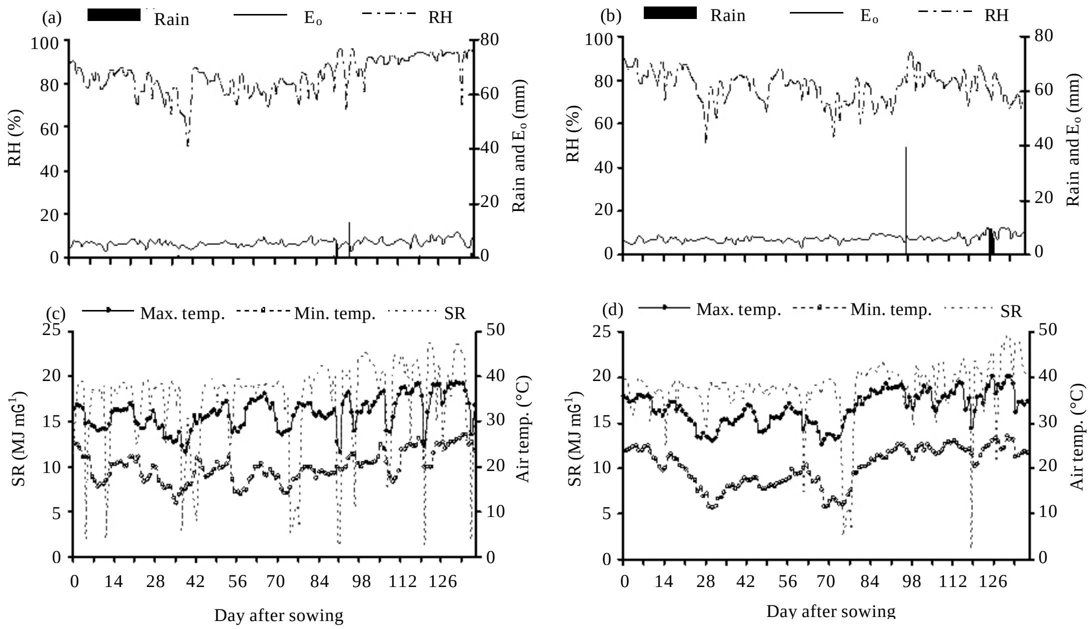

Fig. 1: Rain fall, evaporation (E_O), Relative Humidity (RH), maximum and minimum air temperature (Max .and Min. Temp.) and solar radiation (SR) in (a, b) 2005/06 and (c, d) 2006/07 in Khon Kaen, Thailand

drip-irrigation based on crop water requirement and surface evaporation which were calculated following the methods described by Songsri *et al*. (2008).

Total crop water use for each water treatment was calculated as the sum of crop water requirement and soil evaporation. Crop water requirement was calculated as:

$$Et_{crop} = ET_o \times K_c$$

where, ET_{crop} is crop water requirement (mm day^{-1}), Et_o is evapotranspiration of a reference plant under specified conditions calculated by pan evaporation method, Kc is the crop water requirement coefficient for peanut. Surface evaporation (E_s) was calculated as:

$$E_s = \beta \times (E_o/t)$$

where, E_s is soil evaporation (mm), β is light transmission coefficient measured depending on crop cover, E_o is evaporation from class A pan (mm day^{-1}), t is days from the last irrigation or rain.

Data collection

Weather parameters: Weather data were obtained from the meteorological station near the experimental site and shown in Fig. 1a-d.

Soil moisture status: Soil moistures were measured by the gravimetric method at planting and harvesting at the depths of 0-5, 25-30 and 55-60 cm. The measurement at planting was for calculating the correct amount of water to be applied to the crop and the measurement at harvest was for calculating the water use of the crop. Soil moisture level was maintained at FC in well-watered treatment and allowed to gradually reduce until it reached the predetermined level of the 2/3 AW. Soil moisture volume fraction was also monitored at 7-day intervals using a neutron moisture meter (Type I.H. II SER. N° N0152, Ambe Didcot Instruments Co. Ltd., Abingdon, Oxon, UK). The readings of soil moisture volume fraction were taken from the access tubes from the depth of 30-90 cm at 30 cm intervals. The soil moisture volume fraction is presented in Fig. 2a-f.

