ORIGINAL ARTICLE

Effect of water stress on yield and agronomic characters of peanut (*Arachis hypogaea* L.)

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Abstract

Vorasoot, N., Songsri, P., Akkasaeng, C., Jogloy, S. and Patanothai, A.
Effect of water stress on yield and agronomic characters of peanut
Songklanakarin J. Sci. Technol., 2003, 25(3) : 283-288

Peanut production in Thailand is concentrated in upland area under rain-fed conditions. Unpredictable time and the extent of water deficit occurs every year and causes a reduction in yield and quality. Under these conditions the use of cultivars tolerant to drought and producing high yield should be advantageous. The objective of this study was to investigate the effect of water stress on yield and agronomic characters of peanut cultivars. A glasshouse experiment was conducted for evaluation of 4 peanut cultivars, Tainan 9, Khon Kaen 60-3, ICGV 98308 and ICGV 98324, under three regimes of water (field capacity, 1/2 available water and 1/4 available water) in earthen pots. A 4×3 factorial experiment in randomized complete block design with 4 replications was conducted. Total dry weight, pod yield, seed yield, 100 seed weight and shelling percentage were determined at the final harvest. At field capacity, all peanut cultivars performed well. Yield and agronomic characters of all cultivars were decreased under water stress; and significant response of genotypes was observed. Khon Kaen 60-3 and ICGV 98308 were more sensitive to water stress, comparing with Tainan 9 and ICGV 98324.

Key words : water stress, peanut genotypes, dry matter, dry pod yield, agronomic characters

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Received, 2 Jan 2003 Accepted, 31 March 2003

บทคัดย่อ

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อิทธิพลของการขาดน้ำต่อผลผลิตและลักษณะทางการเกษตรของถั่วลิสง

ว.สงขลานครินทร์ วทท. 2546 25(3) : 283-288

การผลิตถั่วลิสงของประเทศไทยส่วนใหญ่อยู่ในพื้นที่ดอนและอาศัยน้ำฝน ซึ่งเป็นสาเหตุสำคัญให้ถั่วลิสงได้รับผลกระทบจากความแห้งแล้งทุกปี ทำให้ผลผลิตต่ำและคุณภาพไม่ดี ในสภาพเช่นนี้จึงต้องมีการใช้พันธุ์ที่ให้ผลผลิตสูงและมีความทนทานต่อสภาพแห้งแล้ง งานทดลองนี้มีวัตถุประสงค์เพื่อศึกษาอิทธิพลของการกระทบแล้งต่อผลผลิตและลักษณะทางการเกษตรของถั่วลิสงสายพันธุ์ต่าง ๆ โดยทำการทดลองในเรือนกระจก เพื่อทดสอบพันธุ์ถั่วลิสง 4 พันธุ์ คือ พันธุ์ไทนาน 9 ขอนแก่น 60-3 ICGV 98308 และ ICGV 98324 ในสภาพความชื้นดิน 3 ระดับ คือที่ field capacity, $^1/_2$ available water และ $^1/_4$ available water โดยใช้แผนการทดลองแบบ 4×3 factorial experiment in RCB มี 4 ซ้ำ ข้อมูลที่บันทึก คือ น้ำหนักแห้งทั้งหมด ผลผลิตฝัก ผลผลิตเมล็ด น้ำหนัก 100 เมล็ด และเปอร์เซ็นต์กะเทาะ ผลผลิตและลักษณะทางการเกษตรของทุกพันธุ์อยู่ในระดับดี เมื่อได้รับน้ำระดับความจุสนาม แต่เมื่อขาดน้ำ ทุกพันธุ์จะมีผลผลิตและลักษณะทางการเกษตรลดลงตามระดับน้ำที่ลดลงแต่การตอบสนองต่อสภาพการขาดน้ำของพันธุ์ที่ใช้ศึกษาแตกต่างกัน โดยพันธุ์ Khon Kaen 60-3 และพันธุ์ ICGV 98308 จะมีความอ่อนแอต่อสภาพการขาดน้ำมากกว่าพันธุ์ Tainan 9 และพันธุ์ ICGV 98324

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Peanut (*Arachis hypogaea* L.) is an important grain legume in Thailand. The production of the crop is mainly concentrated in upland area under rain-fed conditions where the amount and distribution of rainfall are relatively poor (Jogloy *et al.*, 1996; Vorasoot *et al.*, 1985). Unpredictable and intermittent periods of water deficit commonly occurs during growing season (Vorasoot *et al.*, 1985). Peanut grown during rainy season occasionally encounters the drought stress. Peanut plants may experience water stress during pegging and pod development and then may have adequate amount of water (Jogloy *et al.*, 1996). This would result in a drastic reduction of crop yield, and the magnitude of reduction would depend on peanut cultivars. Not only the yield of peanut but also the quality of products decreases under drought stress (Rucker *et al.*, 1995 ; Stansell and Pallas, 1985), and the latter was aggravated by the contamination of aflatoxin under drought environment (Sander *et al.*, 1993). Under water stress conditions, drought-tolerant varieties producing high yield are required. Therefore, the response of 4 peanut cultivars to water stress was investigated.

