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Yield Responses of Three Groundnut (*Arachis hypogaea* L.) Cultivars to Water Stress at Different Growth Stages*

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Abstract: This study was conducted to investigate the effect of water stress on the yield of three groundnut cultivars (Kiriz, MH383 and Sodari) for two successive seasons (in the summers of 1996/97 and 1997/98) in the Demonstration Farm of the Faculty of Agriculture, Shambat, Sudan. The experiment was executed in a split-plot design, where water stress (irrigation every 21 days) was applied at 50% flowering, at pegging and at pod filling stage. A non-stressed treatment (irrigated every ten days) was used as a control. The stress period was for three weeks for each of the three stages of growth. Yield components (number of pods/plant, weight of 100 seeds, number of seeds per pod and weight of 100 pods) were not affected by the stress treatments. Shelling percentage was greatly different among the cultivars.

INTRODUCTION

Sudan is a major producing and exporting African country of groundnuts. Nevertheless, the production and export decreased during the 1980's and increased thereafter.

Groundnut has diverse uses, and is the third annual oilseed crop in the world as far as production is concerned, following soybean and rapeseed. Seeds are rich in oil (45%-55% of non-drying oil) which is used as salad and cooking oil and for the manufacture of soap and margarine. Seeds are

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also rich in protein and make a major contribution to human nutrition, as they contain 30% digestible protein beside vitamins B and E. Seeds are consumed roasted or raw or crushed for the preparation of groundnut butter. Shells may be used as animal feed, a source of heat and a raw source of some products, e.g., activated carbon, organic chemicals, combustible gases, reducing sugars and alcohols (Purseglove 1968; Khidir 1997).

Groundnut is one of the main cash crops in Sudan and plays a significant role in its economy. An average of 87% of the area under this crop, during 1990- 99, was rain-fed in western Sudan and the rest under irrigation in the central clay plain. The total harvested area was about 2.54 million feddans (one feddan=0.42 ha) in 2003 season, producing 0.78 million metric tons. The total rain-fed harvested area was 2.35 million feddans, producing 0.58 million metric tons (MOAF 2003). The yield was 1026 kg/fed. in the irrigated areas and 248 kg/fed. in the rain-fed areas. The cultivar MH383 was released in 1970 to replace Ashford which used to be dominating in the irrigated sector. Kiriz, a large- seeded cultivar, was released in 1987 for production in the current River Nile State, and Sodari, an early maturing variety, was recommended in 1986 to replace Barberton in the rain-fed areas (Khidir 1997).

The objective of this study was to assess the effects of water deficit at different growth stages on the yield of three groundnut cultivars.

MATERIALS AND METHODS

An experiment was carried out in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum, Shambat (Latitude 15° 40′N, Longitude 32° 32′E) during 1996/97 and 1997/98 seasons. Shambat climate is a semi-arid and tropical with hot summer and rainy during July-September. The soil of the farm is montmorillonitic clay with 48%- 54% clay, 25% - 29% silt and 17%- 25% sand and is moderately alkaline (pH ranges from 7 to 8) in reaction (Saeed 1968).

A split-plot design was used to execute the experiment with four irrigation treatments as main plots and three groundnut cultivars as subplots. The experiment was replicated four times, giving a total of 48

plots. Each plot contained 6 ridges, 60 cm apart. The gross plot size was 4x4 m, separated to the depth of 90 cm by overlapping galvanized iron sheets to restrict lateral water movement to adjacent plots. Earthen embankments, 60 cm high, separated the plots to avoid surface movement of irrigation water between the adjacent plots (El Nadi 1969).

Three groundnut cultivars; namely, Kiriz (V1), MH383 (V2) and Sodari (V3), were obtained from the Plant Propagation Administration, Sennar, Sudan.
Unshelled seeds were dressed with Fernasan-D (a Lindane and Thiram compound) at a rate of 300 g/100 kg seed for protection against soil pathogens. The seeds were sown on 15th of July of 1996 and 1997, on top of ridges and in holes at a spacing of 15 cm. Three seeds were placed in each hole, and after two weeks were thinned to two plants per hole. Reridging was applied after one month to facilitate pegging.
No fertilizers were applied and manual weeding was carried out four times; the first weeding was one month after sowing.

An electric pump of measurable discharge rate supplied water; this set-up was designed by El Nadi (1969). Using this system, four experimental plots could be irrigated with a pressurized rubber attachment, which can be rotated to full circle, with a valve control for opening and closure of water to each plot as required using a stop watch.