SPAD Chlorophyll Meter Reading (SCMR) and Specific Leaf Weight (SLW): Five plants in each plot were randomly selected to record SCMR and SLW at 67 DAS. Second fully-expanded leaves from the top of the main stems were observed during the morning period (0830-0930 h). The readings were recorded twice at the left and right sides for each leaflet using the SPAD Chlorophyll meter (Minolta SPAD-502 meter, Tokyo, Japan). Care was taken to ensure that the SPAD meter sensor fully covered the leaf lamina and to avoid the measurement of vein and midrib areas.

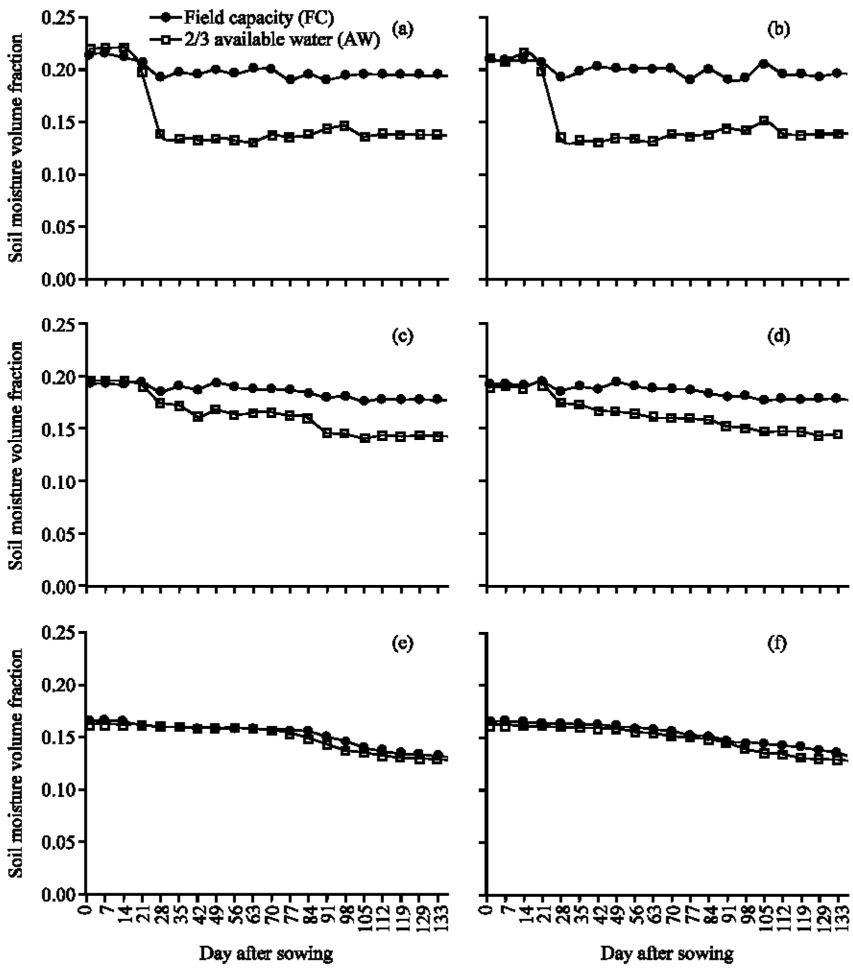

Fig. 2: Soil moisture volume fraction in two available soil water regimes field capacity (FC) and 2/3 available water (AW), at (a, b) 30 cm, (c, d) 60 cm and (e, f) 90 cm of the soil level during the 2005/06 and 2006/07 dry seasons in Khon Kaen, Thailand

The leaf samples were further taken to the laboratory for measurement of leaf area using a leaf area meter (LI 3100C Area Meter, LI-COR Inc., USA). The leaf samples were then dried at 80°C for 48 h to constant weight and dry weight was determined. SLW, the ratio of leaf dry weight to fresh leaf area (g m^{-2}) was calculated as:

$$\text{SLW} = \text{Leaf dry weight (g)/Leaf area (m}^2\text{)}$$

Agronomic traits: For each plot, three rows with 2.8 m in length (4.2 m^2) were harvested at maturity (R8) (Boote, 1982) and their pods were removed before recording fresh shoot weight in the field. A two kg random sample of shoots was oven-dried at 80°C for 48 h and dry weight was measured. Shoot dry matter content was then calculated and used in determining shoot dry weight for a plot. Pod yields were weighed after air drying to approximately 8% moisture content.

