ORIGINAL ARTICLE

Effect of available soil water on leaf development and dry matter partitioning in 4 cultivars of peanut (*Arachis hypogaea* L.)

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Abstract

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Water stress brings about changes in growth and dry matter partition in peanut plants and the changes vary depending on peanut cultivars. The objectives of this study were to investigate the effect of 3 regimes of available soil water on leaf development and dry matter partitioning of 4 peanut cultivars. A 4×3 factorial experiment in randomized complete block design with four replications was used. Treatments were combinations of 4 peanut cultivars; Tainan 9, Khon Kaen 60-3, ICGV 98308 and ICGV 98324, and three soil water regimes; field capacity (FC; 20% soil moisture content), ½ available soil water (½ AW; 8.6% soil moisture content) and ¼ available soil water (¼ AW; 4.3% soil moisture content). On day 75 after seedling emergence, depleting available soil water from FC to ¼ AW significantly (p<0.01) reduced leaf areas of peanut plants. There were also significant differences (p<0.01) in leaf areas among peanut cultivars. At harvest, ½ AW caused more reduction in leaf area but resulted in an increase in weight of fallen leaves than did ¼ AW. On day 75 after seedling emergence, there was a significant effect (p<0.01) of available soil water

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on root:shoot ratios. As available soil water became limited, there was a significant increase (P<0.01) in root:shoot ratios. At harvest, there were interactions between available soil water and peanut cultivars for root:shoot ratio, harvest index and shelling percentage. At FC, there were no significant differences in root: shoot ratio among peanut cultivars. However, at ½ AW and ¼ AW, there were significant differences in root:shoot ratios and the magnitude of differences varied depending on peanut cultivars. At ½ AW and ¼ AW, Khon Kaen 60-3 had root:shoot ratios of 0.55 and 0.48 while ICGV 98324 had the ratios of 0.35 and 0.32, respectively. There were no significant differences in harvest index and shelling percentage among peanut cultivars when available soil water was at FC. At ½ AW and ¼ AW, there was a large decrease in harvest index of Khon Kaen 60-3 and the indices were 0.03 and 0.01, respectively. At the corresponding available soil waters, ICGV 98324 had harvest indices of 0.33 and 0.23, respectively. Shelling percentages at ½ AW and ¼ AW for Khon Kaen 60-3 were 24.9 and 6.8, respectively, while those for ICGV 98324 were 62.3 and 46.6, respectively. Our results indicated that under water stress the partitioning of dry matter into pod yields is more sensitive in drought-sensitive cultivars. Under drought conditions, mobilization of reserved assimilates in leaves could be crucial for supporting pod growth and yields in drought-tolerant cultivars.

Key words : peanut, leaf area, root:shoot ratio, harvest index

บทคัดย่อ

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อิทธิพลของน้ำที่เป็นประโยชน์ในดินต่อการพัฒนาของใบ การแบ่งสันอาหารที่สังเคราะห์ได้ใน 4 สายพันธุ์ของถั่วลิสง (*Arachis hypogaea* L.)