Materials and Methods

A glasshouse trial was conducted in 2002 at field Crop Section, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand. Four peanut cultivars (Table 1); Khon Kaen 60-3, Tainan 9, ICGV 98308 and ICGV 98324, and 3 soil water regimes; at field capacity (FC), $^1/_2$ available water ($^1/_2$ AW) and $^1/_4$ available water ($^1/_4$ AW), were used in this study. A 4×3 factorial experiment in Randomized Complete Block Design with 4 replications was conducted. Clay tubes having a diameter of 25 cm and height of 70 cm were used as pots. Three holes were made at the height levels of 7.5, 25.0 and 42.5 cm from the bottom of each pot to facilitate watering and even distribution of water. Pots were filled with soil (Yasothon series) up to 10 cm from the top (45 kg/pot). The crop water requirements for 3 water regimes were calculated following the methods described by Doorenbos and Pruitt (1992). The calculated amount of water was divided into four fractions, and the first fraction given to the soil surface and the remaining fractions through plas-

Table 1. Cultivars used and some of their growth characteristics

Cultivar	Characteristic
Tainan 9	Spanish botanical type, medium – seeded, high yielding
Khon Kaen 60-3	Virginia botanical type, large – seeded, high yielding
ICGV 98308, ICGV 98324	Spanish botanical type, medium-seeded, drought tolerant cultivars from ICRISAT (International Crops Research Institute for the Semi- Arid Tropics)

tic lines fitted into the three holes as described in the above mention. Seeds were treated with fungicide and four seeds were sown in each pot. On day 14 after emergence (14DAE), seedlings were thinned to obtain two uniform seedlings per pot. The soil near field capacity was maintained in each pot until 14 DAE. After this, soil moisture status for each treatment was maintained until the plants were harvested. Normal cultural practices were followed during the growing season. At harvest, peanut pods from each pot were harvested and dried to approximately 8% moisture content. Total dry weight (shoot and root only) was determined. Pod yield (kg/rai), seed yield (kg/rai), number of seeds per plant and seed weight (g/100 seeds) were measured. Analysis of variance was performed on total dry weight, pod yield, seed yield, number of seeds per plant and seed weight. Duncan's multiple range test was used to detect significant differences among means.

Results and Discussion

Total dry weight

There was a significant effect of soil moisture regimes on total dry weight of peanut crop (Table 2). Total dry weight of peanut plants was significantly higher at FC (19.09 g/plant) than at $^1/_2$ AW (11.74 g/plant) and $^1/_4$ AW (11.94 g/plant), although there was no significant difference in dry matter between $^1/_2$ AW and $^1/_4$ AW water regimes. Two water deficit regimes resulted in a decrease of total dry weight of about 38% (Table 2). There were significant differences in total dry weight among peanut cultivars. Only Khon Kaen 60-3 produced significantly higher total dry weight (17.98 g/plant) than the other three cultivars (Table 2). There was no interaction between soil moisture regimes and peanut cultivars.

Pod dry weight

Under water-limited conditions, pod yield of all peanut cultivars was decreased. Interaction between genotypes and water levels was found (Table 2). At FC, significant difference was not found among genotypes (Table 3) but the difference was found at $^1/_2$ AW and $^1/_4$ AW. At $^1/_2$ AW, Tainan 9 and ICGV 98324 exhibited high yield, while ICGV 98324 performed best at $^1/_4$ AW. Pod yield reduction of Tainan 9 ranged from 57-85% while yield of ICGV 98324 was reduced by 67-68% (Table 3). Khon Kaen 60-3 and ICGV 98308 were highly sensitive to water stress. Pod yield of Khon Kaen 60-3 was decreased by 96-99%.

