Australian Journal of Crop Science

AJCS

AJCS 7(11):1627-1633 (2013) ISSN:1835-2707

Response of reproductive parts of peanut genotypic variation and their contributions to yield after pre-flowering drought

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Abstract

Pre-flowering drought (PFD) has been observed to increase yield of peanut. There is limited information on genotypic variation in reproductive response to PFD and contributions to yield under PFD conditions. The objective of this study was to determine the variability in reproductive response of peanut genotypes subjected to PFD and their contributions to yield. A field experiment was conducted in a split-plot design with four replications for two seasons. PFD (1/3 available water from emergence to 40 days after emergence) and irrigated control were assigned in main-plots, and 11 peanut genotypes were assigned in sub-plots. Data were recorded for reproductive parts (number of flowers, number of pegs, number of pods, and number of mature pods per plant), seed per pod, 100 seed weight and pod yield at harvest. Genotypes differed in their response to PFD, but PFD increased number of flowers, number of pegs, number of pods and number of mature pods per plant in many genotypes. Production of reproductive parts differed significantly under the PFD with ICGV 98300, ICGV 98303, ICGV 98330 and Tainan 9 having the highest in number of flowers, number of pegs, number of pods and number of mature pods. These genotypes also had high yield under PFD conditions. The results indicate that number of mature pods were the most important component contributing to high yield under PFD conditions. Thus, selecting for increased number of mature pods under PFD would be expected to improve pod yields.

Keywords: *Arachis hypogaea*; reproductive efficiency; water stress.
Abbreviations: AW_available water; DAE_days after emergence; DMRT_Duncan's multiple range test; DW_sample dry weight; FC_field capacity; PFD_pre-flowering drought; FW_sample fresh weight; RWC_relative water content; TW_sample turgid weight.

Introduction

Drought is an important factor limiting the yield and quality of peanut. Severity of drought stress depends on the stage of crop development, the duration of stress period and the magnitude of drought stress (Wright and Nageswara Rao, 1994). Several researchers have revealed that drought in the early season, or pre-flowering drought, can increase yield (Puangbut et al., 2010, Nuatiyal et al., 1999, Nageswara Rao et al., 1985). However, Puangbut et al. (2010) also reported that some genotypes exhibited decreased yield under pre-flowering drought. This enhanced or decreased yield could be associated with the development of one or more reproductive parts, i.e. flowers, pegs or mature pods. Thus, the response of these reproductive parts to pre-flowering drought might explain these yield changes. Although variation in reproductive parts greatly affected pod yield under drought conditions (Nuatiyal et al., 1999; Awal and Ikeda, 2002; Nageswara Rao et al., 1985), little information on genotypic variation in reproductive parts in response to pre-flowering drought is available. Previous studies indicated that drought during flowering or pod formation and prolonged drought can substantially reduce yield of peanut (Nautiyal et al., 1999; Songsri et al., 2008; Awal and Ikeda, 2002; Nautiyal et al 1999; Songsri et al., 2008). On the contrary, drought during the vegetative phase or pre-flowering has only small effects on yield (Puangbut et al., 2009a; 2010). In a greenhouse study, plants recovered from drought by initiating a flush of flowering after re-watering (Awal and Ikeda, 2002). This study suggested that the initiation of a strong flowering flush after recovery may compensate for physiological drought damage. However, the contributions of conversions of flowers to pegs, and pods to mature pods is not well understood; similarly, there is limited information on genotypic variation for reproductive development after pre-flowering drought. Recent reports have demonstrated that physiological traits (such as leaf area, transpiration efficiency, N_2 fixed, root dry weight) were important traits contributing to yield under pre-flowering drought (Puangbut et al., 2009b, 2010, 2011a; Songsri et al 2009a; Ali et al., 2009). However, very limited information has been available for the contribution of reproductive development to yield following pre-flowering drought conditions. Selection of superior peanut genotypes with the ability to maintain these physiological traits coupled with increased production of reproductive parts might help to improve yield under pre-flowering drought. A better understanding of their contribution to yield is important for peanut breeding. Therefore, the objective of this study was to investigate the variability in reproductive response of peanut genotypes subjected to pre-flowering drought and their contributions to yield.

Table 1. Number of mature pods per plant, number of seed per pod and 100-seed weight by 11 peanut genotypes under irrigated and pre-flowering drought (PFD) in the rainy (2005) and dry season (2005/06).