The number of mature pods per plant (mature pods was separated from immature pods, which were identified by dark internal pericarp color), number of seed per pod and 100-seed weight were also recorded at final harvest.

HI was computed by the following formula:

$$\text{HI} = \frac{\text{Total pod weight at the final harvest}}{\text{Total biomass at the final harvest}}$$

Drought tolerance index (DTI) for biomass and pod yield were calculated as the ratio of each parameter under stressed treatments (2/3 AW) to that under well-watered (FC) condition.

Statistical analysis: Homogeneity of variance was test and combined analysis of variance over two-year data was performed using general AOV statement function on Statistics 8 software. Because water regime×genotype interaction was significant, each water regime was analyzed separately according to a Randomized Complete Block Design (RCBD) (Gomez and Gomez, 1984). Least Square Difference (LSD) was used to compare means.

RESULTS

Weather and soil data: Weather data were obtained from a Meteorological Station adjacent to the experiment. The experiment was conducted at the same field for two years during the dry seasons from November 2005 to March 2006 and November 2006 to April 2007. There were maximum rainfalls of 13.0 mm at 95 DAS in the dry season 2005/06 and 39 mm at 97 DAS in the dry season 2006/07 (Fig. 1). The seasonal means of maximum and minimum air temperatures ranged from 32.0 and 20.0°C in 2005/06 and 33.0 and 20.0°C in 2006/07. Daily pan evaporations ranged from 2.8 to 9.6 mm in 2005/06 and 2.9 to 9.8 mm in 2006/07. Seasonal means of solar radiation were 16.7 MJ/m^2/day in 2005/06 and 18.8 MJ/m^2/day in 2006/07.

Soil moisture volume fraction was measured using a neutron moisture meter at 7-day intervals until harvest. The results showed reasonable management of soil moisture volume fraction. A clear distinction among soil moisture levels was noted at 30 cm of soil depth and the soil moisture contents at 2/3AW were lower than those at FC throughout the experiment except for a short period of unexpected rainfall. Soil moistures at 90 cm depth were similar between water treatments because the amount of water applied in each treatment was calculated for 0-60 cm (Fig. 2).

Physiological traits: Combined analysis of variance of two-year data showed no significant interaction between peanut cultivar and water regime for SLW, but the interaction was significant for SCMR (data not presented). Peanut genotypes were significantly different for SCMR and SLW. SCMR values ranged from 36.8-48.5 in FC and 40.7-48.8 in 2/3 AW (Table 1). ICGV 98324, KKU 72-1, KK 60-3 and KKU 60 had high values of SCMR, whereas KKU 1 had the lowest SCMR under well-watered conditions. Drought significantly increased SCMR values from 43.3 in FC to 45.5 in 2/3 AW (Table 2). ICGV 98324, KKU 60 and KKU 72-1 had high SCMR, whereas Tainan 9 and KKU 1 had low SCMR under drought (Table 1).

Drought significantly increased SLW from 65.7 g m^{-2} in FC to 68.4 g m^{-2} in 2/3 AW (Table 2) and SLW values were in a range between 60.2-69.9 g m^{-2} in FC and 65.1-72.7 g m^{-2} in 2/3 AW (Table 1). ICGV 98324, KKU 60 and KKU 72-1 had high SLW, whereas Tainan 9, KK 4 and KKU 1 had low SLW under FC. ICGV 98324 performed best for SLW under water deficit followed by KK 60-3, KKU 60 and ICGV 98308, respectively, whereas Tainan 9, KKU 1 and KK 4 had lower SLW under drought (Table 1). KKU 60-3 was identified as drought tolerant and the tolerance degree was similar to that of ICGV 98324. KKU 72-1 was also tolerant but somewhat lower than KK 60-3. KKU 60 and Kalasin 2 had tolerance degree similar to that of ICGV 98308.