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การขาดน้ำทำให้มีการเปลี่ยนแปลงการเติบโต และการแบ่งสันอาหารที่สังเคราะห์ได้ไปใช้สำหรับการเติบโตในอวัยวะต่าง ๆ ของถั่วลิสง และการเปลี่ยนแปลงนี้ขึ้นอยู่กับสายพันธุ์ถั่วลิสง งานทดลองนี้มีวัตถุประสงค์เพื่อศึกษาอิทธิพลของระดับน้ำที่เป็นประโยชน์ในดินต่อการพัฒนาของใบ และการแบ่งสันอาหารที่สังเคราะห์ได้ไปใช้ในการเติบโตในส่วนต่าง ๆ ของถั่วลิสง 4 สายพันธุ์ ใช้งานทดลองแบบแฟกตอเรียล มีปัจจัย 2 ชนิดคือ ระดับน้ำที่เป็นประโยชน์ในดินและสายพันธุ์ถั่วลิสง ใช้แผนการทดลองแบบ randomized complete block มี 4 ซ้ำ ทรีตเมนต์เป็น combinations ของถั่วลิสง 4 สายพันธุ์คือ ไทนาน 9 ขอนแก่น 60-3 ICGV 98308 ICGV 98324 และระดับน้ำที่เป็นประโยชน์ในดิน 3 ระดับคือ ที่ความจุภาคสนาม (FC) ½ ของน้ำที่เป็นประโยชน์ในดิน (½ AW) และ ¼ ของน้ำที่เป็นประโยชน์ในดิน (¼ AW) ในวันที่ 75 หลังจากต้นอ่อนโผล่ การลดปริมาณน้ำที่เป็นประโยชน์ในดินจากระดับ FC ไปเป็น ¼ AW ทำให้พื้นที่ใบของถั่วลิสงลดลงอย่างมีนัยสำคัญทางสถิติ (P<0.01) นอกจากนี้แล้วพื้นที่ใบของถั่วลิสง 4 สายพันธุ์มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ (P<0.01) ที่ระยะเก็บเกี่ยวระดับน้ำที่ ½ AW ทำให้พื้นที่ใบถั่วลิสงลดลงมากกว่า แต่ทำให้น้ำหนักแห้งของใบที่ร่วงเพิ่มมากว่าระดับน้ำที่ ¼ AW ในวันที่ 75 หลังจากต้นอ่อนโผล่การลดปริมาณน้ำที่เป็นประโยชน์ในดินทำให้ลดอัตราส่วนระหว่างราก:ต้นอย่างมีนัยสำคัญทางสถิติ (P<0.01) ที่ระยะเก็บเกี่ยวมีปฏิสัมพันธ์ร่วมกันระหว่างระดับน้ำที่เป็นประโยชน์ในดินและสายพันธุ์ถั่วลิสงสำหรับค่าอัตราส่วนระหว่างราก:ต้น ดัชนีเก็บเกี่ยว และเปอร์เซ็นต์การกะเทาะ อัตราส่วนระหว่างราก:ต้น ของถั่วลิสงแต่ละสายพันธุ์ที่ระดับน้ำที่ FC ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ อย่างไรก็ดีระดับน้ำที่ ½ AW และ ¼ AW ทำให้อัตราส่วนระหว่างราก:ต้นมีความแตกต่างกันทางสถิติ และขนาดของความแตกต่างขึ้นอยู่กับสายพันธุ์ถั่วลิสง เมื่อได้รับน้ำที่ระดับ ½ AW และ ¼ AW อัตราส่วนระหว่างราก:ต้นของสายพันธุ์ขอนแก่น 60-3 มีค่าเท่ากับ 0.55 และ 0.48 ในขณะที่สายพันธุ์ ICGV 98324 มีค่าเท่ากับ 0.35 และ 0.32 ตามลำดับ ระดับน้ำที่ FC ไม่มีอิทธิพลต่อดัชนีเก็บเกี่ยวและเปอร์เซ็นต์การกะเทาะของถั่วลิสงแต่ละสายพันธุ์ ระดับน้ำที่ ½ AW และ ¼ AW ทำให้ค่าดัชนี

เก็บเกี่ยวของสายพันธุ์ขอนแก่น 60-3 ลดลงมาก และค่าดัชนีเก็บเกี่ยวที่ระดับน้ำ 2 ระดับนี้เท่ากับ 0.03 และ 0.01 ที่ระดับน้ำ 2 ระดับนี้ดัชนีเก็บเกี่ยวของสายพันธุ์ ICGV 98324 มีค่าเท่ากับ 0.33 และ 0.23 ตามลำดับ ที่ระดับน้ำ ½ AW และ ¼ AW เปอร์เซ็นต์การกะเทาะสำหรับสายพันธุ์ขอนแก่น 60-3 มีค่าเท่ากับ 24.9 และ 6.8 ในขณะที่สายพันธุ์ ICGV 98324 มีค่าเท่ากับ 62.3 และ 46.6 ตามลำดับ ผลที่ได้จากงานทดลองนี้ชี้ให้เห็นว่า ภายใต้สภาวะการขาดน้ำการแบ่งสันอาหารที่สังเคราะห์ได้ไปใช้สำหรับการเติบโตของฝักและเมล็ดลดลงมากกว่าในสายพันธุ์ที่อ่อนแอต่อการขาดน้ำ และภายใต้สภาวะดังกล่าวการนำอาหารที่สะสมในใบไปใช้สำหรับการเติบโตของฝักและเมล็ดมีความสำคัญมากสำหรับพันธุ์ที่ทนทานต่อการขาดน้ำ

