RESEARCH ARTICLE

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RELATIONSHIPS BETWEEN PHYSIOLOGICAL TRAITS AND YIELD COMPONENTS OF PEANUT GENOTYPES WITH DIFFERENT LEVELS OF TERMINAL DROUGHT RESISTANCE

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SUMMARY

The relationships between physiological traits related to drought tolerance and yield components of peanut genotypes are not well understood. The objective of this study was to investigate the relationships between physiological traits related to drought tolerance and yield components of peanut genotypes with different levels of terminal drought resistance. A field experiment was conducted at Khon Kaen University during 2010/11 and 2011/12. A split plot design with 4 replications for 2 years was used. Five peanut genotypes were assigned in sub-plots and 2 soil moisture levels were assigned in main plots. Data were recorded for physiological traits consisting of leaf area index (LAI), specific leaf area (SLA), relative water content (RWC), SPAD chlorophyll meter reading (SCMR), canopy temperature and stomatal conductance at R7 stage and harvest, and yield components consisting of number of pods plant^{-1}, number of seeds pod^{-1} and 100-seed weight were recorded at harvest. Peanut genotypes with high LAI, SCMR, RWC and stomatal conductance, and low SLA and canopy temperature and high drought tolerant index (DTI) for number of pods plant^{-1}, DTI for number of seeds pod^{-1} and DTI for 100-seed weight could maintain high pod yield under drought conditions. Genotypes ICGV 98324, ICGV 98348 and Tifton 8 performed well for various physiological traits and yield components. The results suggested that ability to maintain physiological traits and yield components could aid peanut genotypes in sustaining high pod yield under stress conditions.

Keywords: *Arachis hypogaea* L., drought stress, drought tolerance, pod yield, water stress

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INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an important cash crop in the semi-arid tropics where drought is a major constraint (Drame *et al*., 2007). Drought resistant varieties have been used to stabilize peanut productivity under drought conditions, and breeding for drought resistance has been an important strategy in alleviating the problem (Jongrungklang *et al*., 2008; Songsri *et al*., 2008a). The response of plants to water stress depends on several factors such as developmental stage, severity and duration of stress and genotype (Beltrano and Ronco, 2008). Information on physiological traits contributing to high yield under drought stress might reveal the underlying mechanism from which improved strategies could be developed to enhance the effectiveness and progress in breeding for drought resistance in peanut (Pimratch *et al*., 2008; Songsri *et al*., 2009). Some physiological characters such as leaf area index (LAI), specific leaf area (SLA), relative water content (RWC), SPAD chlorophyll meter reading (SCMR), canopy temperature and stomatal conductance are related to drought tolerance in peanut. SLA was associated with variation in photosynthetic capacity and chlorophyll density expressed as high SCMR (Wright and Nageswara Rao, 1994; Nageswara Rao *et al*., 1995, 2001). SCMR was directly related to the amount of chlorophyll in the leaves of peanuts (Akkasaeng *et al*., 2003). SCMR was also increased under severe drought (Jongrungklang *et al*., 2008; Boontang *et al*., 2010). Drought tolerant cultivars had lower water potential but higher RWC than drought susceptible cultivars (Joshi *et al*., 1988). Canopy temperature was positively correlated with visual drought stress ratings (Rucker *et al*., 1995). Stomatal conductance in peanut was closely related to water status (Bennet *et al*., 1984). Moreover, yield components are important characters for sustaining pod yield under drought, and peanut genotypes with high pod yield under drought also had high number of mature pods under both non-stress and stress conditions (Songsri *et al*., 2008b; Boontang *et al*., 2010). The reductions in seed size were significantly different among cultivars (Boontang *et al*., 2010).

SCMR under drought conditions was positively correlated with pod number per plant (Puangbut *et al*., 2011; Painawadee et al., 2009; Wunna *et al*., 2009). However, Boontang *et al*. (2010) found that SCMR was not related to number of pods plant^{-1}, number of seeds pod^{-1} and seed size.

The previous investigations were carried out mostly under early season drought, long-term drought and intermittent drought, however, the investigations were not carried out under late season drought. The contrasting results of different studies lead us to hypothesize that drought conditions may modify the relationships among these traits. The relationships between physiological traits and yield components for drought tolerance of peanut genotypes with different levels of terminal drought resistance are still lacking. A better understanding might lead to the development of peanut cultivars with increased yield. Therefore, the aim of the current investigation was to determine the relationships between physiological traits and yield components traits of peanut genotypes with different levels of terminal drought resistance.

MATERIALS AND METHODS

Plant material

The accessions with ICGV number are elite drought resistant lines obtained from ICRISAT, India (Nageswara Rao *et al*., 1994; Nigam *et al*., 2003, 2005) and were identified as drought resistant genotypes in our previous work (Girdthai *et al*., 2010). Tainan 9 is a Spanish-type peanut cultivar having low drought tolerance index (Girdthai *et al*., 2010) and low dry matter (Vorasoot *et al*., 2003). Tifton 8 is a drought resistant Virginia-type peanut with a large root system received from the United States Department of Agriculture (USDA) (Coffelt *et al*., 1985).

Experimental details

The experiment was conducted under field conditions at Field Crop Research Station of Khon Kaen University, Thailand (latitude 16º 28 N, longitude 102º 48 E, 200 m above sea level). The treatments were arranged in a split-plot design with 4 replications during the dry season for 2 years (2010/11 and 2011/12). Two soil moisture levels [field capacity (FC) and 1/3 available water (1/3AW) at R7 growth stage through harvest] were assigned in main plots, and 5 peanut genotypes (ICGV 98308, ICGV 98324, ICGV 98348, Tainan 9 and Tifton 8) were assigned in sub-plots. Plot size was 5 x 5 m with spacing of 50 cm between rows and 20 cm between plants within a row. Rainout shelters were available if necessary.

Crop management

Soil was ploughed 3 times and triple superphosphate at the rate of 122 kg ha^{-1} and potassium chloride at the rate of 62 kg ha^{-1} were incorporated into the soil during soil preparation. 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} seeds and seeds of Tifton 8 were treated with ethrel 48 % at the rate of 2 ml l^{-1} water to break dormancy. Three seeds were planted and later the seedlings were thinned to obtain one plant per hill at 14 days after planting (DAP). *Rhizobium* inoculation was done by applying 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 after planting, and then water was applied to the level of field capacity (FC). Weeds were controlled by an application of alachlor (2-cholro-2’,6’-diethyl-*N*-(methoxymethyl) acetanilide 48 %, w/v, emulsifiable concentrate) at the rate of 3 l ha^{-1} at planting and hand weeding.

Gypsum ($CaSO_4$) at the rate of 312 kg ha^{-1} was applied at 40 days after emergence (DAE). Carbofuran (2,3-dihydro-2,2-dimethylbenzofuran-7-ylmethylcarbamate 3 % granular) was used at the pod setting stage (60 DAE) to protect the crop from ants and other insects. Pests and diseases were controlled by weekly applications of carbosulfan [2-3-dihydro-2,2-dimethylbenzofuran-7-yl (dibutylaminothio) methylcar-bamate 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}, dicofol [2,2,2-trichlor-1,1-bis c4-chlorophenyl ethanol 18.5 %, w/v, emulsifiable concentrate] at the rate of at 2.5 l ha^{-1} and carboxin [5,6-dihydro-2-methyl-1,4-oxathine-3-carboxanilide 75 % wettable powder] at the rate of 1.68 kg ha^{-1}.

Water management

A subsurface drip irrigation system (Super typhoon®; Netafim Irrigation Equipment & Drip systems, Tel Aviv, Israel), a distance of 20 cm between emitters was installed with a spacing of 50 cm between drip lines at 10 cm below the soil surface mid-way between peanut rows to supply water to peanut, and fitted with a pressure valve and water meter to ensure uniform supply of measured amounts of water across each plot. Sub-valves were set up at each sub-plots of water stress plots to control the required water amounts for each genotype according to the predetermined water level (1/3 AW) at their individual growth stages. Soil water level was maintained uniformly at FC at 0-60 cm from planting to harvest in FC plots. Water was withheld to initiate the stress treatments and the soil moisture was allowed to decrease gradually to meet the exact predetermined level of 1/3 AW at R7 growth stage of each genotype. Once the soil moisture reached 1/3 AW, it was maintained at the level of 1/3 AW until harvest. Water was added to the respective plots based on the crop water requirement and surface evaporation, which were calculated following the methods described by Doorenbos and Pruitt (1992) and Singh and Russell (1981), respectively.

The total crop water use for each water treatment was calculated as the sum of transpiration and soil evaporation. Crop water requirement was calculated using the methods described by Doorenbos and Pruitt (1992).

$$ETcrop = ETo \times Kc \qquad (1)$$

where ETcrop = crop water requirement (mm day^{-1}), ETo = evapotranspiration of a reference crop under specified conditions calculated by pan evaporation method, Kc = the crop water requirement coefficient for peanut, which varied depending on growth stages.

Surface evaporation was calculated as (Singh and Russel, 1981):

$$Es = \beta \times (Eo/ t) \qquad (2)$$

where Es = soil evaporation (mm), β = light transmission coefficient measured depending on crop cover, Eo = evaporation from class A pan (mm day^{-1}), t = days since the last irrigation (days).

Meteorological conditions, soil properties and soil moisture content

Relative humidity (%), pan evaporation (mm), rainfall (mm), maximum and minimum air temperature (ºC), and solar radiation (MJ m^{-2} day^{-1}) were recorded daily from planting until harvest by a weather station located 100 m away from the experimental field.

Physical and chemical properties of soils from the experimental site were determined before planting. Soil samples were taken from 4 points of the experimental site at the depths of 0–5, 5–15 and 15–30 cm, the bulk of all soil samples were analyzed to determine soil properties. Soil texture was loamy sand in season 1 and sand in season 2. The soil chemical properties are shown in Table 1.