	Rainy season			Dry season		
Genotypes	Irrigated	PFD	LSD	Irrigated	PFD	LSD
Number of mature pods plant^{-1}						
ICGV 98300	12.7 cd [1/]	17.0 bc	*	14.0 ab	22.0 ab	**
ICGV 98303	10.9 d	21.1 a	**	15.0 ab	30.0 a	**
ICGV 98305	14.2 b	10.2 de	*	14.2 ab	10.2 d	*
ICGV 98308	13.4 bc	12.6 d	ns	13.4 b	15.0 c	*
ICGV 98324	15.3 a	14.0 cd	ns	11.3 b	16.0 bc	**
ICGV 98330	13.0 c	18.5 b	*	13.0 b	18.5 b	*
ICGV 98348	7.9 e	15.3 c	**	9.2 c	15.3 c	**
ICGV 98353	10.2 d	7.5 e	*	10.2 c	8.2 d	*
Tainan 9	11.2 d	20.5 a	**	18.0 a	26.5 a	**
KK 60-3	8.6 e	14.0 cd	**	8.6 c	14.0 c	**
Tifton – 8	9.5 de	13.5 d	**	9.5 c	14.5 c	**
Mean	11.5	14.9		12.4	17.3	
Number of seed pod^{-1}						
ICGV 98300	1.4	1.8	ns	1.9	2.1	ns
ICGV 98303	1.6	1.8	ns	1.8	2.0	ns
ICGV 98305	1.7	1.8	ns	1.8	1.9	ns
ICGV 98308	1.7	2.0	ns	1.9	1.9	ns
ICGV 98324	1.4	2.1	ns	2.1	1.9	ns
ICGV 98330	1.6	1.7	ns	1.9	1.8	ns
ICGV 98348	1.5	1.7	ns	1.9	1.8	ns
ICGV 98353	1.6	1.8	ns	2.1	1.8	ns
Tainan 9	1.6	1.8	ns	1.7	1.8	ns
KK 60-3	1.6	1.9	ns	1.7	1.8	ns
Tifton – 8	1.2	1.8	ns	1.7	2.0	ns
Mean	1.5	1.8		1.9	1.9	
100 seed weight (g)						
ICGV 98300	38.4 b	45.2 b	**	45.7 d	47.5 d	ns
ICGV 98303	39.3 b	47.0 b	**	54.8 c	56.9 b	ns
ICGV 98305	38.6 b	36.5 c	ns	54.2 c	50.6 c	*
ICGV 98308	36.2 b	35.6 c	ns	55.2 b	57.0 b	*
ICGV 98324	38.7 b	37.2 c	ns	55.6 b	58.6 b	*
ICGV 98330	34.4 c	44.1 b	**	56.4 b	57.4 b	ns
ICGV 98348	32.3 c	42.3 b	**	50.2 c	43.4 d	**
ICGV 98353	36.8 b	36.3 c	ns	53.5 c	50.6 c	*
Tainan 9	35.4 c	47.4 b	**	55.9 b	57.1 b	ns
KK 60-3	46.1 a	50.0 b	*	71.1 a	74.4 a	*
Tifton – 8	39.6 b	58.6 a	**	68.9 a	70.8 a	ns
Mean	37.8	43.7		56.5	56.8	

[1/] Means in the same column with the same letters are not significantly different (at $p < 0.05$) by DMRT. ns, * and ** non-significant, significant at $p<0.05$ and significant at $p<0.01$, respectively by LSD.

Results

Effect of PFD on pod yield

Results for pod yield were presented by Puangbut et al. (2009a). They revealed that the imposition of PFD followed by re-watering resulted in increased pod yield compared with fully-irrigated conditions.

Effect of PFD on yield components

Significant interactions between genotypes and water regimes were found for all variables and seasons except numbers of seeds per pod. Genotypes differed significantly in their response to water regimes, as shown by pairwise comparisons for each genotype (Tables 1, 2, and 3) and genotypes differed significantly within water regimes for all variables except seed per pod. Genotypes differed in the numbers of mature pods and seed size within irrigated and PFD conditions in both seasons (Table 1). PFD significantly increased number of mature pods in 7 of 11 genotypes in both seasons, and ICGV 98303 and Tainan 9 had the highest number of mature pods under PFD in both seasons. The number of mature pods in these genotypes also increased significantly under PFD compared to irrigated conditions. Genotypes differed significantly for seed size under PFD with KK 60-3 and Tifton-8 having the highest seed size in both seasons.