Three treatments (W1, W2 and W3) received irrigation every 21 days during 50% flowering (W1), during pegging (W2) and during seed development and seed filling (W3), whereas the control treatment (W4) was irrigated every 10 days. These stress treatments (W1, W2 and W3) were for three weeks for each of the three stages of growth. All the plots received 340 mm of irrigation water in the pre-experimental period. The total amount of irrigation water for W1, W2, and W3 was 1040 mm by the end of the experiment, whereas it was 1340 mm for W4.
In each plot, the outer most rows were left as guard rows, and the following outer two rows were used for destructive sampling, while the middle two rows were left for yield measurements. Data were collected on the following parameters:-

1- Number of pods per plant
2- Weight of 100 seeds
3- Number of seeds per pod
4- Weight of 100 pods
5- Shelling percentage
6- Final pod yield

Soil moisture content was determined by the gravimetric method just before irrigation for the depths: 15, 30 and 45 cm. The average soil moisture content (% W/W) for each depth was based on samples taken from 12 plots, i.e., one plot/treatment for each replication.

RESULTS AND DISCUSSION

Pod yield in the first season was lower than in the second season. This might have been due to the relatively high temperature in August in the first season at the time of flowering and pegging.

The analysis of variance revealed that there was no significant effect of watering treatments on number of pods per plant in the second season (Table 1). This is in agreement with the findings of Su *et al*. (1964) who reported that the reduction in number of flowers would not greatly lower the yield, because the number of flowers may be 20 times the number of mature fruits.

There was no significant effect of watering treatments on weight of 100 seeds during the second season (Table 2). This is in contrast with the findings of Reddy *et al*. (1980, 1982) and Ishag (1982) who reported reduction in 100- seed weight in groundnut with water stress.

The cultivars had highly significant different responses in the first season. The interaction between watering treatments and cultivars was not significant, in both seasons.

Table1. Effect of water-stress and cultivars on mean number of pods per plant during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety V1	V2	V3	Mean
		1996/97 season		
W1	43.7	37.3	53.3	44.80
W2	42.5	33.3	41.2	39.00
W3	36.4	40.8	33.9	37.00
W4	40.3	50.9	34.0	41.70
Mean	40.7	40.6	40.6	
L.S.D. 0.05 (W)		5.44		
L.S.D. 0.05 (V)		6.65		
L.S.D. 0.05 (W x V)		13.31		
		1997/98 season		
W1	25.9	27.1	23.7	25.60
W2	20.6	25.9	26.4	24.30
W3	31.4	27.7	30.4	29.80
W4	41.2	31.8	41.8	38.30
Mean	29.8	28.1	30.6	
L.S.D. 0.05 (W)		21.48		
L.S.D. 0.05 (V)		7.85		
L.S.D. 0.05 (W x V)		15.70		

V1 = Kiriz; V2= MH383; V3= Sodari
W1= irrigation every 21 days during 50% flowering;
W2= irrigation every 21 days during pegging;
W3= irrigation every 21 days during pod filling;
W4= irrigation every 10 days (control)

Table 2. Effect of water-stress and cultivars on mean weight of 100 seeds (g) during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety			Mean
	V1	V2	V3	
		1996/97 season		
W1	48.9	49.3	41.6	46.60
W2	34.5	44.3	27.4	35.50
W3	42.3	48.0	26.0	38.80
W4	51.6	53.5	43.0	49.40
Mean	44.3	48.8	34.5	
L.S.D. 0.05 (W)		11.41		
L.S.D. 0.05 (V)		6.68		
L.S.D. 0.05 (W x V)		13.36		
		1997/98 season		
W1	49.5	57.3	50.5	52.40
W2	55.5	48.3	33.5	45.80
W3	59.5	42.3	52.8	51.50
W4	80.3	62.5	64.3	69.00
Mean	61.2	52.6	50.2	
L.S.D. 0.05 (W)		21.62		
L.S.D. 0.05 (V)		8.08		
L.S.D. 0.05 (W x V)		16.16		

Abbreviations as in Table 1

The water treatment had no significant effect on the number of seeds per pod in both seasons. The cultivars showed highly significant ($P \leq 0.01$) differences in the first season only (Table 3). This is in agreement with the findings of Momen *et al.* (1979) who reported that the reproductive attributes are insensitive to moisture stress applied at any stage of growth. Furthermore, El Amin (1984), working on broad bean, suggested that the number of seeds per pod is genetically controlled. Also, Pandey *et al*. (1984) reported that water stress had less influence on seed number than on yield and pod number. The interaction was not significant in both seasons.