Soil moisture content was measured by gravimetric method at planting, the last day of irrigation, R7 growth stage and at harvest at the depth of 0–5, 10–15, 25–30, 40–45 and 55–60 cm. Soil samples from all sub plots were measured and soil moisture calculated as follows:

Soil moisture content = (wet weight – dry weight/ dry weight) x 100 (3)

Data collection

Relative water content (RWC), specific leaf area (SLA), SPAD chlorophyll meter reading (SCMR), leaf area index (LAI), canopy temperature and stomatal conductance were measured at R7 stage and harvest. SCMR, RWC and stomatal conductance were recorded from leaflets of the second fully expanded leaf from the top of the main stem from 5 chosen plants, which were randomly selected from each plot. SCMR was recorded twice on each leaflet of the tetra foliate leaf along the mid-rib at 10.00 to 12.00 hr using a Minolta SPAD–502 meter, Tokyo, Japan.

RWC was recorded from each plot at 10.00 to 12.00 hr. Once leaves were harvested and transported to the laboratory, leaf fresh weight was recorded. The leaf samples were then soaked in distilled water for 8 hours and blotted for surface drying and water saturated leaf weight was determined. The samples were oven-dried at 80 ºC until reaching constant weight and leaf dry weight was determined. RWC was calculated based on the formula suggested by Gonzalez and Gonzalez–Vilar (2001) as follows:

RWC = {(fresh weight-dry weight)/ (turgid weight-dry weight)} x 100 (4)

Stomatal conductance was measured at 10.00 to 12.00 hr using a porometer (Delta-T Devices in Cambridge, U.K.). Canopy temperature was observed 12.00 to 13.00 hr on the same days, using an infrared thermometer (TESTO 830 T1, Hotek Technologies, Tocoma, Washington, USA). LAI was computed as the ratio between leaf area and the corresponding ground surface area.

The same leaf samples were used for determination of SLA. Leaf area was first measured using a leaf area meter (LI 3100C Area Meter, LI-COR Inc., USA). The leaves were then oven-dried at 80 ºC for at least 48 hours until reaching constant weight and leaf dry weight was determined. SLA was calculated using the following formula:

SLA= Leaf area (cm^2)/ Leaf dry weight (g) (5)

The number of pods $plant^{-1}$, number of seeds pod^{-1}, and 100-seed weight (seed size) were determined from harvest area of 9 m^2 and subsamples from 18 plants selected randomly from each plot. Drought tolerance index (DTI) for each parameter were calculated for the trait under 1/3 AW to that under FC conditions as suggested by Girdthai *et al*. (2010).

DTI = drought tolerance index (stress (1/3 AW)/ non-stress (FC)) (6)

Data analysis

The statistical analysis was conducted using MSTAT-C package (Bricker, 1989). The data were subjected to analysis of variance according to a split plot design. Individual analysis of variance was performed for each character in each year. Error variances for 2 years were tested for homogeneity by Bartlett's test

(Hostmand, 2006). Combined analyses of variance were done for those characters where error variances for 2 years were homogeneous, and Duncan's multiple range test (DMRT) was used to compare means.

RESULTS

Meteorological conditions

The relative humidity values ranged from 69 to 95 % and 71 to 91 %, the total amount of rainfall was 81.1 and 41.4 mm and mean daily pan evaporation was 4.47 and 5.14 mm in the first and second seasons, respectively (Figures 1a and c). Maximum temperature and minimum temperature were slightly different among seasons. Temperatures in the first and the second seasons were 14.0 to 34.4 ºC and 12.0 to 37.0 ºC, respectively, and the seasonal means of solar radiation were 13.23 and 19.18 MJ m^{-2} day^{-1} in the first and second season respectively (Figures 1b and d).

Soil moisture content

Soil moisture content was near field capacity for non-stress and stress treatments at sowing for both seasons, and at the last day of irrigation for season 2 (Table 2). For season 1, we added water by subsurface drip-irrigation based on crop water requirement, which was calculated by using ETcrop alone. However, the crop was more stressed, and later after water withholding for 10 days, Es was also included in the calculation of water requirement. For season 2, ETcrop plus Es was used for calculating of crop water requirement throughout the experiment. Soil moisture content was near field capacity for non-stress treatment and soil moisture content in stress treatment reached 1/3 AW for stress treatment at R7 stage and harvest for both seasons.

Plant water status (relative water content; RWC)

For both seasons, the differences in RWC between non-stress (FC) and stress (1/3 AW) treatments were not significant at the last day of irrigation (Figure 2). Non-stress (FC) and stress (1/3 AW) treatments were significantly different for RWC at the R7 stage and at harvest. Non-stressed peanut had higher RWC than did the stressed peanut for both seasons.

Yield components

Differences between years were not significant for number of pods $plant^{-1}$, number of seeds pod^{-1} and 100-seed weight (Table 3). Significant differences between water regimes were observed for number of pods $plant^{-1}$ and 100-seed weight, and significant differences among peanut genotypes were observed for number of pods $plant^{-1}$, number of seeds pod^{-1} and 100-seed weight.

The interactions between year and water regime (Y x W) and between water regime and genotype (W x G) were significant for number of pods $plant^{-1}$. The interaction between year and genotype (Y x G) was significant for 100-seed weight and other interactions were not significant.

Water regime contributed to large portion (54.9 %) of total variation for number of pods $plant^{-1}$, whereas genotype contributed to large variations for number of seeds pod^{-1} (63.9 %) and 100-seed weight (95.7 %). The contribution of genotype x water regime interaction for number of pods $plant^{-1}$ was much smaller than that of water regimes.

Drought stress more severely reduced number of pods $plant^{-1}$, than number of seeds pod^{-1} and 100-seed weight (Table 4). Significant differences among peanut genotypes were found for number of pods $plant^{-1}$ under FC and 1/3 AW. Under 1/3 AW ICGV 98348 performed best for this character followed by ICGV 98324**,** but Tainan 9 showed the lowest number of pods $plant^{-1}$.

Significant differences among peanut genotypes were found for number of seeds pod^{-1} under FC and 1/3 AW, Tainan 9 had the highest number of seeds pod^{-1} under both water regimes followed by ICGV 98348, whereas ICGV 98308 showed the lowest number of seeds pod^{-1}.

Significant differences among peanut genotypes were found for 100-seed weight under both water regimes, and Tifton 8 had the highest 100-seed weight followed by ICGV 98324, whereas ICGV 98348 had the lowest 100-seed weight.

Physiological traits

Differences between years were significant for SLA at R7 stage, SCMR at both stages and canopy temperature at harvest (Tables 5 and 7). Significant differences between water regimes were observed for LAI at harvest, SLA, SCMR and canopy temperature at both stages and stomatal conductance at R7 stage, genotypes were also significantly different for LAI at R7 stage, SLA and canopy temperature at harvest and SCMR at both stages.

The interactions between year and water regime were significant for LAI at R7 stage and SLA, SCMR and stomatal conductance at harvest. The interactions between water regime and genotype were significant for LAI and canopy temperature at R7 stage. The interactions between year and genotype were significant for LAI, SLA at harvest and SCMR and canopy temperature at both stages.

The interactions of year, water regime and genotype were significant for LAI and canopy temperature at R7 stage. It is clear that contribution of water regimes to total variation were rather high in LAI at harvest (29.3 %), canopy temperature at R7 stage (30.3 %) and at harvest (31.5 %) and stomatal conductance (29.9 %), and genotypes contributed to a large percentage of variations in SCMR at R7 stage (28.8 %) and harvest (57.2 %).

Drought reduced LAI at both stages and SLA at harvest (Table 6). Significant differences among peanut genotypes in LAI were observed at R7 stage under 1/3 AW. Under drought Tifton 8 gave the highest LAI at R7 stage. Differences in SLA among peanut genotypes were also observed under FC at harvest.

Drought stress significantly increased SCMR, but it reduced stomatal conductance (Table 8). Significant differences among peanut genotypes were found for SCMR at both stages under both conditions. Under drought conditions ICGV 98324, Tifton 8 and ICGV 98348 had high SCMR at both stages. Significant differences among peanut genotypes were found for stomatal conductance under 1/3 AW at harvest. However, under drought conditions ICGV 98348 had the highest stomatal conductance at both stages.

Drought stress tended to increase canopy temperature at R7 stage (Table 8). However, ICGV 98324 tend to have the lowest canopy temperature under drought conditions at both stages although there were no significant differences under both stages.

Relationships between physiological traits with yield components

The relationships between physiological traits and yield components at R7 stage and harvest of 2 years in 2010/11 and 2011/12 were presented in Figures 3 to 8.

The relationship between LAI and DTI (number of pods plant^{-1}), ICGV 98348 had high LAI and had high DTI (number of pods plant^{-1}) at R7 stage but not found genotypes had high LAI and also had high DTI (number of pods plant^{-1}) at harvest (Figures 3a and d). The relationship between LAI and DTI (number of seeds pod^{-1}), Tifton 8 and ICGV 98348 had high LAI and also had high DTI (number of seeds pod^{-1}) at R7 stage, and Tifton 8, ICGV 98348 and ICGV 98324 had high LAI and also had high DTI (number of seeds pod^{-1}) at harvest (Figures 3b and e). The relationship between LAI and DTI (100-seed weight), Tifton 8, ICGV 98348 and ICGV 98308 had high LAI and had high DTI (100-seed weight) at R7 stage, and Tifton 8 and ICGV 98324 had high LAI and also had high DTI (100-seed weight) at harvest (Figures 3c and f).