Effect of PFD on reproductive parts and reproductive efficiency

There were significant differences among genotypes for number of flowers, number of pegs and number of pods under irrigated and PFD treatment in both seasons (Table 2). PFD significantly increased number of flowers in 7 and 9 genotypes in the rainy and dry season, respectively, number of pegs in 8 and 9 genotypes in the rainy and dry season, respectively, and number of pods in 7 of 11 genotypes in both seasons. In the rainy season, ICGV 98303, ICGV 98330 and Tainan 9 had the highest number of flowers, number of pegs

Table 2. Numbers of flowers, pegs and pods per plant produced by 11 peanut genotypes under irrigated and pre-flowering drought (PFD) conditions in the rainy (2005) and dry seasons (2005/06).

	Rainy season			Dry season		
Genotypes	Irrigated	PFD	LSD	Irrigated	PFD	LSD
Number of flowers plant^{-1}						
ICGV 98300	92 a [1/]	104 b	**	93 a	124 b	**
ICGV 98303	87 b	140 a	**	80 b	136 a	**
ICGV 98305	94 a	85 c	*	68 cd	59 e	*
ICGV 98308	90 a	72 d	**	63 d	76 d	*
ICGV 98324	90 a	87 d	ns	62 d	80 d	**
ICGV 98330	88 b	120 ab	**	62 d	79 d	*
ICGV 98348	80 bc	110 b	**	64 d	74 d	*
ICGV 98353	86 b	69 d	**	66 d	52 e	*
Tainan 9	76 c	136 a	**	75 bc	128 b	**
KK 60-3	62 d	102 b	**	68 cd	87 c	*
Tifton – 8	63 d	83 c	**	64 d	85 c	*
Mean	83	101		70	89	
Number of pegs plant^{-1}						
ICGV 98300	39 ab	51 c	*	45 a	76 b	**
ICGV 98303	44 a	78 a	**	47 a	86 a	**
ICGV 98305	40 b	36 d	ns	41 a	38 e	ns
ICGV 98308	38 ab	38 d	ns	28 c	48 d	**
ICGV 98324	42 a	48 c	*	25 c	54 d	**
ICGV 98330	44 a	72 a	**	32 bc	56 d	**
ICGV 98348	37 ab	68 b	**	34 bc	44 d	*
ICGV 98353	37 ab	34 e	ns	32 bc	29 f	ns
Tainan 9	36 ab	80 a	**	38 b	78 b	**
KK 60-3	26 c	50 c	**	28 c	68 c	**
Tifton – 8	28 c	41 c	**	25 c	62 c	**
Mean	37	54		34	58	
Number of pods plant^{-1}						
ICGV 98300	19 a	24 b	*	25 a	33 b	*
ICGV 98303	20 a	30 a	**	26 a	38 a	**
ICGV 98305	19 a	16 c	ns	25 a	22 c	ns
ICGV 98308	19 a	14 c	ns	22 b	25 c	ns
ICGV 98324	21 a	19 d	ns	16 c	28 b	*
ICGV 98330	18 b	26 b	**	20 b	30 b	**
ICGV 98348	16 c	22 bc	*	23 b	25 c	ns
ICGV 98353	16 c	14 c	ns	21 b	16 d	*
Tainan 9	17 b	25 b	*	28 a	34 b	*
KK 60-3	16 c	21 bc	*	20 b	26 c	*
Tifton – 8	15 c	21 bc	*	20 b	24 c	*
Mean	18	21		22	27	

[1/]Means in the same column with the same letters are not significantly different (at $p < 0.05$) by DMRT, ns , * and ** non-significant, significant at p<0.05 and significant at p<0.01, respectively by LSD.