Table 3. Effect of water-stress and cultivars on mean number of seeds per pod during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety			Mean
	V1	V2	V3	
1996/97 season				
W1	1.05	1.5	1.6	1.40
W2	0.9	1.6	1.3	1.30
W3	0.9	1.6	1.3	1.30
W4	1.2	1.6	1.4	1.40
Mean	1.0	1.6	1.4	
L.S.D. 0.05 (W)	0.29			
L.S.D. 0.05 ((V)	0.15			
L.S.D. 0.05 ((W x V)	0.31			
1997/98 season				
W1	1.7	1.6	1.9	1.70
W2	1.5	1.8	1.5	1.60
W3	1.3	1.5	1.9	1.60
W4	1.6	2.0	1.7	1.80
Mean	1.5	1.7	1.8	
L.S.D. 0.05 (W)	0.35			
L.S.D. 0.05 (V)	0.30			
L.S.D. 0.05 (W x V)	0.06			

Abbreviations as in Table 1

The water treatment had no significant interaction effect on the weight of 100 pods in the first season. The cultivars were significantly affected by water treatment in both seasons (Table 4). It is likely that stress at 50% flowering caused flower shedding, rather than affecting the pod weight. The pods that succeeded to develop resumed growth successfully. However, Ishag (1982) reported that water-stress during the stage of pod filling results in reduction in pod weight

Table 4. Effect of water-stress and cultivars on weight of 100 pods (g) during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety			Mean
	V1	V2	V3	
1996/97 season				
W1	83.3	69.5	70.7	74.50
W2	64.1	65.8	47.5	59.10
W3	79.3	70.5	48.8	66.20
W4	87.3	78.8	66.3	77.50
Mean	78.5	71.0	55.6	
L.S.D. 0.05 (W)		14.14		
L.S.D. 0.05 (V)		11.88		
L.S.D. 0.05 (W x V)		23.77		
1997/98 season				
W1	88.5	80.5	73.0	80.70
W2	96.0	73.8	49.5	73.50
W3	102.5	68.3	78.0	82.90
W4	122.8	92.8	88.8	101.4
Mean	102.5	78.9	72.3	
L.S.D. 0.05 (W)		21.16		
L.S.D. 0.05 (V)		12.88		
L.S.D. 0.05 (W x V)		25.75		

Abbreviations as in Table 1

Watering treatment had significant effect on shelling percentage in the first season (Table 5). The cultivars were significantly ($P \leq 0.05$) affected in both seasons. The interaction between watering treatments and cultivars showed no significant effects on shelling percentage in both seasons (Table 5).

Table 5. Effect of water-stress on the shelling percentage of the three groundnut cultivars during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety			Mean
	V1	V2	V3	
		1996/97 season		
W1	57.6	71.8	69.3	66.20
W2	54.0	67.2	57.7	59.60
W3	53.1	67.7	56.1	59.00
W4	58.8	68.1	65.8	64.20
Mean	55.9	68.7	62.2	
L.S.D. 0.05 (W)		5.40		
L.S.D. 0.05 (V)		4.60		
L.S.D. 0.05 (W x V)		9.20		
		1997/98 season		
W1	55.3	70.4	68.1	64.60
W2	56.7	64.5	65.7	62.30
W3	58.0	57.4	68.4	61.30
W4	61.0	69.3	73.8	68.00
Mean	57.8	65.4	69.0	
L.S.D. 0.05 (W)		9.81		
L.S.D. 0.05 (V)		4.72		
L.S.D. 0.05 (W x V)		9.43		

Abbreviations as in Table 1

Rao *et al.* (1985) reported that shelling percentage is hardly affected by water deficit, suggesting more effect would be on pod development than on seed filling under prolonged water deficit. MH383 produced higher shelling percentage than the other cultivars in the first season, and this is

in line with the findings of Ishag (1982), whereas Sodari produced higher shelling percentage in the second season. The effect of water stress on shelling percentage varied in the two seasons for unknown reasons. But, the effect among cultivars can be explained in terms of the differences in the ratios of pod to shell weight in the three cultivars.