The relationship between SLA and DTI (number of pods plant^{-1}), ICGV 98348 had low SLA but had high DTI (number of pods plant^{-1}) at both stages (Figures 4a and d). The relationship between SLA and DTI (number of seeds pod^{-1}), ICGV 98324 and ICGV 98348 had low SLA and had high DTI (number of seeds pod^{-1}) at R7 stage, and ICGV 98324 and Tifton 8 had low SLA and had high DTI (number of seeds pod^{-1}) at harvest (Figures 4b and e). For the relationship between SLA and DTI (100-seed weight), showed result same the relationship between SLA and DTI (number of seeds pod^{-1}) (Figures 4c and f).

Table 1. Chemical and physical properties of soil in the experimental fields at the depth 0-30 cm.

Year	pH (1:1 H_20)	EC (1:5 H20) (dS m^{-1})	CEC (c mol kg^{-1})	OM (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable		Particle size, mum (USDA system)			Texture class
							K (mg kg^{-1})	Ca (mg kg^{-1})	Sand: 2.0 – 0.05 (%)	Silt: 0.05– 0.002 (%)	Clay: <0.002 (%)	
2010/11	6.08	0.03	5.22	0.44	0.02	23.95	33.09	418.33	85.08	7.30	7.62	Loamy sand
2011/12	6.18	0.05	5.93	0.41	0.01	40.74	38.34	446.67	89.99	8.32	1.70	Sand

Table 2. Soil moisture content (%) at sowing, the last day of irrigation, R7 stage and harvest stage under field capacity (FC) and 1/3 available water (1/3 AW) experiments conducted at the Field Crop Research Station of Khon Kaen University, Thailand during October–February in 2010/11 (season 1) and in 2011/12 (season 2).

Seasons	Treatments	Soil moisture content (%)			
		Sowing	The last day of irrigation	R7 stage	Harvest
2010/11	FC	10.33	7.67	8.24	9.51
	1/3 AW	10.26	7.47	5.91	6.43
2011/12	FC	10.81	10.63	10.83	10.76
	1/3 AW	10.42	10.42	6.12	6.44

2010/11; FC = 10.14%, PWP= 4.47, 1/3 AW= 6.33 and 2011/12; FC = 10.18%, PWP= 4.50, 1/3 AW= 6.37 using pressure plate method.

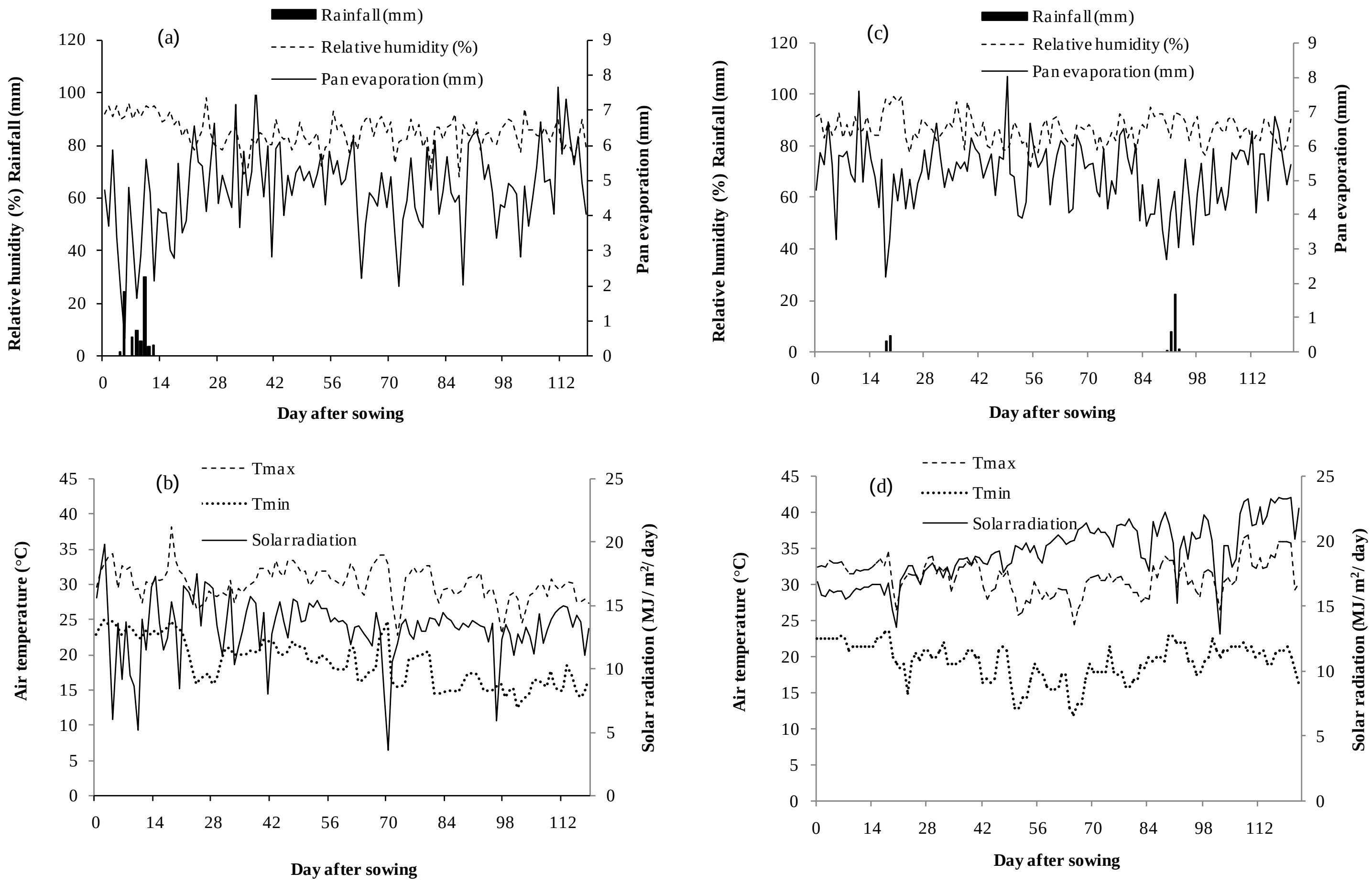

Figure 1. Rainfall, Relative humidity (RH), evaporation (E0), maximum (Tmax) and minimum (Tmin) temperatures and solar radiation during October– February 2010/11 (a, b) and 2011/12 (c, d) at the meteorological station, Khon Kaen University, Thailand.

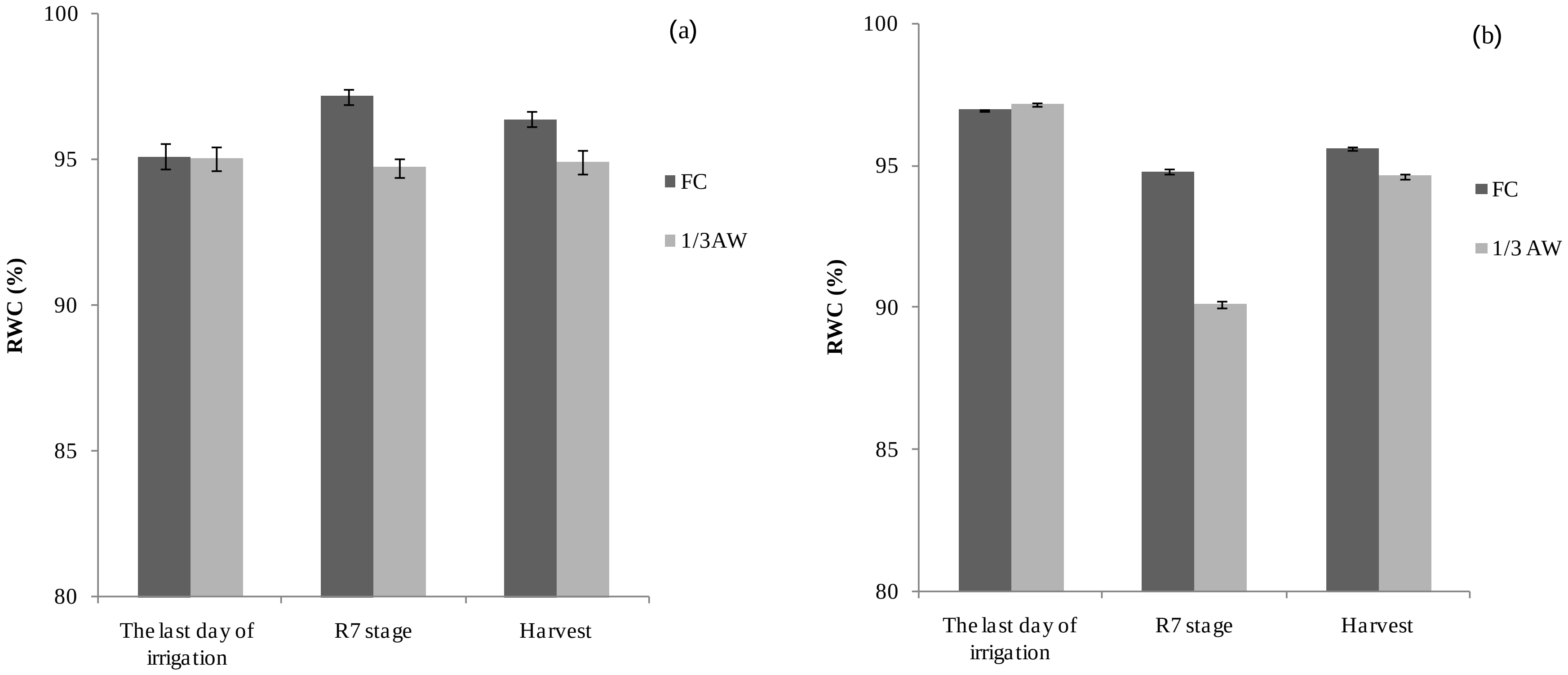

Figure 2. Relative water content (RWC) at the last day of irrigation, R7 stage and harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11 (a) and 2011/12 (b).