and number of pods under PFD conditions, whilst ICGV 98308 and ICGV 98353 had the lowest. In the dry season, the greatest numbers of flowers, pegs, and pods were found in ICGV 98300, ICGV 98303 and Tainan 9, while ICGV 98305 and ICGV 98353 had the lowest under PDF conditions. There were significant differences among genotypes for conversion of flowers to pegs, pegs to pods and of pods to mature pods under irrigated and PFD conditions in both seasons (Table 3). PFD significantly increased conversion of flowers to pegs in 7 and 10 genotypes (rainy and dry season, respectively), of pegs to pods in 7 and 9 genotypes (rainy and dry season, respectively), and of pods to mature pods in 6 and 7 genotypes in rainy and dry season, respectively. In the rainy season, PFD increased conversion of flowers to pegs by 11%, of pegs to pods 7% and of pods to mature pods by 6% compared with irrigated conditions (Table 3). The greatest conversion of flowers to pegs under PFD conditions was observed in ICGV 98348 followed by ICGV 98303 and ICGV 98330, while ICGV 98305 followed by ICGV 98353 had the lowest. The greatest conversion of pegs to pods under PFD conditions was found in IGCV 98303, while ICGV 98353 had the lowest. Under PFD conditions, Tainan 9 exhibited the greatest conversion of pods to mature pods, and ICGV 98353 showed the lowest. In the dry season, PFD increased conversion of flowers to pegs by 34%, of pegs to pods by 10% and of pods to mature pods by 10% compared to the irrigated conditions (Table 3). The greatest conversion of flowers to pegs was observed in KK 60-3 and Tifton-8, while ICGV 98353 had the lowest conversion under PFD conditions. The greatest conversion of pegs to pods was found in IGCV 98303, while ICGV 98353 had the lowest under PFD conditions. Under PFD conditions, ICGV 98303 and Tainan 9 exhibited the greatest conversion of pods to mature pods and ICGV 98305 showed the lowest.

Table 3. Conversion of flowers to pegs and pods to mature pods of 11 peanut genotypes under irrigated and pre-flowering drought (PFD) in the rainy (2005) and dry seasons (2005/06).

	Rainy season			Dry season		
Genotypes	Irrigated	PFD	LSD	Irrigated	PFD	LSD
Flowers to pegs (%)						
ICGV 98300	43.5 c [1/]	49.9 c	*	48.4 bc	61.3 c	**
ICGV 98303	50.6 b	60.0 b	**	58.8 a	63.2 b	*
ICGV 98305	42.6 c	42.4 c	ns	60.3 a	64.4 b	*
ICGV 98308	51.1 b	52.8 c	ns	44.4 c	63.2 b	**
ICGV 98324	55.6 a	55.2 c	ns	40.3 c	67.5 bc	**
ICGV 98330	50.0 b	60.0 b	**	51.6 ab	70.9 b	**
ICGV 98348	50.0 b	70.9 a	**	53.1 ab	59.5 c	*
ICGV 98353	46.5 c	49.3 c	*	48.5 b	55.8 d	**
Tainan 9	47.4 c	58.8 bc	**	50.7 ab	60.9 c	*
KK 60-3	54.8 b	49.0 c	**	41.2 c	78.2 a	**
Tifton – 8	44.4 c	49.4 c	*	39.1 d	72.9 a	**
Mean	48.8	54.3		48.8	65.2	
Pegs to pods (%)						
ICGV 98300	31.8 ab	33.3 ab	*	42.7 b	52.0 ab	*
ICGV 98303	31.6 ab	39.6 a	**	46.1 a	56.9 a	*
ICGV 98305	32.5 ab	28.3 bc	**	44.6 ab	40.2 c	*
ICGV 98308	29.1 b	29.0 b	ns	39.0 c	42.8 c	*
ICGV 98324	30.6 b	29.2 b	ns	38.0 c	44.0 c	**
ICGV 98330	29.5 b	35.7 ab	**	40.2 c	46.1 bc	**
ICGV 98348	27.8 c	29.5 b	*	46.6 a	50.9 b	*
ICGV 98353	25.0 c	24.0 c	*	38.3 c	37.6 d	ns
Tainan 9	31.1 ab	35.6 ab	*	46.4 a	50.5 b	*
KK 60-3	25.3 c	31.8 b	**	44.8 ab	46.3 bc	*
Tifton – 8	33.9 a	34.4 ab	*	40.2 c	44.5 c	*
Mean	29.1	31.2		42.4	46.5	
Pods to mature pods (%)						
ICGV 98300	66.8 b	70.8 b	*	56.0 c	66.7 b	**
ICGV 98303	54.5 c	70.3 b	**	57.7 c	78.9 a	**
ICGV 98305	74.7 a	63.8 c	**	56.8 c	46.4 e	**
ICGV 98308	70.5 a	60.0 c	**	60.9 bc	60.0 bc	ns
ICGV 98324	73.9 a	72.7 b	ns	70.6 a	57.1 c	**
ICGV 98330	62.2 b	74.2 b	**	65.0 b	61.7 bc	*
ICGV 98348	49.4 d	69.5 b	**	40.0 e	61.0 bc	**
ICGV 98353	63.8 b	53.6 d	**	48.8 d	51.3 d	*
Tainan 9	65.9 b	82.0 a	**	64.3 b	77.9 a	**
KK 60-3	53.8 c	66.7 bc	**	43.0 e	53.8 d	**
Tifton – 8	63.3 b	64.3 c	ns	47.5 d	60.4 bc	**
Mean	64.3	68.0		55.5	61.4	