ภาควิชาพืชไร่ คณะเกษตรศาสตร์ มหาวิทยาลัยขอนแก่น อำเภอเมือง จังหวัดขอนแก่น 40002

Peanut (*Arachis hypogaea* L.) is commonly grown in rainfed cropping systems where there is a high variation in the amount and distribution of rainfall during the growing season (Vorasoot *et al.*, 1985). This would inevitably create drought stress during growing periods of peanut (Jogloy *et al.*, 1996). In general, total dry matter and grain yields of peanut invariably decreased under drought conditions but some peanut cultivars displayed certain features of adaptive capability (Vorasoot *et al.*, 2003; Wright and Nageswara Rao, 1994). Water stress caused a reduction in leaf development by reducing leaf initiation and leaf expansion (Wright and Nageswara Rao, 1994). In greenhouse experiments, drought stress resulted in a significant reduction in net photosynthetic rate of groundnut plants (Bhagsari *et al.*, 1976; Nautiyal *et al.*, 2002). Although the photosynthetic capacity of peanut plants is lower under water stress, the pattern of photoassimilate partitioning into individual organs during vegetative or reproductive growth of peanut cultivars is mainly unknown. When water deficit began, root:shoot ratio commonly increased as roots were less sensitive than shoots to growth inhibition by low water potentials (Wu and Cosgrove, 2000). Under water stress, drought-tolerant cultivars had greater accumulated dry matter in pods and seed than drought-sensitive cultivars (Collino *et al.*, 2000). The patterns of photoassimilate partitioning could be of dynamics during each stage of growth and development of peanut crops. These changes may be shifted by water stresses and the extent of changes may vary depending on peanut cultivars (Wright and Nageswara Rao, 1994). The insight of photoassimilate partitioning under drought stress may lead to reveal some morphological and physiological bases for drought-adapted cultivars of peanut. The objectives of this study were to investigate the effect of 3 regimes of available soil water on leaf development and dry matter partitioning of 4 cultivars of peanut.

Materials and Methods

A greenhouse experiment was carried out at Field Crop Section, Faculty of Agriculture, Khon Kaen University during December 2001 and February 2002. A 4×3 factorial experiment in randomized complete block design with four replications was used. Treatments were combinations of 4 peanut cultivars; Tainan 9, Khon Kaen 60-3, ICGV 98308 and ICGV 98324, and three soil water regimes; field capacity (FC; 20% soil moisture content), ½ available soil water (½ AW; 8.6% soil moisture content) and ¼ available soil water (¼ AW; 4.3% soil moisture content). Details of agronomic practice and water management were previously described (Vorasoot *et al.*, 2003). Two samplings were completed on day 75 after emergence (75 DAE) and at harvest. For the first sampling, leaf areas, and root:shoot ratios were recorded for individual plants. In the second harvest, leaf areas, fallen leaf weights, root:shoot ratios, harvest index (HI) and shelling percentage were determined for each plant. Leaf areas were measured using automatic leaf area meter (Hayashi Denkon Model AAC-400). Fallen leaves were collected during a growing period and oven-dried for dry weight determination. HI was defined as the ratio of pod weight:shoot weight for individual plants. Shelling percentage is defined as percentage of seed dry weight in seed-filled pods. Analysis of variance was performed for all recorded parameters. Least significant difference was used to indicate significant differences among treatment means.

Results and Discussion

Leaf area and weight of fallen leaves

There was a significant effect (p<0.01) on leaf area of available soil water and peanut cultivars on day 75 after emergence and at harvest (Table 1). As soil water was maintained at ½ AW, leaf area significantly decreased and a more reduction occurred at ¼ AW. When averaged over 4 peanut cultivars, leaf areas of peanut plants grown at FC, ½ AW and ¼ AW were 1,325, 839 and 694 cm^2 per plant, respectively (Table 1). When averaged over available soil water, peanut cultivar Khon Kaen 60-3 had the highest leaf area (1,087 cm^2 per plant) and followed by Tainan 9 (884 cm^2 per plant), ICGV 98308 (849 cm^2 per plant) and ICGV 98324 (807 cm^2 per plant). At harvest, leaf area of peanut was significantly affected (p<0.01) by available soil water and peanut cultivars. Leaf area at FC (1,406 cm^2 per plant) was ranged the first and followed by those at ¼ AW (735 cm^2 per plant) and at ½ AW (579 cm^2 per plant). Khon Kaen 60-3 was able to maintain the highest leaf area (1,087 cm^2 per plant) and followed by Tainan 9

Table 1. Effect of available soil moisture regimes on leaf area, root:shoot ratio, weights of fallen leaves, harvest index and shelling percentage of peanut at 75 days after seedling emergence and at harvest.