Table 3. Mean squares from combined analysis for number of pods plant^{-1}, number of seeds pod^{-1} and 100-seed weight at harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11and 2011/12.

Source	DF	number of pods plant^{-1}	number of seeds pod^{-1}	100-seed weight
Year (Y)	1	0.1^{ns}(0.0)	0.0^{ns}(0.0)	0.0^{ns}(0.0)
Rep within Year	6	55.6^{ns}(4.5)	0.0^{ns}(12.1)	2.4^{ns}(0.2)
Water regimes (W)	1	4120.5**(54.9)	0.0^{ns}(0.6)	70.6**(1.0)
YxW	1	258.9**(3.5)	0.0^{ns}(0.2)	0.5^{ns}(0.0)
Error (b)	6	12.2(1.0)	0.0(1.1)	4.1(0.4)
Genotypes (G)	4	320.1**(17.1)	0.3**(63.9)	1665.8**(95.7)
YxG	4	10.1^{ns}(0.5)	0.0^{ns}(2.0)	8.3*(0.5)
WxG	4	69.2*(3.7)	0.0^{ns}(2.6)	2.9^{ns}(0.2)
YxWxG	4	19.7^{ns}(1.1)	0.0^{ns}(1.3)	0.8^{ns}(0.0)
Error (c)	48	21.7(13.9)	0.0(16.2)	2.9(2.0)
CV (%) (b)		15.7	3.3	3.6
CV (%) (c)		20.9	4.6	3.1

ns, *, ** = non-significant and significant at $P < 0.05$ and $P < 0.01$ probability levels, respectively
Values in parenthesis are percentages of sum squares.

Table 4. Number of pods plant^{-1}, number of seeds pod^{-1} and 100-seed weight at harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11 and 2011/12.

Genotypes (G)	number of pods plant^{-1} $^{1/}$		number of seeds pod^{-1} $^{1/}$		100-seed weight $^{1/}$	
	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW
ICGV 98308	28.08ab	13.18bc	1.55c	1.46c	53.51b	51.22b
ICGV 98324	36.28a	17.03ab	1.57c	1.58b	55.60b	53.45b
ICGV 98348	30.06a	21.06a	1.74b	1.77a	46.18c	44.23c
Tainan 9	21.17b	9.72c	1.86a	1.79a	54.56b	51.97b
Tifton 8	31.69a	14.52abc	1.64bc	1.65b	72.87a	72.47a
Mean	29.46	15.10	1.67	1.65	56.55	54.67

$^{1/}$ = means followed by the same letter in the same column were not significantly difference (at $P < 0.05$) by DMRT

Table 5. Mean squares from combined analysis for leaf area index (LAI) and specific leaf area (SLA) at R7 stage and harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11 and 2011/12.

Source	DF	LAI		SLA	
		R7 stage	Harvest	R7 stage	Harvest
Year (Y)	1	0.6^{ns}(1.4)	0.0^{ns}(0.1)	6595.4*(5.8)	181.1^{ns}(1.0)
Rep within Year	6	0.7^{ns}(8.6)	0.4^{ns}(5.9)	844.5^{ns}(4.5)	58.9^{ns}(2.0)
Water regimes (W)	1	0.0^{ns}(0.1)	12.1**(29.3)	63.9*(0.1)	2024.1**(11.1)
YxW	1	9.2**(20.7)	2.0^{ns}(5.0)	177.0^{ns}(0.2)	799.9*(4.4)
Error (b)	6	0.3(4.3)	0.5(7.8)	1880.3(10.0)	130.9(4.3)
Genotypes (G)	4	0.8* (6.8)	0.6^{ns}(5.9)	3183.7^{ns}(11.3)	560.3*(12.3)
YxG	4	0.6^{ns}(2.9)	0.9*(8.9)	2372.4^{ns}(8.4)	611.7**(13.4)
WxG	4	1.5**(7.7)	0.6^{ns}(5.2)	709.7^{ns}(2.5)	260.2^{ns}(5.7)
YxW xG	4	1.4**(12.1)	1.5^{ns}(13.8)	197.6^{ns}(0.7)	184.1^{ns}(4.0)
Error (c)	48	0.3(27.2)	0.3(31.9)	1337.2(56.7)	158.3(41.7)
CV (%) (b)		21.7	22.7	23.7	6.8
CV (%) (c)		19.3	16.3	20.0	7.5

ns, *, ** = non-significant and significant at $P < 0.05$ and $P < 0.01$ probability levels, respectively

Values in parenthesis are percentages of sum squares.

Table 6. Leaf area index (LAI) and specific leaf area (SLA) at R7 stage and harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11 and 2011/12.

Genotypes (G)	LAI$^{1/}$				SLA (cm^{2} g^{-1})$^{1/}$			
	R7 stage		Harvest		R7 stage		Harvest	
	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW
ICGV 98308	2.86	2.69ab	3.54	2.73	192.53	207.68	183.80a	171.98
ICGV 98324	2.82	2.02c	3.94	2.89	186.52	166.09	182.17a	160.37
ICGV 98348	2.50	2.93a	3.16	2.71	174.33	180.70	172.20ab	163.74
Tainan 9	2.50	2.14bc	3.91	2.85	175.69	181.58	169.83ab	162.88
Tifton 8	2.41	3.15a	3.51	3.00	194.03	195.98	162.20b	160.92
Mean	3.61	2.84	2.62	2.58	184.62	186.41	174.04	163.98

$^{1/}$ = means followed by the same letter in the same column were not significantly difference (at $P < 0.05$) by DMRT

Table 7. Mean squares from combined analysis for SPAD chlorophyll (SCMR), canopy temperature and stomatal conductance at R7 stage and harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11and 2011/12.

Source	DF	SCMR		Canopy temperature		Stomatal conductance	
		R7 stage	Harvest	R7 stage	Harvest	R7 stage	Harvest
Year (Y)	1	744.8**(32.8)	360.8**(14.4)	3.88^{ns}(0.6)	89.8**(21.1)	0.0^{ns}(0.0)	0.7^{ns}(5.0)
Rep within Year	6	16.2^{ns}(4.3)	2.5^{ns}(0.6)	4.7^{ns}(4.6)	2.9^{ns}(4.0)	0.2^{ns}(6.5)	0.4**(16.1)
Water regimes (W)	1	254.7**(11.2)	205.9*(8.2)	185.1**(30.3)	134.2**(31.5)	5.5**(29.9)	0.1^{ns}(0.3)
YxW	1	11.6^{ns}(0.5)	0.1**(0.0)	10.2^{ns}(1.7)	1.4^{ns}(0.3)	0.1^{ns}(0.5)	0.6*(4.1)
Error (b)	6	5.6(1.5)	15.1(3.6)	9.3(9.1)	4.9(6.9)	0.1(3.2)	0.1(2.1)
Genotypes (G)	4	163.2**(28.8)	358.9**(57.2)	2.9^{ns}(2.4)	11.1**(13.1)	0.1^{ns}(2.8)	0.6**(15.7)
YxG	4	39.2**(6.9)	22.6**(3.6)	27.0**(22.7)	3.4*(4.0)	0.3^{ns}(6.5)	0.1^{ns}(1.9)
WxG	4	10.5^{ns}(1.8)	3.1^{ns}(0.5)	6.0*(4.9)	2.4^{ns}(2.8)	0.2^{ns}(3.7)	0.2^{ns}(5.4)
YxWxG	4	5.5^{ns}(1.0)	2.4^{ns}(0.4)	4.9*(4.0)	0.7^{ns}(0.8)	0.2^{ns}(3.3)	0.3^{ns}(7.6)
Error (c)	48	5.3(11.1)	6.1(11.5)	2.1(20.3)	66.1(15.5)	0.2(43.7)	0.1(41.7)
CV (%) (b)		5.4	9.0	10.6	8.0	44.6	36.8
CV (%) (c)		5.2	5.7	5.0	3.8	58.6	58.3

ns, *, ** = non-significant and significant at $P < 0.05$ and $P < 0.01$ probability levels, respectively. Values in parenthesis are percentages of sum squares.

Table 8. SPAD chlorophyll meter reading (SCMR), canopy temperature and stomatal conductance at R7 stage and harvest stage of five peanut genotypes grown under field capacity (FC) and 1/3 available water (1/3 AW) in the dry seasons 2010/11and 2011/12.