[1/] Means in the same column with the same letters are not significantly different (at $p < 0.05$) by DMRT. ns , * and ** non-significant, significant at $p < 0.05$ and significant at $p < 0.01$, respectively by LSD.

Table 4. Contributions of reproductive parts to pod yield under irrigated and pre-flowering drought (PFD) conditions in the rainy season (2005) and dry season (2005/06).

	Explained by regression (%)			
Traits	Rainy season		Dry season	
	Irrigated	PFD	Irrigated	PFD
Regression	70.22**	81.35**	81.60 **	83.78**
Flower No. plant^{-1}	1.46*	5.04**	0.95*	0.02**
Peg No. plant^{-1}	0.02	0.97**	2.61**	0.15**
Pod No. plant^{-1}	5.19**	0.41**	2.10**	3.16**
Mature pod No. plant^{-1}	63.55**	74.92**	78.55**	80.45**

* and ** significant at $p<0.05$ and significant at $p<0.01$, respectively; PFD- Pre-flowering drought.

Factors contributing to yield under PFD and irrigated conditions

Multiple regression analysis showed that numbers of flowers, pegs, pods and mature pods significantly contributed to pod yield under PFD conditions in both years (Table 4). In the rainy season, number of mature pods was the major contributing factor to yield under irrigated (63.55%) and PFD conditions (74.92%), while number of pegs and number of pods showed the least contribution to yield under irrigated and PFD conditions, respectively. In the dry season, number of mature pods was still the major contributing factor to yield under both PFD (80.45%) and irrigated conditions (78.55%).

Discussion

The present study revealed that PFD followed by adequate water supply can result in increased production of reproductive parts compared with irrigated conditions in several of the genotypes we tested. In a parallel study, Puangbut et al. (2010) also reported that PFD increased gross yield in peanut. Most previous research on the effects of PFD has focused on a limited number of peanut genotypes; hence there was little information on genotypic variation in reproductive response and their contributions to yield under PFD conditions. The current study revealed significant genotypic variation in reproductive response to PFD which could explain observed increases in yield. ICGV 98300, ICGV 98303 and Tainan 9 had the highest number of reproductive parts after PFD in both years. Puangbut et al. (2009a) also reported that these genotypes had the highest yield after early season drought conditions. Recently, several researchers reported that certain physiological traits were associated with yield after pre-flowering drought (Puangbut et al., 2009b, 2010, 2011a). However, the contributions of reproductive parts to yield after PFD conditions are not fully understood. Selection of superior peanut genotypes for ability to maintain productive physiological traits coupled with production of greater numbers of reproductive parts might help to improve yield under pre-flowering drought. There were greater numbers of flower, pegs, pods, and mature pods after PFD in the dry season trial than in the rainy season trial. Paungbut et al. (2009a) also reported that yield after PFD was greater in the dry season than in the rainy season trial. The reduced response to PFD in the rainy season may be due to the lower RWC during the drought period, resulting in lower yield after recovery. Increased production of reproductive parts under PFD could be associated with increased physiological productivity. Enhanced physiological traits after recovery may compensate for the physiological drought injury to promote overall plant growth and reproduction (Jangpromma et al., 2012, Jongrungklang et al., 2010; Puangbut et al., 2010; Awal and Ikida, 2002). Enhanced leaf area and N_2 fixation coupled with increased root growth rate after recovery may contribute to high biomass production, resulting in enhanced reproductive growth and development (Puangbut et al., 2010; Awal and Ikeda, 2002). Therefore, physiological responses could be a factor contributing to increased numbers of reproductive parts after PFD conditions. Previous studies also revealed that a strong flowering flush after recovery was associated with greater pod yield (Awal and Ikeda, 2002; Nageswara Rao et al., 1988). Our result also indicated that the reproductive efficiency was higher after PFD than under fully irrigated conditions for many genotypes. The higher reproductive efficiency of these plants was demonstrated by the higher conversion rates of flowers to pegs, of pegs to pods and of total pods to mature pods. Likewise, Nautiyal et al. (1999) suggested that the conversion of flowers to pegs and of pegs to pods was higher in plants which experienced stress in the vegetative phase. Our result also suggested that higher percentage of pods to mature pods is associated with higher yield. Songsri et al. (2009b) also observed that conversion of a high percentage of flowers to mature pods and pods to mature pods were strongly associated with yield under long period drought. Numbers of seed per pod and seed size were not important factors for explaining the differences in yield performance after PFD. Results indicated that difference in numbers of reproductive parts appear to be more important factors for maintaining high yield under PFD conditions. This is in agreement with Songsri et al. (2008) who reported that reproductive parts were more important factors influencing yield than yield components under long period drought. The contribution of number of mature pods was the major component contributing to pod yield and was higher under PFD treatment than under well-watered treatment. Songsri et al. (2008) also found that there was a strong correlation between number of mature pods and pod yield under long period drought conditions. Therefore, the number of mature pod per plant seemed to play an important role in maintaining high pod yield. It was apparent that an increased pod yield under the PFD followed by re-watering was associated with enhanced production of reproductive parts. Thus, selecting for enhanced number of mature pods under PFD conditions would be expected to increase peanut yields. Therefore, number of mature pods should be used as a surrogate trait for yield because this trait has lower genotype × environment interactions than pod yield (Puangbut et al., 2011b; Songsri et al., 2008). Selection of superior peanut genotypes for ability to maintain high physiological productivity coupled with a greater number of reproductive parts could improve yield under PFD conditions.