Treatment	LA at 75 DAE	Root:shoot ratio at 75 DAE	LA at harvest	WFL at harvest	Root:shoot ratio	HI	%Shelling
Soil moisture regimes (A)							
FC	1,325a[1/]	0.20b[1/]	1,406a[1/]	2.42b[1/]	0.21	0.41	71.5
½ AW	839b	0.27a	579c	6.11a	0.40	0.24	53.4
¼ AW	694c	0.29a	735b	2.21b	0.42	0.12	35.0
F-Test	**	**	**	**	**	**	**
Cultivars(B)							
Tainan 9	969B[2/]	0.22	884B[2/]	3.58	0.30	0.34	63.8
Khon Kaen 60-3	1,069A	0.26	1,087A	4.26	0.41	0.14	33.1
ICGV 98308	850C	0.28	849B	3.15	0.36	0.23	56.2
ICGV 98324	922BC	0.26	807B	3.35	0.29	0.33	60.2
F-Test	**	NS	**	NS	**	**	**
Interaction(AXB)	NS	NS	NS	NS	**	**	**
CV (%)	11.3	25.3	21.9	49.0	16.5	22.5	16.0

LA, leaf area (cm^2/plant)
WFL, weight of fallen leaves (g/plant)
HI, harvest index
%Shelling, shelling percentage
[1/] means in the same column followed by the same lower case letter are not significantly different by LSD at p<0.01
[2/] means in the same column followed by the same upper case letter are not significantly different by LSD at p<0.01
NS, ** non significance, significance at P<0.01, respectively

(884 cm^2 per plant), ICGV 98308 (849 cm^2 per plant) and ICGV 98324 (807 cm^2 per plant) (Table 1)

Although there was no significant difference in weights of fallen leaves among 4 peanut cultivars, available soil water had a significant effect (p<0.01) on fallen leaf weights (Table 1). Weight of fallen leaves was highest, 6.11 g per plant, when available soil water was maintained at ½ AW. At FC and ¼ AW, weights of fallen leaves were 2.42 and 2.21 g per plant, respectively.

Root:shoot ratio

On day 75 after emergence, there were no significant differences in root:shoot ratios among peanut cultivars. The ratios were in the range of 0.22-0.28. Root:shoot ratios of peanut plants were significantly different (P<0.01) among three regimes of available soil water and at FC, ½ AW and ¼ AW, root:shoot ratios were, 0.20, 0.27 and 0.29, respectively (Table 1). At harvest, there were significant effects (p<0.01) on root:shoot ratios of available soil water and peanut cultivars and there was an interaction of the two factors (Table 1). Each peanut cultivar displayed different trends in root:shoot ratio as available soil water became progressively depleted. Root:shoot ratios of Tainan 9 and ICGV 98308 increased progressively as available soil water was lowered while that of Khon Kaen 60-3 increased at ½ AW but decreased at ¼ AW. Root:shoot ratios of ICGV 98324 increased as available soil water was reduced to ½ AW and remained relatively constant thereafter (Table 2). Under ½ AW and ¼ AW, Khon Kaen 60-3 had root:shoot ratios of 0.55 and 0.48, respectively, and these ratios were higher than those of the other cultivars. ICGV 98324 had root:shoot ratios of 0.35 and 0.32 at ½ AW and ¼ AW, respectively (Table 2).

Harvest index and shelling percentage

There were significant effects of available soil water and peanut cultivars on harvest index and shelling percentage. There were also interactions of the two factors for harvest index and shelling percentage (Table 1).

At FC, there were no differences in harvest index among peanut cultivars. However, at available soil water lower than FC, changes in harvest index was quite unique for each peanut cultivar (Table 3). At ½ AW, Tainan 9 and ICGV 98324 had relatively high values of harvest index, 0.39 and 0.33, respectively. Harvest indices of Khon Kaen 60-3 and ICGV 98308 at this available soil water were only 0.03. and 0.20, respectively. At ¼ AW, harvest indices for Khon Kaen 60-3 and ICGV 98308 were very low, 0.01 and 0.09, respectively, while those for ICGV 98324 and Tainan 9 were 0.23 and 0.16, respectively.

At FC, shelling percentages were quite similar among peanut cultivars (Table 4). At ½ AW, shelling percentages of Tainan 9 and ICGV 98324 were quite high, 71.9 and 62.3, respectively while that of ICGV 98308 was lower, 54.8 and

Table 2. Effect of available soil moisture regimes on root:shoot ratio of 4 peanut cultivars at harvest.

Cultivars	Root:shoot ratio		
	FC	½ AW	¼ AW
Tainan 9	0.18	0.30	0.41
Khon Kaen 60-3	0.21	0.55	0.48
ICGV 98308	0.21	0.39	0.47
ICGV 98324	0.21	0.35	0.32
LSD(P<0.05)(A)		0.11	

(A) **The LSD value is applied to all means in the table.**

Table 3. Effect of available soil moisture regimes on harvest index of 4 peanut cultivars.