Genotypes (G)	SCMR$^{1/}$				Canopy temperature (°C) $^{1/}$				Stomatal conductance (cm s^{-1}) $^{1/}$			
	R7 stage		Harvest		R7 stage		Harvest		R7 stage		Harvest	
	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW	FC	1/3 AW
ICGV 98308	38.43b	44.70bc	41.37b	44.31b	28.07	29.08	27.36	28.80	0.98	0.38	0.80	0.54a
ICGV 98324	45.00a	48.10a	44.47ab	48.68a	28.06	29.08	28.34	26.52	1.23	0.40	0.54	0.63a
ICGV 98348	42.99a	45.57ab	42.90ab	46.94ab	28.63	29.18	27.62	28.22	0.98	0.55	0.61	0.87a
Tainan 9	38.00b	41.71c	33.95c	36.14c	28.18	29.66	28.01	27.05	0.77	0.48	0.42	0.18b
Tifton 8	46.26a	48.44a	44.84a	47.49ab	28.53	28.60	27.27	27.67	0.85	0.38	0.83	0.73a
Mean	42.13	45.70	41.50	44.71	28.29	29.12	27.72	27.65	0.96	0.44	0.64	0.59

$^{1/}$ = means followed by the same letter in the same column were not significantly difference (at $P < 0.05$) by DMRT

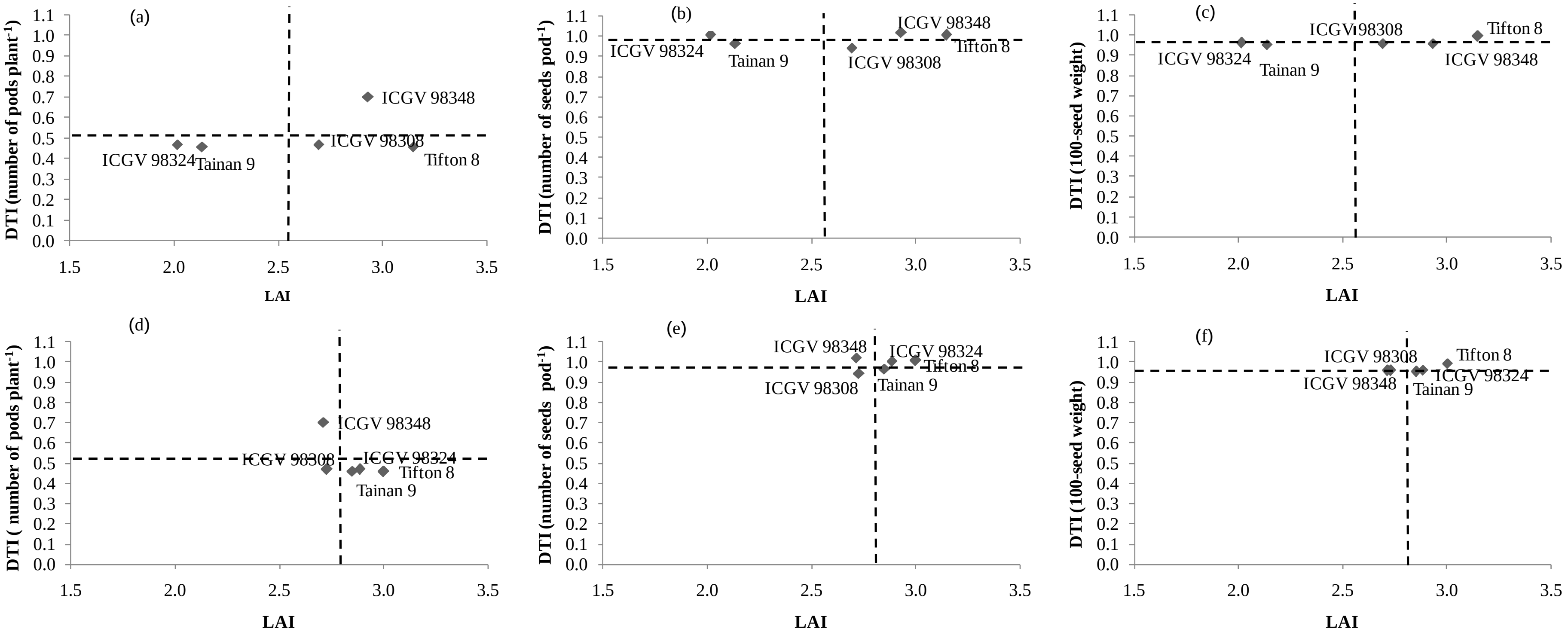

Figure 3. Relationships between leaf area index (LAI) and DTI (number of pods plant^{-1}) (a) DTI (number of seeds pod^{-1}) (b) DTI (100-seed weight) (c) at R7 stage and relationships between leaf area index (LAI) and DTI (number of pods plant^{-1}) (d) DTI (number of seeds pod^{-1}) (e) DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

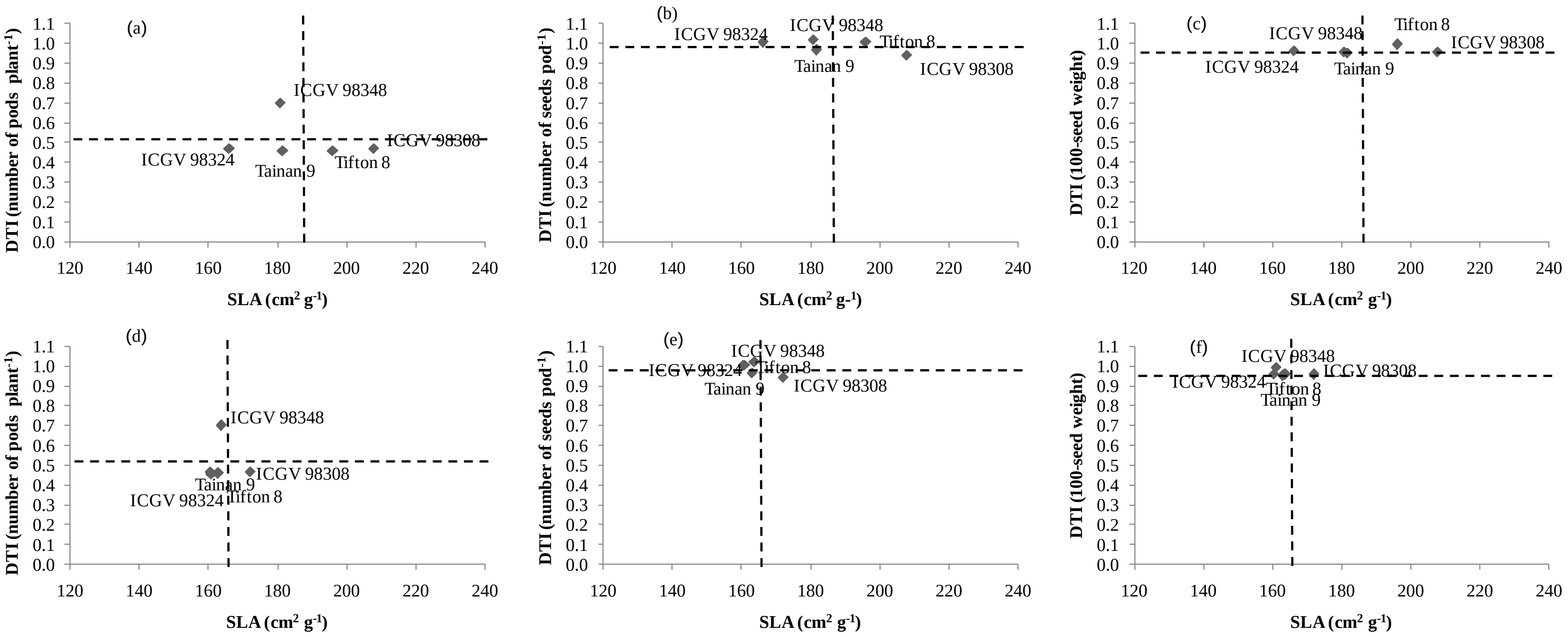

Figure 4. Relationships between specific leaf area (SLA) and DTI (number of pods plant^{-1}) (a), DTI (number of seeds pod^{-1}) (b), DTI (100-seed weight) (c) at R7 stage and relationships between specific leaf area (SLA) and DTI (number of pods plant^{-1}) (d), DTI (number of seeds pod^{-1}) (e), DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

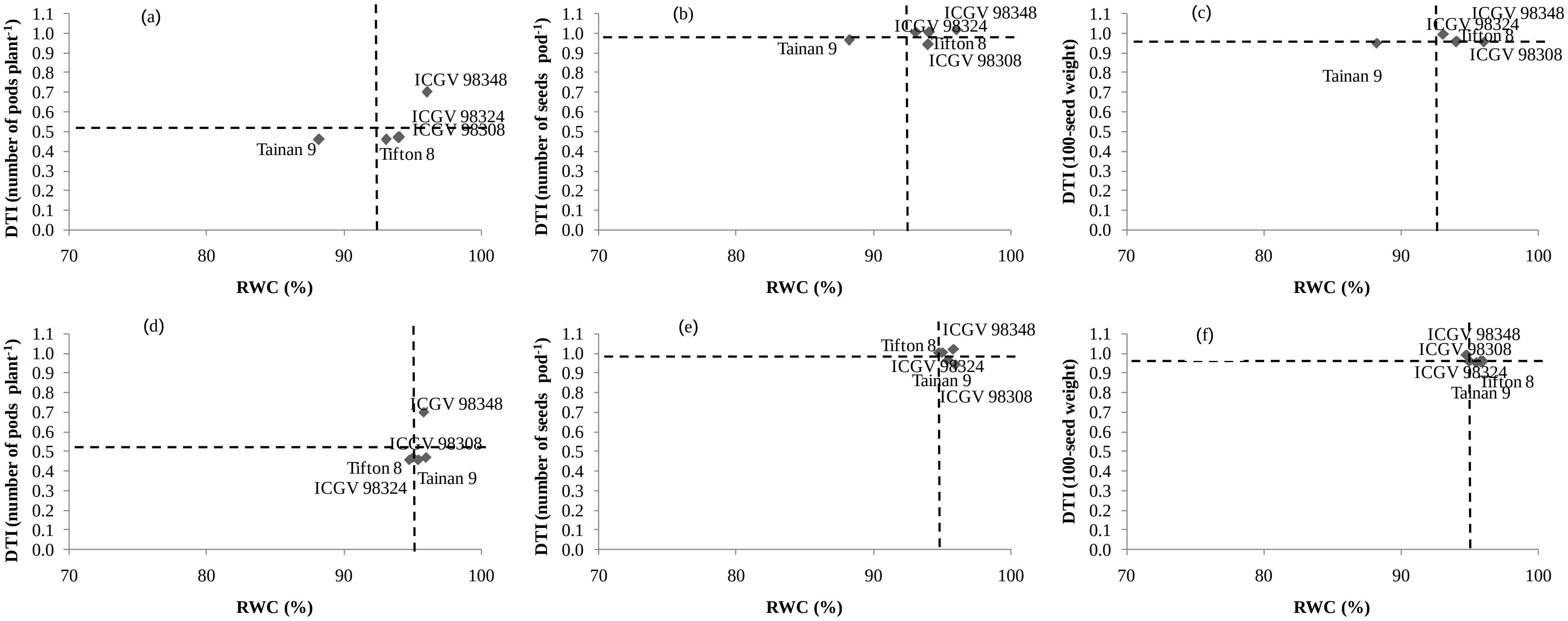

Figure 5. Relationships between RWC and DTI (number of pods plant^{-1}) (a), DTI (number of seeds pod^{-1}) (b), DTI (100-seed weight) (c) at R7 stage and relationships between RWC and DTI (number of pods plant^{-1}) (d), DTI (number of seeds pod^{-1}) (e), DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