Number of seeds per plant

There was a significant interaction between soil moisture regimes and peanut cultivars for number of seeds (Table 2). At FC, there was no significant difference in number of seeds per plant among peanut cultivars and the number of seeds was in the range of 20-25 seeds per plant (Table 4). At $^1/_2$ AW, number of seeds per plant in Khon Kaen 60-3 and ICGV 98308 decreased drastically to 2 and 7 seeds per plant or by 90% and 70%, respectively. Number of seeds per plant in Tainan 9 and ICGV 98324 decreased by 33% and 56%, respectively (Table 4). At $^1/_4$ AW, there was no further decrease in number of seeds per plant in ICGV 98324. However, no seed was harvested in Khon Kaen 60-3. Number of seeds per plant in ICGV 98308 and Tainan 9 decreased by 91% and 94%, respectively (Table 4).

Table 2. Effect of three soil moisture regimes on total dry weight yield and some agronomic characters of four peanut cultivars

Treatment	Total dry wt[1/] (g/plant)	Pod dry wt[1/] (kg/rai)	Seed dry wt[1/] (kg/rai)	100 seed wt [1/] (g)	Number of seed[1/] per plant
Soil moisture					
FC (20.0% soil moisture content)	19.09[a]	431.29[a]	309.85[a]	41.97[a]	23[a]
1/2 AW (8.6% soil moist content)	11.74[b] (38.5%)[2/]	111.22[b] (74.2%)[2/]	71.75[b] (76.8%)[2/]	22.91[b] (45.3%)[2/]	7[b] (69.5%)[2/]
1/4 AW (4.3% soil moist content)	11.94[b] (37.5%)[2/]	61.70[c] (85.7%)[2/]	25.73[c] (91.7%)[2/]	10.67[c] (74.4%)[2/]	6[c] (73.9%)[2/]
F-test	**	**	**	**	**
Cultivar					
Tainan 9	12.23[B]	222.63[A]	170.08[A]	28.02[A]	16[A]
Khon Kaen 60-3	17.98[A]	157.43[B]	104.36[B]	21.00[B]	7[C]
ICGV 98308	13.84[B]	172.72[B]	114.13[B]	24.01[AB]	11[B]
ICGV 98324	12.98[B]	241.85[A]	154.54[A]	27.70[A]	16[A]
F-test	**	**	**	*	**
Interaction (A×B)	NS	**	*	*	**
C.V.%	14.6	19.0	25.4	23.9	22.5

1/ **means in the same column followed by the same capital or small letter are not significantly different by DMRT at $P \leq 0.05$**
ns, *,** **non significance , significance at $P \leq 0.05$ and $P \leq 0.01$, respectively.**
2/ **number in parenthesis is a reduction percentage.**

Table 3. Effect of soil moisture regimes on pod yield of 4 peanut cultivars

Cultivar	Pod dry weight (kg/rai)[1/]		
	FC	1/2 AW	1/4 AW
Tainan 9	443.94 a	190.70 b (57.0%)[2/]	66.25 de (85.1%)[2/]
Khon Kaen 60-3	449.27 a	18.88 ef (95.8%)	4.14 f (99.1%)
ICGV 98308	393.25 a	89.42 cd (77.3%)	35.49 def (91.0%)
ICGV 98324	438.71 a	145.89 bc (66.8%)	140.92 bc (67.9%)

1/ means followed by the same letter are not significanly different by DMRT at $P \leq 0.05$
2/ number in parenthesis is a reduction percentage.

Seed yield

Interaction between genotypes and water levels was found (Table 2). Under increasing moisture-deficit, seed yields of all cultivars were decreased. At FC, Tainan 9 and ICGV 98324 exhibited high yield followed by Khon Kaen 60-3 and ICGV 98308, respectively (Table 5). At water stress (1/2 AW and 1/4 AW), Tainan 9 and ICGV 98324 performed top seed-yield. Khon Kaen 60-3 and ICGV 98308 were highly sensitive to drought. Yield reductions of Khon Kaen 60-3 were 98% and 100% at 1/2 AW and 1/4 AW, respectively (Table 5).

Table 4. Effect of soil moisture regimes on number of seeds per plant of 4 peanut cultivars.

Cultivars	Number of seed per plant[1/]		
	FC	$^1/_2$ AW	$^1/_4$ AW
Tainan 9	24 a	16 b (33.3%)[2/]	8 cd (66.7%)[2/]
Khon Kaen 60-3	20 a	2 e (90.0%)	0 e (100.0%)
ICGV 98308	23 a	7 cd (69.5%)	4 de (82.6%)
ICGV 98324	25 a	11 c (56.0%)	11 c (56.0%)

[1/] means followed by the same letter are not significantly different by DMRT at $P \leq 0.05$
[2/] number in parenthesis is a reduction percentage.

Table 5. Effect of soil moisture regimes on seed yield of 4 peanut cultivars.