Agronomic traits: Drought also significantly reduced biomass (Table 2). There were differences among peanut genotypes for biomass production both under well-irrigated and drought conditions (Table 3). Biomass production ranged from 7.2 to 10.9 t ha^{-1} in FC and 6.3 to 9.0 t ha^{-1} in 2/3 AW. KK 60-3 and KKU 72-1 had high biomass, whereas Kalasin 2 has low biomass under well-irrigated. KK 60-3 and Tainan 9 could maintain high biomass under drought, whereas KKU 1, KK 4 and Kalasin 2 could not. The results indicated that KK 60-3 had higher biomass because of low reduction and high potential, whereas KKU 72-1 had lower biomass under

Table 1: SPAD Chlorophyll Meter Reading (SCMR) and specific leaf weight of 9 peanut genotype under two water regimes, Field Capacity (FC) and 2/3 available water (2/3 AW)

	SCMR		SLW (g m^{-2})	
Genotype	FC	2/3 AW	FC	2/3 AW
ICGV 98308	41.9c	44.3c	66.6c	68.9bcd
ICGV 98324	48.5a	48.8a	69.9a	72.7a
KK 60-3	46.8ab	46.9ab	68.7ab	70.5b
Tainan 9	41.4c	41.8d	63.8de	65.8ef
KKU 72-1	46.7ab	48.0ab	65.5cd	68.2cd
KKU 1	36.8e	40.7d	60.2f	65.1f
KK 4	39.4d	44.3c	62.5e	67.2de
KKU 60	45.5b	48.1ab	67.2bc	69.3bc
Kalasin 2	42.9c	46.4bc	66.5c	68.2cd
CV(%)	4.27	4.77	2.79	2.68
LSD	1.86	2.18	1.84	1.84
F-test	**	**	**	**
Genotype×year	ns	ns	ns	ns

ns, * and **: Non significant, significant at $p \le 0.05$ and significant at $p \le 0.01$, respectively. Mean in the same column with the same letter(s) are not significantly different by LSD at $p \le 0.05$

Table 2: Means for SPAD chlorophyll meter reading (SCMR), Specific Leaf Weight (SLW), biomass, pod yield, harvest index (HI), number of mature pods, shelling percentage, 100-seed weight and number of seeds per pod of nine peanut genotypes grown under two water regimes

Water regimes	SCMR	SLW (g m^{-2})	Biomass (t ha^{-1})	Pod yield (t ha^{-1})	HI	No. mature pod plant^{-1}	Shelling percentage	100 seed weight (g 100 seeds^{-1})	No. seed pod^{-1}
FC	43.3b	65.7b	8.4a	2.33a	0.28a	18.5a	64.5	52.0a	1.80a
2/3 AW	45.5a	68.4a	7.2b	1.87b	0.26b	13.7b	63.8	48.5b	1.73b
LSD	0.58	0.57	0.25	0.07	0.08	1.33	ns	0.76	0.02

ns: Non significant. Means in the same column with the same letter(s) are not significantly different by LSD at $p \le 0.05$

Table 3: Biomass, pod yield, harvest index (HI), mature pod, shelling percentage, 100 seed weight and number of seed per pod of 9 peanut genotype under two water regimes, field capacity (FC) and 2/3 available water (2/3 AW)