Materials and Methods

Plant materials

Eleven peanut genotypes were used in this study. Eight elite drought resistant Spanish type varieties (ICGVs 98300, 98303, 98305, 98308, 98324, 98330, 98348 and 98353) were donated from the International Crops Research Institute for Semi-Arid Tropics (ICRISAT). Tifton-8, a Virginia-type drought resistant line, was kindly provided by the United States Department of Agriculture (USDA). KK 60-3 (Virginia type, drought susceptible) and Tainan 9 (Spanish type and drought susceptible) are the cultivars commercially released in Thailand. Plant material has been described in detail by Puangbut et al (2009a). The experiment was conducted in the rainy season from June to October 2005 and in the dry season from December 2005 to April 2006 at the Field Crop Research Station of Khon Kaen University located in Khon Kaen province, Thailand (16° 28´ N, 102° 48´ E, 200 masl). The experiment was repeated across seasons instead of years to expose genotypes to a wide range of environmental conditions (Puangbut et al (2011a). In the rainy season, rainout shelters were available if necessary, but in the dry season the experiment was carried out under field conditions without rainout shelters. The soil type is Yasothon series (Yt: fine-loamy; siliceous, isohypothermic, Oxic Paleustults). A split-plot in a randomized complete block design with four replications was used in both seasons. Main-plots were two water treatments [field capacity (FC) and 1/3 available water (1/3 AW), below], and sub-plot treatments were 11 peanut genotypes. Plot sizes were 2.5 x 2.1 m in the rainy season and 3 x 3 m in the dry season with a spacing of 30 cm between rows and 10 cm between plants.

Crop management

Lime at the rate of 625 kg ha^{-1} was incorporated into the soil during land preparation. Basal fertilizers as triple superphosphate at the rate of 122 kg ha^{-1} and potassium chloride at the rate of 62 kg ha^{-1} were then incorporated into the soil. A pre-emergence herbicide was applied after planting.

Seeds were treated with captan at the rate of 5 g kg^{-1}. The seeds of two Virginia-type cultivars (KK 60-3 and Tifton-8) were separately treated with ethrel (2 ml l^{-1}) to break seed dormancy before planting. The seedlings were thinned to one plant per hill at 7 days after emergence (DAE). Gypsum was applied at pegging stage at the rate of 312 kg ha^{-1}. Carbofuran was applied to the soil at pod setting stage to control soil insects. Standard management practices were followed with appropriate pest and disease management practices as described by Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