Cultivars	Seed yield (kg/rai)[1/]		
	FC	$^1/_2$ AW	$^1/_4$ AW
Tainan 9	342.78 a	137.61 c (59.8%)[2/]	29.85 ef (91.3%)[2/]
Khon Kaen 60-3	306.25 ab	6.31 ef (97.9%)	0.0 f (100.0%)
ICGV 98308	275.28 b	51.78 def (81.2%)	15.33 ef (94.4%)
ICGV 98324	315.08 ab	91.32 cd (71.0%)	57.22 de (81.8%)

[1/] means followed by the same letter are not signifcantly different by DMRT at $P \leq 0.05$
[2/] number in parenthesis is a reduction percentage.

Table 6. Effect of soil moisture regimes on 100 seed weight of 4 peanut cultivars

Cultivar	100 seed weight (g)[1/]		
	FC	$^1/_2$ AW	$^1/_4$ AW
Tainan 9	43.42 a	28.17 b (35.1%)[2/]	12.48 d (71.2%)[2/]
Khon Kaen 60-3	46.51 a	13.13 cd (71.8%)	3.35 e (92.9%)
ICGV 98308	38.11 a	22.07 bc (42.0%)	11.85 de (68.8%)
ICGV 98324	39.86 a	28.25 b (29.1%)	14.99 cd (62.4%)

[1/] means followed by the same letter are not significantly different by DMRT at $P \leq 0.05$
[2/] number in parenthesis is a reduction percentage.

Seed size (100 seed weight)

Seed size of all cultivars decreased when available water was reduced. Tainan 9 and ICGV 98324 had the biggest seed size (Table 2) ; however, there was interaction between the two factors. At FC, no significant difference among cultivars was found. Under water stress, Tainan 9 and ICGV 98324 had the biggest seed (Table 6) and seed size of Tainan 9 and ICGV 98324 were reduced by 35% and 29% , respectively (Table 6). Regarding seed size, Khon Kaen 60-3 was the most sensitive cultivar under water stress. Seed size of Khon Kaen 60-3 was reduced by 72% at $^1/_2$ AW.

Dry matter production, pod yield, seed yield, number of seed per plant and seed size of all peanut cultivars significantly decreased under two water stress regimes. Differences in such responses for tested cultivars were remarkable. It has frequently been reported that under water stress, pegging and seed set responses of various peanut cultivars varied substantially, this leads to a large reduction in pod yield, and the reduction percentage also varies among peanut cultivars (Haris *et al*., 1988, Nageswara Rao *et al*., 1989). Khon Kaen 60-3 produced higher dry matter than other peanut cultivars under any soil water regimes. Under sufficient soil water, Khon Kaen 60-3 was in a group of the highest seed yield. However, under moderate water stress ($^1/_2$ AW) there was a drastic reduction in pod yield, number of seed per plant, seed size and seed yield. Under severe water stress ($^1/_4$ AW), pod and seed yield was negligible. Almost all seeds aborted under severe water stress, while normal pod development was observed at FC. It is not known whether the failure of seed development occurs prior to the further supply of assimilates or the abortion of seed occurs as a result of a restriction of assimilate supply to the seed. In either case, the assimilate would be utilized for further vegetative growth as reflected by a higher total dry matter of the Khon Kaen 60-3 as compared to those of other cultivars grown in two regimes of soil moisture stress. It is apparent that the accumulated dry matter was not a good index for assessing drought tolerance. Tainan 9 and ICGV 98324 cultivars produced significantly lower total dry matter than Khon Kaen 60-3. Under moderate water stress ($^1/_2$ AW), the two cultivars were able to produce seed yields to some extent. Compared with the non-stressed plants, the reduction in seed yield was 60% and 70% for Tainan 9 and ICGV 98324, respectively. A reduction in number of seeds per plant and seed size for Tainan 9 was 33% and 35%, and those for ICGV 98324 were 56% and 29%, respectively. It appeared that there was a small reduction in seed size under this soil water regime. Under severe water stress ($^1/_4$ AW), there was a further reduction in seed yield and the high reduction was observed in Tainan 9 cultivar. The high reduction in seed yield was associated with a high reduction in number of seeds per plant and seed size of Tainan 9. Regarding the capability of seed development, ICGV 98324 cultivar performed better under severe water stress. From this study, it could be suggested that partitioning of assimilates to vegetative or reproductive growth would be a better means for assessing drought tolerance.

Acknowledgments

This work was funded by the Senior Research Scholar Project of Dr. Aran Patanothai under the Thailand Research Fund.

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