	Biomass ($t\ ha^{-1}$)			Pod yield ($t\ ha^{-1}$)			HI		No. mature pod $plant^{-1}$		Shelling percentage		100 seed weight ($g\ 100\ seeds^{-1}$)		No. seed pod^{-1}	
Genotype	FC	2/3AW	DTI	FC	2/3AW	DTI	FC	2/3AW	FC	2/3AW	FC	2/3AW	FC	2/3AW	FC	2/3AW
ICGV 98308	7.8b	7.1c	0.92a	2.28cd	2.10b	0.92ab	0.29bc	0.29b	22.5ab	17.2a	66.8abc	70.2ab	49.5cd	41.2e	1.58e	1.52de
ICGV 98324	7.7b	7.1cd	0.93a	2.41bc	2.17b	0.91ab	0.32b	0.31b	24.4a	15.8abc	73.0a	72.7a	47.1cd	47.6d	1.56e	1.48e
KK 60-3	10.9a	9.0a	0.83a	2.54b	1.85c	0.73d	0.24d	0.21d	14.0d	12.6d	62.1c	58.7de	58.0b	56.2b	1.68d	1.73bc
Tainan 9	8.2b	7.7b	0.94a	2.22cd	1.67d	0.76cd	0.27c	0.22d	21.0bc	15.4bc	62.7c	66.7abc	45.8d	40.6e	1.83c	1.83b
KKU 72-1	10.3a	7.1cd	0.71b	2.19d	1.75cd	0.80cd	0.21d	0.25c	13.2d	12.8d	60.2cd	62.2cde	61.8b	49.6cd	1.74d	1.68c
KKU 1	7.9b	6.8cde	0.86a	2.27cd	2.14b	0.95a	0.29bc	0.32b	20.8bc	14.6c	65.1bc	63.1cd	50.9c	52.2bc	1.86c	1.74bc
KK 4	7.7b	6.6de	0.86a	2.34bcd	1.71cd	0.74d	0.30b	0.26c	20.5bc	11.6d	54.1d	64.8bcd	50.9c	48.4cd	1.99b	1.72bc
KKU 60	8.0b	6.9cd	0.88a	3.20a	2.70a	0.84bc	0.40a	0.39a	20.1c	17.2ab	65.6abc	56.2e	70.7a	66.7a	1.75d	1.64cd
Kalasin 2	7.2b	6.3e	0.88a	1.53e	0.76e	0.50e	0.22d	0.12e	9.6e	5.9e	70.6ab	59.6de	33.5e	34.3f	2.25a	2.24a
CV(%)	11.8	8.10	13.57	8.90	8.60	11.69	10.40	8.90	11.8	12.80	11.70	10.00	8.10	8.70	4.30	7.10
LSD	0.99	0.58	0.12	0.21	0.16	0.09	0.03	0.02	2.19	1.76	7.57	6.42	4.26	4.27	0.08	0.12
F-test	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Genotype× Year	ns	ns	ns	ns	**	ns	ns	**	*	ns	ns	ns	**	ns	ns	ns

ns, * and ** non significant, significant at $p \le 0.05$ and significant at $p \le 0.01$, respectively. Mean in the same column with the same letter(s) are not significantly different by LSD at $p \le 0.05$. DTI was calculated by the ratio of stressed (2/3 available water (AW)) / non-stressed (field capacity (FC)) conditions

drought because of high reduction as indicated by the lowest DTI value of 0.71 although the potential was also high (Table 3).

Drought also significantly reduced number of matured pods and pod yield (Table 2). The average of mean pod yield was decreased from 2.33 to 1.87 $t\ ha^{-1}$ and the number of matured pod was decreased from 18.5 to 13.7 pod $plant^{-1}$. Significant differences in number of matured pod and pod yields among genotypes were observed. KKU 60, KK 60-3 and ICGV 98324 had high pod yield under FC, whereas Kalasin 2 has the lowest pod yield (Table 3).

Under drought conditions, however, ICGV 98308, KKU 60 and ICGV 98324 had high number of matured pod. KKU 60 performed best for pod yield under 2/3 AW and it had the highest pod yield under well-watered conditions, whereas Kalasin 2 had the lowest number of matured pod and pod yield. Kalasin 2 seemed to be the most sensitive cultivar as it had the highest reduction in pod yield (lowest DTI value = 0.50) (Table 3).

The reduction in harvest index was significant under drought stress (Table 2). However, the reduction in general was small, ranging from 0.28 to 0.26. KKU 60 was the best cultivar for HI in FC, whereas Kalasin 2 KKU 72-1 and KK 60-3 had the lowest HI (Table 3). Under water stress, KKU 60 also performed best for HI followed by KKU 1, ICGV 98324 and ICGV 98308, respectively, whereas Kalasin 2 has lowest HI under drought stress.