In both seasons, watering treatments had no significant effect on pod yield (ton/ha) (Table 6). This may be due to the fact that the level of water-stress applied in this work was not severe enough to cause reduction in pod yield. Kiriz had significantly higher mean yield (2.5 ton/ha) than both Sodari (2.1 ton/ha) and MH383 (1.9 ton/ha). The yield of MH383 was not significantly different from that of Sodari.

Table 6. Effect of water-stress on pod yield (ton/ha) of the three groundnut cultivars during 1996/97 and 1997/98 seasons

Irrigation treatment	Variety			Mean
	V1	V2	V3	
		1996/97 season		
W1	1.6	1.6	1.7	1.60
W2	1.4	1.3	0.9	1.20
W3	3.2	1.5	0.8	1.80
W4	1.2	2.0	1.0	1.40
Mean	1.9	1.6	1.1	
L.S.D. 0.05 (W)		0.78		
L.S.D. 0.05 (V)		0.70		
L.S.D. 0.05 (W x V)		1.40		
		1997/98 season		
W1	2.2	2.3	1.7	2.10
W2	2.0	2.0	1.6	1.80
W3	2.2	1.4	2.1	1.90
W4	3.5	1.9	2.9	2.80
Mean	2.5	1.9	2.1	
L.S.D. 0.05 (W)		1.30		
L.S.D. 0.05 (V)		0.35		
L.S.D. 0.05 (W x V)		0.69		

Abbreviations as in Table 1

The data in Table 7 illustrate the soil moisture content (% W/W) under the three irrigation treatments during 1996/97 and 1997/98 seasons. There was a similar pattern of soil moisture changes during both seasons. In all the sampling depths, the moisture content was higher under the control watering treatment, which was irrigated every 10 days, and decreased with depth, whereas it increased with depth for the stress treatment (21 days).

The three groundnut cultivars, Kiriz, MH383 and Sodari, seemed to behave similarly with respect to soil moisture extraction. This is similar to the findings of Ismail (1987), who also reported that the bulk of available moisture for plant growth was held in the top 15 to 60 cm of the soil and smaller moisture changes were detected below this level. The higher soil moisture with depth under the stressed treatment may also be due to the shallow roots of groundnut which produced most of the pods in the top 8 cm of the soil. Similar results were reported by El Rayah (1975).

Table 7. Average soil moisture content (W/W%) at different soil depths under three groundnut cultivars during 1996/97 and 1997/98 seasons

Treatment	Soil depth (cm) in 1996/97			Soil depth (cm) in 1997/98		
	15	30	45	15	30	45
W1	17.0	18.1	19.3	18.2	19.0	20.0
W4	24.1	23.8	23.0	23.1	22.5	22.0
W2	16.3	17.2	19.0	17.1	18.0	18.3
W4	23.0	24.1	24.4	22.2	21.1	20.8
W3	16.1	17.2	18.0	16.8	17.3	18.1
W4	22.3	21.1	20.4	21.0	20.6	20.3

W1= irrigation every 21 days during 50% flowering;
W2= irrigation every 21 days during pegging;
W3= irrigation every 21 days during pod filling;
W4 = irrigation every 10 days (control)

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استجابة انتاجية ثلاثة اصناف من الفول السوداني للاجهاد المائى فى فترات نمو مختلفة*

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موجز البحث: اجريت تجربة فى المزرعة التجريبية بكلية الزراعة بشمبات لموسمين (1996 / 97 و 1997/ 98) لدراسة تأثير الاجهاد المائي على إنتاجية ثلاثة أصناف من الفول السوداني هى كرز و MH383 وسودري .

استخدم تصميم القطع المنشقة فى تنفيذ التجربة وتحديد الاجهاد المائي بامتداد فترة الرى (interval) إلى 21 يوماً بالمقارنة مع معاملة الشاهد التى تروى كل عشرة أيام . وكانت مراحل النمو التى عرضت للإجهاد المائي هى مرحلة الإزهار بنسبة 50 % ومرحلة تكوين المهاميز (Pegging) ومرحلة امتلاء القرون (Pod filling) ، حيث كانت فترة الإجهاد ثلاثة اسابيع لكل مرحلة . اسفرت النتائج عن عدم وجود فروقات معنوية فى عدد القرون بالنبات الواحد ووزن مائة بذرة ، وعدد البذور فى القرن الواحد ، ووزن مائة قرن . اي ان الإجهاد المائي لم يؤثر علي مكونات الإنتاجية . وكانت الفروقات معنوية فقط فى نسبة التقشير (وزن القشور إلى وزن البذور) فى الأصناف الثلاثة .

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