Soil moisture treatment

A subsurface drip-irrigation system (Super Typhoon®, Netafim Irrigation equipment & Drip systems, Israel) was installed with a spacing of 30 cm between driplines and 20 cm between emitters. The driplines were installed 10 cm below the soil surface mid-way between rows and a pressure valve and water meter were fitted to ensure controlled application of water to the treatments. Soil moisture was initially supplied with water at field capacity (FC) to a depth of 20 cm and to facilitate uniform emergence. The soil moisture treatments and results are described in more detail by Puangbut et al (2011a). Briefly, the results showed reasonable management of soil moistures. Under the PFD treatment, soil moisture was reduced during water deficit (0-40 DAE) in both years. Relative water content for PFD treatment was clearly lower than those for the irrigated treatment in both years at the end of the stress period (40 DAE) (Puangbut et al 2011a). In maintaining the specified soil moisture levels, water was added to the respective main-plots by subsurface drip-irrigation based on crop water requirement and surface evaporation which were calculated following the methods of Doorenbos and Pruitt (1992) and Singh and Russell (1981), respectively.

Reproductive parts

The number of flowers was recorded daily on five plants from each plot during the morning (6.00-8.00 h, Thailand standard time) from the date of first flowering until harvest. The reproductive parts were recorded at harvest as the number of flowers, number of pegs (hanging pegs + pods), number of total pods (immature + mature pods) and number of mature pods per plant which identified by their shriveled seeds and dark internal pericarp color. Conversion of flowers to pegs and pegs to pods and pods to mature pods were calculated based on the formula suggested by Nautiyal (1999) as follows;

$$\text{Flowers to pegs} = \frac{(\text{hanging peg number} + \text{pod number})}{\text{total flower number}} \times 100$$

$$\text{Pegs to pods} = \frac{(\text{Immature pods number} + \text{mature pod number})}{\text{hanging peg number} + \text{pod number}} \times 100$$

$$\text{Pods to mature pods} = \frac{(\text{mature pod number})}{\text{Immature pod number} + \text{mature pod number}} \times 100$$

Statistical analysis

Individual analysis of variance was performed for each character in each experiment. Error variances for the two seasons were tested for homogeneity by Bartlett's test (Hoshmand, 2006). Individual analysis of variance showed significant differences between water regimes and among peanut genotypes for all traits (data not shown). Because season x genotype interactions and water regime x genotype interactions were significant for all variables (data not presented), data of each season and each water regime were analyzed separately according to a randomized complete block design (RCBD) (Bricker, 1989). Duncan's multiple range tests (DMRT) was used to compare means within genotypes and Least significant difference (LSD) was used to compare means between water regimes for each genotype. Multiple-linear regression was used to determine the relative contribution of number of flowers, number of pegs, number of pods, and mature pods to pod yield under irrigated and PFD treatments. The analysis was based on the following statistical model (Hoshmand, 2006):

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \delta_i$$

where Y_i is pod yield of genotype i, α is the Y intercept, X_{1i}, X_{2i}, X_{3i} and X_{4i} are number of flowers, number of pegs, number of pods and number of mature pod of genotype i, respectively, β_1, β_2, β_3 and β_4 are regression coefficients for the independent variables X_1, X_2, X_3 and X_4 and δ_i is the associated deviation from regression. The analysis was carried out by fitting the full model first and then determining the relative importance of the individual independent variables. A sequential fit was then performed by fitting the more important variable first. The relative contributions of the individual independent variables to the pod yield under drought stress were determined from the percentages of regression sum of squares due to the respective independent variables to total sum of squares in the sequential fitted analysis. All analyses were conducted with Statistix 8 software program.

Conclusion

The results demonstrated that PFD increased the number of reproductive parts produced following drought in both seasons. The variation among peanut genotypes in production of reproductive parts after PFD was consistent across seasons. The genotypes with greater production of reproductive parts, number of mature pods, also had enhanced pod yield under PFD conditions. The result revealed that number of mature pods was the major factor contributing to yield. Therefore, selecting for enhanced number of mature pods would be expected to increase peanut yields.

Acknowledgments

This work was supported by the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission, through the Food and Functional Food Research Cluster of Khon Kaen University. Grateful acknowledgments are made to the Peanut and Jerusalem artichoke Improvement for Functional Food Research Group and Plant Breeding Research Center for Sustainable Agriculture, Khon Kaen University. Grateful acknowledgement is made to the Thailand Research Fund, the commission for High Education and Khon Kaen University for providing financial supports to this research through the Distinguished Research Professor Grant of Professor Dr. Aran Patanothai. I would like to thank Dr. Barbara Shew for her language editing.

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