Drought did not significantly affect shelling percentage, but significantly reduced 100-seed weight and number of seeds per pod (Table 2). The reductions were from 64.5 to 63.8 for shelling percentage, 52.0 to 48.5 g for 100-seed weight and 1.80-1.73 for number of seeds per pod. Shelling percentage, 100 seed weight and number of seed per pod were significantly different among peanut genotypes. ICGV 98308, ICGV 98324 and Tainan 9 had high shelling percentage, whereas KKU 60, KKU 72-1, Kalasin 2 and KK 60-3 had low shelling percentage. KKU 60 has the highest 100-seed weight, whereas Kalasin 2 has the lowest 100-seed weight under 2/3 AW. Kalasin 2 had the highest number of seeds per pod, whereas ICGV 98324 has the lowest number of seeds per pod (Table 3).

DISCUSSION

Physiological traits: Peanut has been grown in Thailand for several decades and dozens of cultivars has been released so far from public or private breeding institutions in Thailand. However, the released cultivars have not been tested for drought tolerance. In this study, some released cultivars commonly grown in Thailand were tested for drought tolerance compared to the tolerant lines previously identified by ICRISAT. The reason underlying this investigation is that there would be some degrees of drought tolerance in these released cultivars because they have long been cultivated under diverse conditions where drought is a problem in the semi-arid tropics. The research also compared the efficacy of SCMR and SLW in identifying drought tolerant genotypes.

SLW was more stable than SCMR and it could identify drought tolerant genotypes somewhat better than did SCMR as it had low interactions between cultivar and environments (G×E) (water regime and year). The results were in agreement with those reported previously. Songsri *et al.* (2009) also reported low G×E interaction for SLA and high heritability estimates for this trait. Vasanthi *et al.* (2006) and Upadhyaya (2005) suggested the use of SLA to evaluate drought tolerance in peanut. SLA and SLW are closely associated. The results supported previous findings and confirmed the usefulness of SLW in identifying drought tolerant peanut genotypes.

In general, the peanut lines previously identified as drought tolerant lines based on pod yield and biomass under drought had higher SCMR and SLW than did the commercial cultivars except for some cultivars. This indicated that the released cultivars investigated had some degrees of drought tolerance in terms of SCMR and SLW. This is not surprising because they have long been cultivated under rainfed conditions in the North and the Northeast of Thailand where drought is a concurring problem (Jogloy *et al*., 1992).

ICGV 98324 had the highest SCMR and SLW, but ICGV 98308 had lower SCMR and SLW than did ICGV 98324 although they both were identified as drought tolerant. ICGV 98308 is considered drought tolerant possibly due to its lower reduction in pod yield under drought and this observation is also evident for ICGV 98324. However, ICGV 98324 still had higher SCMR and SLW than did some released cultivar especially for SLW under drought conditions.

Both SCMR and SLW could identify the same peanut genotypes (KKU 1, Tainan 9) with lower SCMR and SLW than drought tolerant checks. When G x E interaction was considered, SLW was somewhat better than SCMR. Madhava *et al.* (2003) suggest that SCMR might be useful for screening peanut genotypes in early segregating populations as it is much simpler than SLW and SLW might be suitable for screening the advanced generations.

Agronomics traits: The drought tolerant cultivars should be of high pod yield, high HI and high biomass under drought conditions. The correlation between SLA and SCMR was significant (r.) =0.77, $p<0.01$) for the second leaf from the apex but the correlation declined for leaves sampled from lower nodal positions. The genotypic correlations (-0.61 and -0.66) and phenotypic correlations (-0.61 and -0.66) between SLA and SCMR were strong and negative under 2/3 AW and FC. Under 2/3 AW conditions, SCMR was positively correlated with pod yield and seed size (Songsri *et al*., 2008). This study did not show significant correlations between the surrogate traits (SCMR and SLW) and pod yield (data not presented). The lack of significant correlation could be due to differential responses of the cultivars tested. However, the cultivars with high pod yield under drought also had high SCMR and SLW (ICGV 98324 and KKU 60).

Drought significantly reduced biomass and there were differences among peanut genotypes under well-watered conditions and in response to drought. Similarly, Pimratch *et al.* (2008) also found that drought could reduce biomass by 13 and 32.7% when cultivars were imposed to drought at 2/3 and 1/3 AW, respectively. KK 60-3 had highest biomass production under drought conditions because of low reduction and high potential of biomass.