Cultivars	Harvest index		
	FC	½ AW	¼ AW
Tainan 9	0.46	0.39	0.16
Khon Kaen 60-3	0.38	0.03	0.01
ICGV 98308	0.40	0.20	0.09
ICGV 98324	0.42	0.33	0.23
LSD (P<0.05)[(A)]		0.12	

[(A)] **The LSD value is applied to all means in the table.**

Table 4. Effect of available soil moisture regimes on shelling percentage of 4 peanut cultivars.

Cultivars	Shelling percentage		
	FC	½ AW	¼ AW
Tainan 9	77.1	71.9	42.4
Khon Kaen 60-3	67.7	24.9	6.8
ICGV 98308	69.8	54.8	44.2
ICGV 98324	71.6	62.3	46.6
LSD (P<0.05) [(A)]		17.5	

[(A)] **The LSD value is applied to all means in the table.**

that of Khon Kaen 60-3 was even much lower, 24.9. At ¼ AW, three peanut cultivars, ICGV 98324, Tainan 9 and ICGV 98308 had harvest indices between 42 and 46 while Khon Kaen 60-3 had a harvest index of only 6.8.

Available soil water significantly affected leaf development and partitioning of dry matter into individual organs. Leaf areas were highest at FC in both samplings, on day 75 after seedling emergence and at harvest. As available soil water was depleted from FC to ¼ AW, there was a progressive reduction in leaf areas of peanut plants on day 75 after emergence. Lower leaf areas under limited supply of water could be due to lower numbers and sizes of leaves in each plant (Ong *et al*., 1985; Leong and Ong, 1983). However, at harvest, ½ AW caused a more reduction in leaf area than ¼ AW. Lower leaf area at ½ AW was associated with higher weight of fallen leaves as compared to that at ¼ AW (Table 1). Although peanut cultivars differed significantly in leaf areas, the change in leaf area during day 75 after seedling emergence and harvest is quite interesting. Leaf areas of Khon Kaen 60-3 and ICGV 98308 remained unchanged during this period. However, there was a large reduction in leaf areas of Tainan 9 and ICGV 98324. This could be due in part to an acceleration of leaf senescence caused by water stress (Pandey *et al*., 1984).

Under limited available soil water, all peanut cultivars allocated increasing amount of dry matter to root growth, especially cultivars Khon Kaen 60-3 and ICGV 98308. ICGV 98324 had relatively low and constant root:shoot ratios under two regimes of water stress. The ability to allocate dry matter into pod and seed dry matter under any water stresses is probably most important feature of crop plants. Under FC, partitioning of dry matter to pod and seed yield is quite similar for all peanut cultivars. However, such partitioning changed remarkably when available soil water became limited. At ½ AW and ¼ AW, ICGV 98324 allocated 33% and 23%, respectively, of shoot dry matter, for pod yields. At the corresponding available soil water, Khon Kaen 60-3 allocated only 3% and 1% of shoot dry matter for pod yields. A similar response of drought sensitive or drought tolerant was reported (Collino *et al.*, 2000). Under ½ AW and ¼ AW, ICGV 98324 partitioned 62.3% and 46.6% of total pod dry matter into seed yield while Khon Kaen 60-3 allocated only 25% and 6.8% to seed yields, respectively.

The ability to partition dry matter into harvestable yields under limited water supply is an important trait for drought tolerant cultivars (Wright and Nageswara Rao, 1994). Khon Kaen 60-3 and ICGV 98308 could be considered drought-sensitive cultivars. ICGV 98324 and, perhaps, Tainan 9 could be a drought-tolerant cultivar as it is able to produce seed yield to satisfactory extent under water stress. When the two groups of peanut cultivars are re-examined in terms of dry matter partitioning, it appears that, as compared to drought-sensitive cultivars, drought-tolerant cultivars allocated relatively less dry matter for root growth while they allocated relatively more dry matter for pod and seed yields under water stress conditions. It is also interesting to note that, at harvest, when averaged over three regimes of available soil water, there was a large reduction in leaf areas in the two drought-tolerant cultivars while in the two drought-sensitive cultivars leaf areas remained unchanged (Table 1). During this period, there was a large increase in weight of fallen leaves by ½ AW (Table 1) where satisfactory yield was obtained (Vorasoot *et al.*, 2003). It is most likely that moderate water stress may accelerate leaf senescence to remobilize some assimilates for pod and seed growth. Although the role of vegetative assimilates in pod and seed development in groundnut under water stress remains controversial (Wright and Nageswara Rao, 1994), our evidence seems to suggest a crucial role of leaf assimilates for pod and seed growth of tolerant cultivars under drought stress.

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