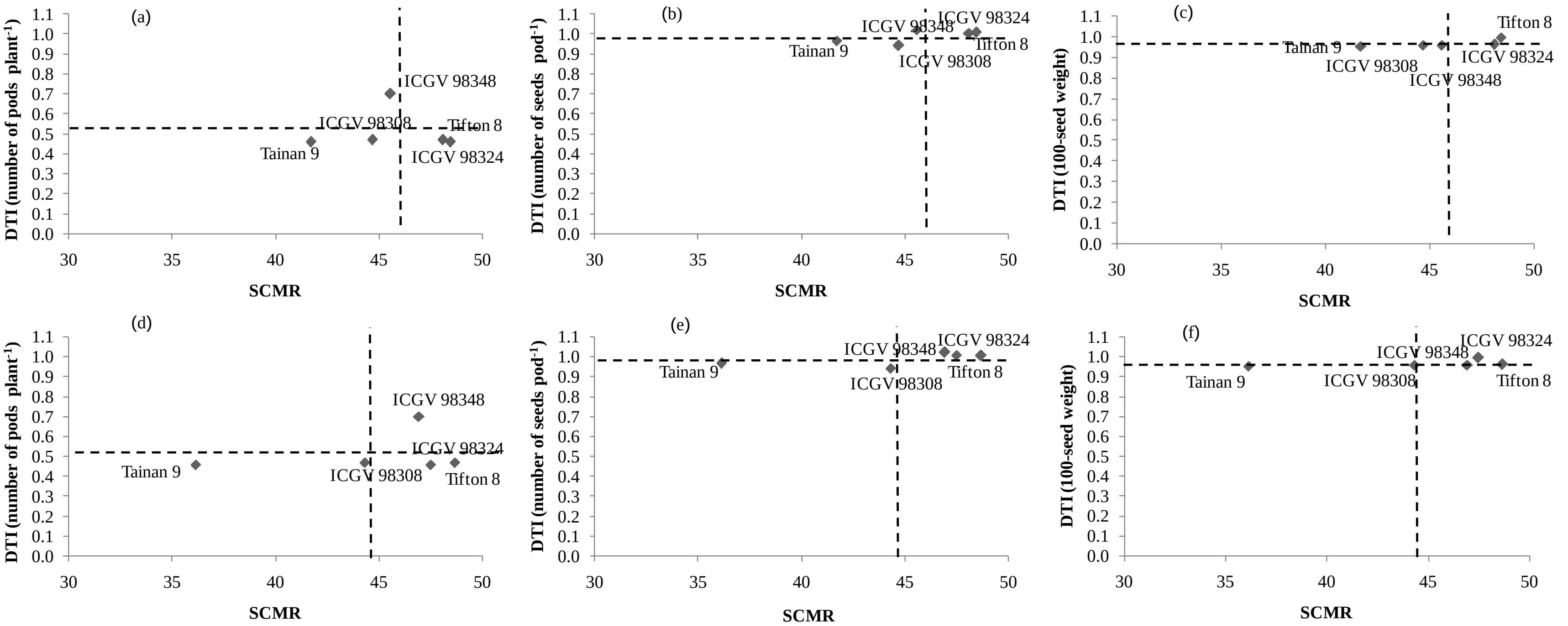

Figure 6. Relationships between SPAD chlorophyll meter reading (SCMR) and DTI (number of pods plant^{-1}) (a), DTI (number of seeds pod^{-1}) (b), DTI (100-seed weight) (c) at R7 stage and relationships between SPAD chlorophyll meter reading (SCMR) and DTI (number of pods plant^{1}) (d), DTI (number of seeds pod^{-1}) (e), DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

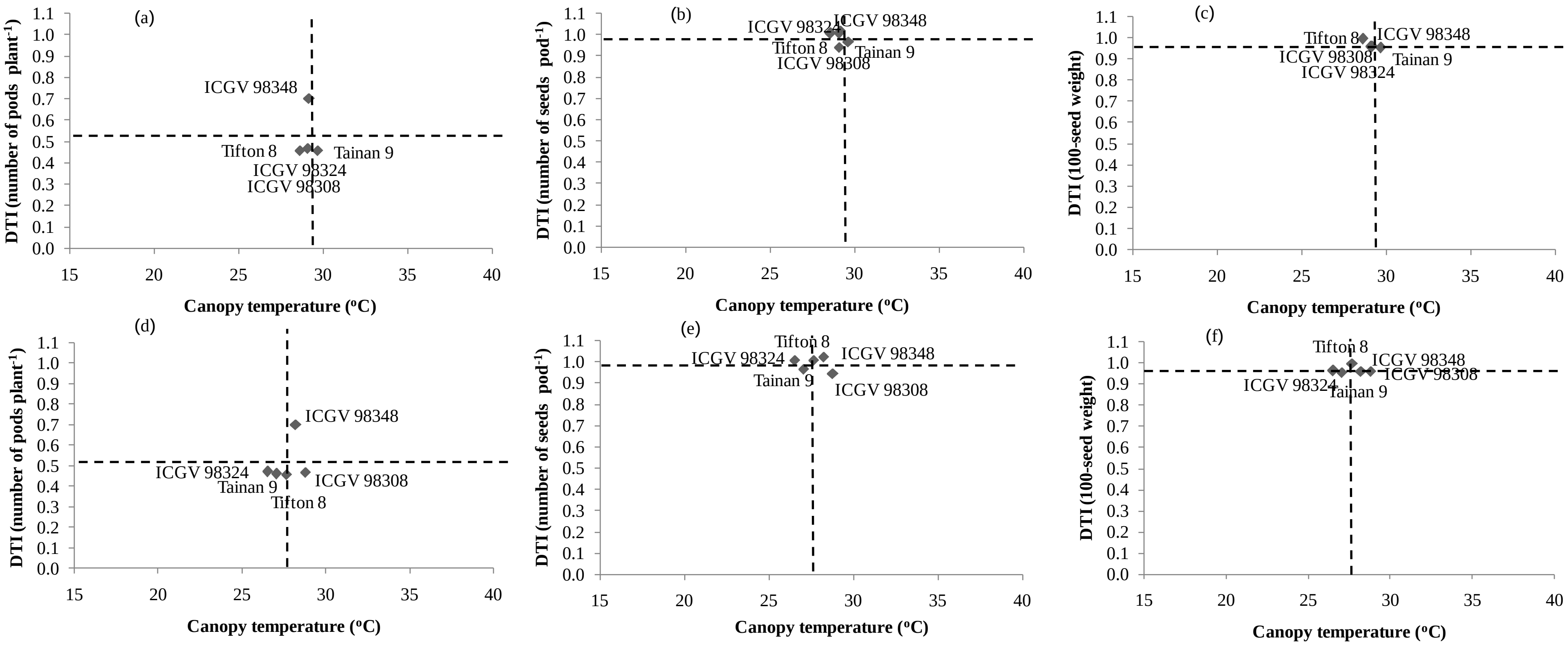

Figure 7. Relationships between canopy temperature and DTI (number of pods plant^{-1}) (a), DTI (number of seeds pod^{-1}) (b), DTI (100-seed weight) (c) at R7 stage and relationships between canopy temperature and DTI (number of pods plant^{-1}) (d), DTI (number of seeds pod^{-1}) (e), DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