Similar to biomass production, the number of matured pods and pod yield were reduced under drought conditions. The interactions between peanut genotype and water regime and between peanut genotype and year were significant (Table 3). The results indicated that yield was not stable across environments and selection for drought tolerance using yield alone can be difficult. Surrogate traits such as SCMR and SLA might be useful if they can identify genotypes with high pod yield under drought (Nigam *et al.*, 2005).

Pod development stage is the most sensitive to drought stress, resulting in severe yield reduction by lowering number of matured pods (Reddy *et al*., 2003; Nageswara Rao *et al*., 1988, 1989). Similar to pod yield, the interactions between number of mature pods and water regime and number of mature pods and year were also significant. The results indicated that number of mature pods is a complex trait and selection for number of mature pod is also difficult.

Kalasin 2 seemed to be most sensitive to drought as it had the lowest DTI and it also had very low potential of biomass and pod yield. KKU 60 had the highest pod yield under drought because of low reduction and high potential of pod yield. KK 60-3 had rather high potential of pod yield but the reduction was also high. ICGV 98324 had rather high potential of pod yield and low reduction. Therefore, it could maintain high yield under drought. KKU 1 and ICGV 98308 had intermediate yield under fully-irrigated conditions but the reductions were also low. Therefore, these cultivars could maintain high yield under drought. The results indicated that the responses to drought were different among peanut genotypes. Some genotypes could maintain high pod yield under drought due largely to either high potential or low reduction (e.g., KKU 1 and ICGV 98308), but some genotypes were dependent on both high potential and low reduction (e.g., KKU 60 and ICGV 98324). The yield surpass of KKU 60 over those of the drought tolerant line of ICRISAT under drought conditions might indicate specific adaptation of KKU 60 under growing conditions in Thailand.

In general, harvest index was slightly reduced by drought. This could be due to the differences in responses to drought of peanut cultivars. KKU 60 was the best cultivar for HI under drought because of the highest potential and low reduction. The results indicated that

KKU 60 had high degree of drought tolerance base on yields under drought. This cultivar is useful for use in breeding for drought tolerance in peanut.

Peanut genotypes responded differently for shelling percentage, 100-seed weight and number of seeds per pod and these traits were not related to drought tolerance based on pod yield. This could be due to the compensation among yield components of different genotypes For example, most genotypes reduced number of mature pods per plant to maintain larger seeds under drought. In contrast, under well-watered conditions, number of mature pod is well-known as a good determinant for pod yield. However, most drought tolerant genotypes (ICGV 98308 and ICGV 98324) had good shelling percentage except for KKU 60. KKU 60 had low shelling percentage but it had the highest 100-seed weight because of larger seeds and thicker shells. High number of seeds did not contribute much to yield because the seeds were very small such as in Kalasin 2.

CONCLUSION

Peanut cultivars tested in presented study had levels of drought tolerance similar to lines previously identified by ICRISAT in terms of SCMR and SLW. They are KK 60-3, KKU 72-1 and KKU 60. However, SCMR and SLW gave higher contribution to biomass under drought than to pod yield. Harvest index and number of mature pods were factors contributing to high pod yield under drought. The cultivars with high pod yield under drought should be of high potential for pod yield under well-irrigated conditions or low reduction under drought or both. KKU 60 had the highest pod yield under water-limited conditions because it had the highest pod yield under well-watered conditions and the lowest reduction in pod yield under water-limited conditions.

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REFERENCES

Arunyanark, A., S. Jogloy, C. Akkasaeng, N. Vorasoot and T. Kesmala *et al*., 2008. Chlorophyll stability is an indicator of drought tolerance in peanut. J. Agron. Crop Sci., 194: 113-125.

Arunyanark, A., S. Jogloy, N. Vorasoot, C. Akkasaeng, T. Kesmala and A. Patanothai, 2009. Stability of relationship between chlorophyll density and soil plant analysis development chlorophyll meter readings in peanut across different drought stress conditions. Asian J. Plant Sci., 8: 102-110.

Boote, K.J., 1982. Growth stage of peanut (*Arachis hypogaea* L.). Peanut Sci., 9: 35-40.

Branch, W.D. and C.K. Kvien, 1992. Peanut breeding for drought resistance. Peanut Sci., 19: 44-46.