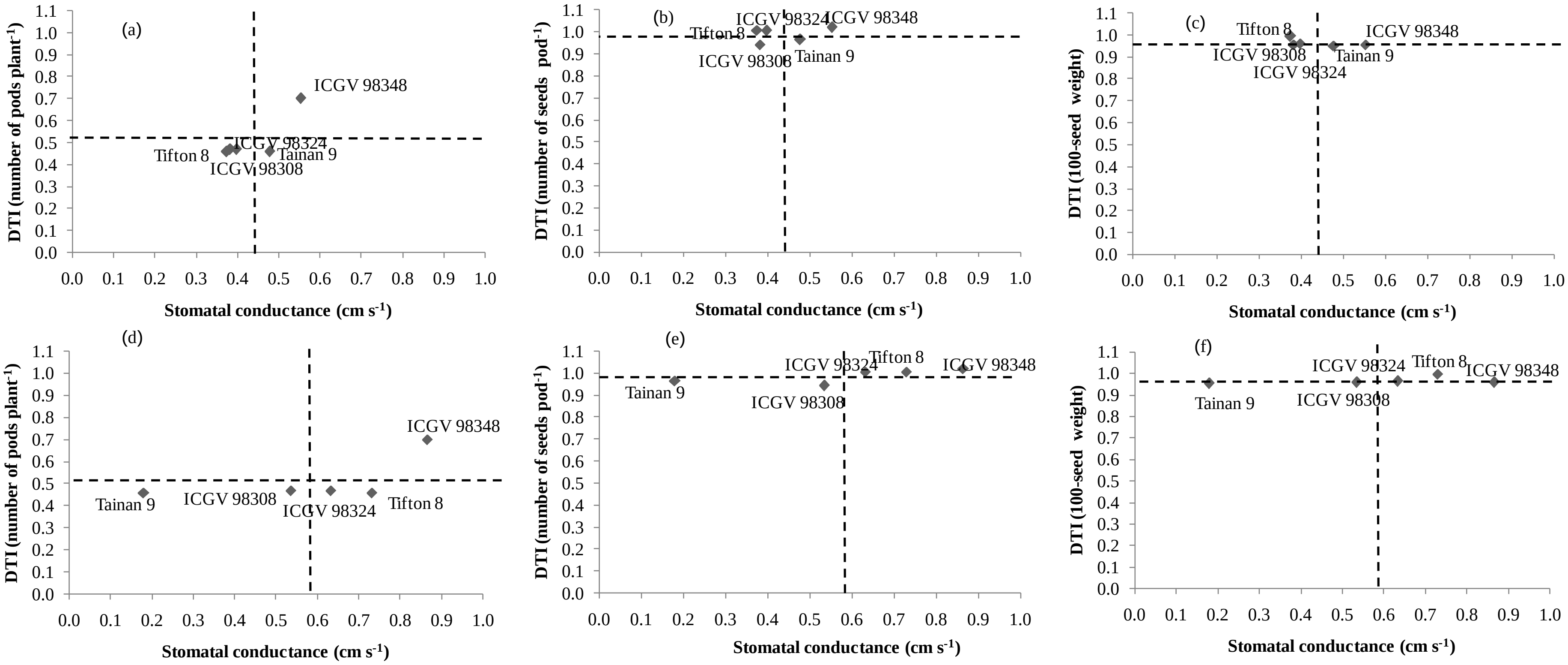

Figure 8. Relationships between stomatal conductance and DTI (number of pods plant^{-1}) (a), DTI (number of seeds pod^{-1}) (b), DTI (100-seed weight) (c) at R7 stage and relationships between stomatal conductance and DTI (number of pods plant^{-1}) (d), DTI (number of seeds pod^{-1}) (e), DTI (100-seed weight) (f) at harvest stage of five peanut genotypes grown under 1/3 available water (1/3 AW) in 2010/11 and 2011/12.

The relationship between RWC and DTI (number of pods plant^{-1}), ICGV 98348 had high RWC and had high DTI (number of pods plant^{-1}) (Figures 5a and d). The relationship between RWC and DTI (number of seeds pod^{-1}), ICGV 98324 and ICGV 98348 had high RWC and also had high DTI (number of seeds pod^{-1}) (Figures 5b and e). For the relationship between RWC and DTI (100-seed weight), all genotypes had high RWC and had high DTI (number of 100-seed weight) except for Tainan 9 (Figures 5c and f).

The relationship between SCMR and DTI (number of pods plant^{-1}), not found genotypes had high SCMR and had high DTI (number of pods plant^{-1}) at R7 stage whereas, ICGV 98348 had high SCMR and also had high DTI (number of pods plant^{-1}) at harvest (Figure 6a, d). The relationship between SCMR and DTI (number of seeds pod^{-1}), ICGV 98324 and Tifton 8 had high SCMR and also had high DTI (number of seeds pod^{-1}) at R7 stage, and ICGV 98324, ICGV 98348 and Tifton 8 had high SCMR and also had high DTI (number of seeds pod^{-1}) at harvest, and this result same in the relationship between SCMR and DTI (100-seed weight) at R7 stage and harvest (Figures 6b, e, c and f).

The relationship between canopy temperature and DTI (number of pods plant^{-1}), not found genotypes had low canopy temperature and had high DTI (number of pods plant^{-1}) at R7 stage and harvest (Figures 7a and d). The relationship between canopy temperature and DTI (number of seeds pod^{-1}), Tifton 8 and ICGV 98324 had low canopy temperature and had high DTI (number of seeds pod^{-1}) at R7, whereas only ICGV 98324 had low canopy temperature and had high DTI (number of seeds pod^{-1}) at harvest, and this result same in the relationship between canopy temperature and DTI (100-seed weight) at R7 stage and harvest (Figures 7b, e, c and f).

The relationships between stomatal conductance and DTI (number of pods plant^{-1}), DTI (number of seeds pod^{-1}) and DTI (100-seed weight) followed the same pattern at R7 stage (Figure 8). ICGV 98348 had high stomatal conductance and also had high DTI (number of pods plant^{-1}), DTI (number of seeds pod^{-1}) and DTI (100-seed weight) at R7 stage (Figures 8a, b, c and d), whereas ICGV 98348, Tifton 8 and ICGV 98324 had high stomatal conductance and also had high DTI (number of seeds pod^{-1}) and DTI (100-seed weight) at harvest (Figures 8e and f).

DISCUSSION

Relationships between physiological traits with yield components

Physiological traits have been known to be related to yield in many crop species. Under drought conditions, relative water content explains how plant can maintain high water that contributes to normal biochemical activities. SCMR contributes to high photosynthesis and ultimately contributes to yield. SLA indicates high chlorophyll content in leaves that contributes to high photosynthesis and yield.

The studies on drought resistance in peanut were completed in this study. In the previous investigations of the project, continuous long term drought (Songsri *et al.*, 2008b, 2009), pre-flowering drought (Puangbut *et al.*, 2009, 2011; Wunna *et al.*, 2009) and mid-season drought (Jongrungklang *et al.*, 2012) were studied. In this study, the highlight of the research project was to understand the relationships between physiological traits and yield components. A better understanding on the relationships between physiological traits and yield components in peanut under terminal drought should provide an appropriate selection strategy for better genotypes to sustain yield under terminal drought.

We raised the questions that in peanut genotypes with high pod yield under terminal drought which yield components that contributed to high pod yield and which physiological traits that were associated with high pod yield. In this study, peanut genotypes with high pod yield under terminal drought as indicated by high drought tolerance index (DTI) for pod yield and DTI for yield components had some good physiological traits that may contribute to drought resistance in these genotypes.

ICGV 98324 had high RWC, SCMR and low SLA and canopy temperature and had high DTI for number of seeds pod^{-1} and DTI for 100-seed weight ICGV 98348 had high stomatal conductance, LAI, RWC, SCMR and low SLA and had high DTI for number of pods plant^{-1}, DTI for number of seeds pod^{-1} and DTI for 100-seed weight. Tifton 8 had high LAI, RWC, SCMR and low SLA and canopy temperature and had high DTI for number of seeds pod^{-1} and DTI for 100-seed weight.

The results indicated that peanut genotypes with high SCMR, RWC, LAI, stomatal conductance and lower SLA and canopy temperature under terminal drought had higher pod yield under drought. In previous study, peanut genotypes with high SCMR and low SLA were more tolerant to long term drought (Songsri *et al*., 2009). SCMR under pre-flowering drought after recovery was moderately correlated with number of pods plant^{-1} (Puangbut *et al*., 2011). SCMR evaluated at 60 days after emergence under early drought was significantly correlated with number of pods plant^{-1} (Wunna *et al*., 2009), and SCMR under drought at pod setting growth stage was correlated with number of pods plant^{-1} (Painawadee *et al*., 2009).

The contrasting results were also reported. Boontang *et al*. (2010) found that SCMR evaluated at 80, 90 and 100 DAP under terminal drought with the same genotypes were not related to number of pods plant^{-1}. The difference in the results may be due to the difference in the weather and drought severity among the experiments. In addition, the evaluation of SCMR at late growing season was too late because of the old age plants.

In general, pod yield and yield components are well associated with physiological traits. The results suggested that yield components and physiological traits are useful as selection criteria for pod yield under drought conditions.

Yield components

In this study, number of pods plant^{-1} was reduced from 29.46 pods under well watered conditions to 15.12 pods under drought conditions, and peanut genotypes were significantly different for this trait. Reductions in number of pods plant^{-1} were more severe than reductions in number of seeds pod^{-1} and seed size. The reduction in number of seeds pod^{-1} though significant was not too severe, ranging from 1.67 to 1.65 seeds. The reduction in seed size from 56.55 g/100-seed weight under well-watered conditions to 54.67 g/100-seed weight. Under drought was not severe compare to the reduction in number of pods plant^{-1}.

In general, number of pods plant^{-1} is greatly affected by drought, which occurs at any growth stage, whereas the reduction in number of seeds pod^{-1} and seed size is less affected. The results from previous findings in peanut and other pulses also indicated greater reduction in number of pods plant^{-1} than number of seeds pod^{-1} and seed size.

In previous study under terminal drought, Boontang *et al*. (2010) found that small reduction in number of pods plant^{-1}, and the reduction in seed size, thought significant, was not too severe. Under early season drought, the reductions were moderate to high for number of pods plant^{-1}, high for seed size and moderate in number of seeds pod^{-1} (Wunna *et al*., 2009). Under long term drought, Songsri *et al*. (2008b) found that the reductions were high for number of pods plant^{-1} and seed size, but low for number of seeds pod^{-1}.

In pulses, the reductions in number of pods plant^{-1} were also high in mungbean, cowpea, soybean and peanut, the reductions in number of seeds pod^{-1} were moderate, and the reductions in seed size were low (Pandey *et al*., 1984). The results in this study in general supported previous findings. However, the results were slightly different in magnitude of reductions among different studies, and this could be due to differences in materials used and experimental conditions.