Brown, R.H. and G.T. Byrd, 1996. Transpiration efficiency, specific leaf weight and mineral concentration in peanut and pearl millet. Crop Sci., 36: 475-480.

Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edn., John Wiley and Sons Inc., New York, pp: 95-109.

Jogloy, S., R.M. Abilay, T. van Lai, S.Z. Ramawas, K.T. Adisarwanto and A. Kasno, 1992. Groundnut production and research in Southeast Asia. Proceeding of an International Workshop on Groundnut a Global Perspective, Nov. 25-29, ICRISAT., pp: 149-156.

Madhava, H.B., M.S. Sheshshayee, A.G. Shankar, T.G. Prasad and M. Udayakumar, 2003. Use of SPAD chlorophyll meter to assess transpiration efficiency of peanut. Proceedings of Breeding of Drought-Resistance Peanut, Feb. 25-27, ACIAR., pp: 3-9.

Nageswara Rao, R.C., J.A. Williams, M.U.K. Sirakumas and K.D.R. Wadia, 1988. Effects of water deficit at different growth phases of peanut. II. Responses to drought during pre-flowering phase. Agron. J., 80: 431-438.

Nageswara Rao, R.C., J.H. Williams and M. Singh, 1989. Genotypic sensitivity to drought and yield potential of peanut. Agron. J., 81: 887-893.

Nageswara Rao, R.C. and G.C. Wright, 1994. Stability of the relationship between specific leaf area and carbon isotope discrimination across environments in peanut. Crop Sci., 34: 98-103.

Nautiyal, P.C., R.C. Nageswara Rao and Y.C. Joshi, 2002. Moisture-deficit-induced changes in leaf-water content, leaf carbon exchange rate and biomass production in groundnut cultivars differing in specific leaf area. Field Crops Res., 74: 67-79.

Nigam, S.N., S. Chandra, K.R. Sridevi, M. Bhukta and A.G.S. Reddy *et al*., 2005. Efficiency of physiological traits-based and empirical selection approaches for drought tolerance in groundnut. Ann. Applied Biol., 146: 433-439.

Pimratch, S., S. Jogloy, N. Vorasoot, B. Toomsan, A. Patanothai and C.C. Holbrook, 2008. Relationship between biomass production and nitrogen fixation under drought-stress condition in peanut genotypes with different levels of drought resistance. J. Agron. Crop Sci., 194: 15-25.

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

Roy, R.C., D.P. Stonehouse, B. Francois and D.M. Brown, 1988. Peanut response to imposed drought conditions in southern Ontario. Peanut Sci., 15: 85-89.

Sheshshayee, M.S., H. Bindumadhava, N.R. Rachaputi, T.G. Prasad, M. Udayakumar, G.C. Wright and S.N. Nigam, 2006. Leaf chlorophyll concentration relates to transpiration efficiency in peanut. Ann. Applied Biol., 148: 7-15.

Songsri, P., S. Jogloy, C.C. Holbrook, T. Kesmala, N. Vorasoot, C. Akkasaeng and A. Patanothai, 2009. Association of root, specific leaf area and SPAD chlorophyll meter reading to water use efficiency of peanut under different available soil water. Agric. Water Manage., 96: 790-798.

Songsri, P., S. Jogloy, N. Vorasoot, C. Akkasaeng, A. Patanothai and C.C. Holbrook, 2008. Root distribution of drought-resistant peanut genotypes in response to drought. J. Agron. Crop Sci., 194: 92-103.

Upadhyaya, H.D., 2005. Variability for drought resistance related traits in the mini core collection of peanut. Crop Sci., 45: 1432-1440.

Vasanthi, R.P., P.V. Reddy, V. Jayalakshmi, P. Sudhakar and M. Asalatha *et al*., 2006. A high-yielding drought-tolerance groundnut variety Abhaya. Int. Arachis Newlett., 26: 15-16.

Wright, G.C. and R.C. Nageswara Rao, 1994. Groundnut Water Relations. In: The Groundnut Crop: A Scientific Basis for Improvement, Smartt, J. (Ed.). Chapman and Hall, London, ISBN: 978-0412408205, pp: 281-325.