The reduction in number of pods plant^{-1}could be possibly due to low number of pegs that can form pods and only the pegs occur at early growth stages can form mature pods (Songsri *et al*., 2008b). Peanut has 2 to 5 number of seeds pod^{-1} depending on types of peanut (Michael, 2006). In general, Spanish and Virginia type peanuts have fewer number of seeds pod^{-1} than Valencia peanut (Kottapalli *et al*., 2008). Late-season drought in the longer season reduced pod yields in Virginia type more severely than in the Spanish type because of the reduction in number of pods plant^{-1} and kernel size (Wright *et al*., 1991).

The reduction in number of seeds pod^{-1} in peanut was less severe compared to other pulses possibly because of its low number of seeds pod^{-1}. Faisal and Abdel (2010) reported in cowpea that number of pods plant^{-1} and number of seeds pod^{-1} of cowpea were the most important traits for maintaining stable and high seed yield, may be due to high number of seeds pod^{-1} in cowpea.

Peanut has subterranean pods that can imbibe water and nutrients especially for calcium for pod development (Skelton and Shear, 1971). The ability to imbibe calcium is limited and peanut genotypes with different pod characters have different ability to imbibe calcium that is important for pod development (Tillman *et al*., 2010). In general, small pods imbibe calcium better than large pods (Walker, 1975). Therefore, reduction in seed size was greater in peanut genotypes with larger seeds than in peanut genotypes with smaller seeds.

Vorasoot *et al*. (2003) found that large seed genotypes were more sensitive to environmental change than smaller seed genotypes. Songsri *et al*. (2008b) also found that KK 60-3 and Tifton 8 had large seed size under non-stressed conditions and also had higher rates of reduction in seed size than did the medium seed genotypes under stressed conditions.

In a parallel study for biomass, pod yield and harvest index, the peanut genotypes with high pod yield under terminal drought were ICGV 98324 and ICGV98348, whereas Tifton 8 had higher biomass under FC and terminal drought and its pod yield was also high under terminal drought. ICGV 98324 had high pod yield under FC and drought and also had high harvest index. ICGV 98348, in contrast, had low pod yield under FC but had high pod yield under drought (Koolachart *et al*., 2013).

Although the three genotypes were drought resistant, they were different. Tifton 8 was drought resistant because of high biomass and pod yield under FC (high potential). ICGV 98324 was drought resistance because of high pod yield under FC although its biomass was lower than that of Tifton 8, whereas ICGV 98348 was drought resistant because of low reduction in pod yield under drought.

In this study, ICGV 98324, ICGV 98348 and Tifton 8 were very similar in number of pods plant^{-1} in both water conditions, but they were different in number of seeds pod^{-1} and seed size. Number of pods plant^{-1} is an important character to maintain high yield under drought in these peanut genotypes. For number of seeds pod^{-1}, however, all peanut genotypes could maintain high number of seeds pod^{-1} under drought especially for Tainan 9 with the highest number of seeds pod^{-1}, but number of seeds pod^{-1} contributed less to yield because high number of seeds pod^{-1} was often associated with small seed size. In contrast to Tainan 9, Tifton 8 had the highest seed size in both seasons, but its large seed size did not contributed much to high pod yield.

In previous studies under different drought conditions, ICGV98348 also had high number of pods plant^{-1} (Songsri *et al*., 2008b; Boontang *et al*., 2010), Tainan 9 had high number of seeds pod^{-1} (Songsri *et al*., 2008b) and Tifton 8 had high seed size (Songsri *et al*., 2008b; Boontang *et al*., 2010).

The results indicated that under different drought conditions, peanut genotypes responded very similar in pattern but different in magnitude. The drought resistant genotypes had either high potential under FC or low reduction under drought. Drought affected number of pods plant^{-1} greater than number of seeds pod^{-1} and seed size.

In peanut genotypes with high potential, although it had large reductions in number of pods plant^{-1}, number of seeds pod^{-1} and seed size, the performance for these traits in these peanut genotypes was still higher than average. In some peanut genotypes with low potential, the performance for these traits under drought was comparable to those with high potential. The results highlighted the importance of high potential and low reduction in maintaining high pod yield under drought.

The results are conclusive for the contribution of high number of pods plant^{-1} under any drought conditions to pod yield. High number of pods plant^{-1} under drought could be obtained either by selecting the peanut genotypes with high number of pods plant^{-1} under non-stress conditions or selecting the peanut genotypes with low reduction in number of pods plant^{-1} under drought.

Physiological traits

In this study, drought reduced LAI, SLA, RWC and stomatal conductance, but it increased SCMR and canopy temperature. The effects of terminal drought on these physiological traits were rather similar to early season drought (Puangbut *et al*., 2009), mid-season drought (Lal *et al*., 2009) and long term drought (Songsri *et al*., 2009). Therefore, it has been concluded that drought at any conditions reduces LAI, SLA, RWC and stomatal conductance, but increase SCMR and canopy temperature.

The decrease in LAI was associated with low leaf area, and the decrease in photosynthetic capacity was attributed to reduction of chlorophyll in leaf. Drought reduced photosynthetic rate in peanut because of partial closure of leaf stomata that inhibited the diffusion of carbon dioxide to the leaves (Bhagsari *et al*., 1976).

RWC is directly related to SLA and peanut genotypes with drought resistance can maintain high RWC in leaves (Nautiyal *et al*., 2002). Peanut genotypes with low SLA (thick leaf) could maintain higher RWC in the leaf (Nautiyal *et al*., 2002; Songsri *et al*., 2009).

SCMR is an indicator of the photosynthetic capacity of leaves and positively correlated with chlorophyll content and chlorophyll density (Arunyanark *et al*., 2008). Moreover, Upadhyaya *et al*. (2005) found that SCMR was correlated with pod yield of peanut.

Increase in canopy temperature was expected under drought conditions. Reduction in stomatal conductance is associated with low water transpiration and therefore increases canopy temperature. Jongrungklang *et al*. (2008) found that canopy temperature of peanut under stressed conditions had higher than non–stressed conditions. The peanut genotypes with low canopy temperature had higher transpiration and higher CO_2 exchange rate than peanut genotypes with high canopy temperature (Jongrungklang *et al*., 2008).

Photosynthesis is reduced by water stress due to reduced stomatal conductance and reductions in leaf area. As moisture stress increases, stomata start closing as a mechanism to reduce transpiration. Consequently, the entry of carbon dioxide is also reduced (Reddy *et al*., 2003). Water conductivity of the stomata in peanut is reduced due to the partial closure of stomata, resulting in low CO_2 diffusion into the leaf and reduction in photosynthesis (Ravindra *et al*., 1990).

Under drought conditions Tifton 8 tended to had high LAI under both stages due to Tifton 8 had the highest biomass, could maintain leaf area. Photosynthesis is closely related to biomass production in most crops (Anyia and Herzog, 2004). This similar to previous result from Puangbut *et al*. (2009) found that Tifton 8 had the highest for LAI under early drought conditions. Moreover, Wunna *et al*. (2009) found that higher chlorophyll density under early drought might support the biomass production instead of partitioning to sink. This indicated that Tifton 8 had high leaf area, increase photosynthetic capacity and chlorophyll in leaves.

In present study it seems like that, ICGV 98324 has better adaptation for SLA in response to drought. ICGV 98324 had the lowest SLA at both stages although there were no significant differences under both stages. This similar to previous result from Puangbut *et al*. (2009) and Songsri *et al*. (2009) found that ICGV 98324 had low SLA. Peanuts with low specific leaf area or thick leaf when water stress can maintain high RWC, carbon exchange rate (CER), stomatal conductance and harvest index (HI). SLA was associated with variation in photosynthetic capacity and chlorophyll density expressed as high SCMR (Wright and Nageswara Rao, 1994; Nageswara Rao *et al*., 1995, 2001). This indicated that ICGV 98324 had high photosynthetic capacity and chlorophyll density in leaves.

ICGV 98324 and Tifton 8 tended to high SCMR under water stress, whereas Tainan 9 had the lowest SCMR. This indicated that ICGV 98324 and Tifton 8 could maintain chlorophyll in leaves. Chlorophyll plays an important role in plants. Chlorophyll is the pigment that acts primarily on the photosynthesis of plants with light in the wavelength visible to the eye (visible light) to provide energy (Bowyer and Leegood, 1997). Chlorophyll has been used as an index measuring the ability of photosynthesis and growth of plants. ICGV 98324 had high SCMR and the results also support previous finding (Boontang *et al*., 2010; Puangbut *et al*. 2009; Songsri *et al*., 2009) found that ICGV 98324 had high SCMR. Tifton 8 had high SCMR due to Tifton 8 had the highest LAI. This indicated that Tifton 8 had high leaves affected to could maintain chlorophyll in leaves.

ICGV 98324 tend to low canopy temperature than other genotypes although there were no significant differences. This indicated that ICGV 98324 had high transpiration affected to have higher CO_2 exchange rate than other genotypes.

ICGV 98348 had high stomatal conductance value than other genotypes under terminal drought. This indicated that ICGV 98348 genotype had higher CO_2 exchange rate because it had high transpiration that resulted in higher photosynthetic capacity. Stomatal conductance in peanut was closely related to water status (Bennet *et al*., 1984).

Under terminal drought, ICGV 98324, ICGV 98348 and Tifton 8 performed well for physiological traits. The results indicated that physiological traits associated with yield productivity under terminal drought. The results suggested that peanut genotypes performed well for physiological traits that ability to maintain pod yield under drought conditions.

CONCLUSION

This study determined the relationships between physiological traits and yield components related to pod yield of peanut genotypes under terminal drought conditions. If all peanut genotypes were considered, the relationships between physiological traits and yield components were not clear. However, if individual peanut genotypes were considered, the clear relationships were observed. ICGV 98324, ICGV 98348 and Tifton 8 performed well for physiological traits and yield components. The results suggested that ability to maintain physiological traits and yield components under stress condition could aid peanut genotypes in maintaining high pod yield under water limited conditions.

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