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Response of Three Indigenous Pulse Crops to Different Moisture Conditions*

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Abstract: A field experiment was conducted in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum for two seasons (January to May 2005 and December 2005 to May 2006). The objective of the experiment was to study the effect of 7 and 14 days irrigation intervals on growth and yield of three local pulse crops; namely, *Vigna unguiculata* 'Lubia Hilu', *V. sinensis* 'Lubia Kordofani' and *Lablab purpureus* 'Lubia Afin'. The results showed that irrigation every 14 days reduced dry matter production and seed yield, but increased the percentage of crude protein in the seeds of the three crops as a result of increase in the ratio proteins: carbohydrates.

Key words: Pulse crops; irrigation

INTRODUCTION

Seed legumes are an important constituent in the diet of inhabitants of Africa and Asia and especially so among low-income groups for whom animal proteins are hardly affordable. FAO (1984) made a special reference to cowpea *(Vigna* spp.).

The genus *Vigna* comprises a number of species some for human food and others for animal feed. Like all other legumes, *Vigna* species improve soil fertility by fixing atmospheric nitrogen in the soil. *V. sinensis* (L.) and *V. unguiculata* (L.), locally known as 'Lubia Hilu' and 'Lubia Kordofani', respectively, are widely used in Sudan, especially in rural areas where about 70% of the population earn their living (MOAF 2005).

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V. unguiculata (L.) (cowpea) is usually grown under irrigation in small plots or in the periphery of the main crop. When grown as a dual-purpose crop, the green leaves are stripped off the growing plants and are cooked with other ingredients for food. Regeneration of leaves and growth of the plants to maturity produce seeds that are used for food.

V. sinensis is grown mostly as a rain crop for seed production, either as a pure stand in small areas or inter-cropped with others.

Lablab purpureus is a dual purpose crop, usually grown for fodder, obtained from cutting the crop and after re-growth seeds are obtained from the mature pods. This crop received some research attention due to its place in the Gezira rotation (e.g., Ishag 1994) and in other irrigated areas (e.g., Abusuwar 2005).

Early in the 20th century, researchers found that water stress results in reduction of different growth parameters and yield of crops. This reduction varies with the magnitude and duration of water stress and also with the stage of crop development. (Slatyer 1967; Kramer 1969; El Nadi 1970, 1975; Mingcai *et al*. 2004; Ahmed and Ali 2006).

During water stress, cowpea maintains constant predawn leaf water potential at a level not lower than that of unstressed plants (Turk and Hall 1980). Early and erect cowpea cultivars proved to be useful in some dry environments because of their ability to escape drought (Hall and Patal 1985).

In the Sudan, 'Lubia Afin' can be grown all the year round, but the best productivity is achieved when sown in July and the lowest productivity results from sowing in the cool season (November to February) (Mustafa *et al.* 1999). There is paucity of information about the productivity of the other two crops.

The objectives of this study were, therefore, (i) to study the responses of the three crops to different soil moisture conditions, imposed by two irrigation intervals, (ii) to compare the water use efficiency of the two

Vigna species for seed production and also for fodder and seed production of *Lablab purpureus*.

MATERIALS AND METHODS

Experimental site, climatic and soil factors

This study was carried out in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (Lat. 15°40′N and long. 32°32′E). The climate of the locality is semi-arid, with low relative humidity. The maximum daily temperature in summer reaches 45°C or more and is around 20°C in winter, but night temperatures are lower. Average daily solar radiation is between 20.3 and 26.3 Megajouls M^2/day in January and April, respectively. Lower values were recorded as a result of clouds during the short rainy summer (Adam 2002).

The soil is alkaline, with a pH between 8.0 and 8.5, and the clay content ranges between 45 and 55 in the top 60 cm. The soil structure and water infiltration are poor. The field capacity (0.3 bar) is 53% and the 15-bar value is 16%. The bulk density ranges between 1.25 and 1.50 at the depths of 15 and 75 cm, respectively (Drover 1966).

Land preparation and method of irrigation

The experimental site was disc ploughed, cross-disced, harrowed and leveled. Ridges, 80 cm apart, were made. The experimental area was then divided into border strips 6 m wide and 40 m long and separated by earthen embankments 40 cm wide. Each border strip was divided into plots 5.6 x 5.6 m and contained seven ridges. Every two strips were irrigated by a branch field channel which received water from the main canalization system of the whole field. Each plot was irrigated manually according to the scheduled time by opening and closing the water-inlet of each plot by a mass of consolidated clay.

Experimental design and treatments

The experimental design was split plot with three replications. The main plots were assigned for the two irrigation treatments: W_1, irrigated every seven days and W_2 irrigated every 14 days. The sub-plots were allocated

for the three pulse crops; namely, *V. unguiculata*, *V. sinensis* and *Lablab purpureus*. The experiment was conducted for two consecutive seasons, the first was during Jan to May 2005 and the second was during Dec. 2005 to May 2006. The seed rate (in kg/ha), as recommended by Abusuwar (2005), was 16 for 'Lubia Hilu', 17 for 'Lubia Kordofani' and 25 for 'Lubia Afin'.

The experiment received three hand weedings during each of the two growing seasons. In the first season, the insecticide Actara 25 was applied for the control of aphids and white flies and in the second season, the insecticides Folimat and Confidor were applied to control heavy infestation of pod borers.

Data collection

In the two seasons, samples from the crops were taken from the outer two ridges of each plot, and the five internal ridges were reserved for the final harvest. The samples were taken from plants 58, 72 and 85 days old for the following determinations:-

1. The dry weight of leaves and stems: Leaves were separated from the stems of 15 plants and the dry weight was used to determine the leaf/stem ratio.
2. The average growth rate (A.G.R.), calculated for average increase in dry matter during the period of two successive samples
3. The soil moisture content, determined in a mixed sample from the surface to 30 cm depth and from 30–60 cm, two days after each irrigation. Similarly, the moisture content at the mentioned depths was determined just before the next irrigation. Thus, the total moisture depletion for the irrigation cycles of the whole season was determined and crop water use efficiency (WUE) was calculated.
4. The final harvest (86 days after sowing), total dry matter, total seed yield, 100-seed weight and harvest index (H.I.)
5. The crude protein content of the seeds of the first season

RESULTS AND DISCUSSION

Water stress, imposed by irrigation every 14 days, compared with irrigation every seven days, resulted in reduction of growth parameters of *V. ungiculata*, *V. sinensis* and *Lablab purpureus* (Table 1).

Leaf/stem ratio: The ratio of the weight of leaves to the weight of stems decreased with plant age when monitored at the age of 58, 72 and 86 days after sowing (Table 1). High values of this ratio are desirable for 'Lubia Hilo', since both the leaves and seeds are used for food. This finding suggests that harvesting the leaves of 'Lubia Hilo' should not be delayed later than 58 days after sowing.

The decline in this ratio after the age of 58 days was common for the three crops and under the two water regimes, with the sole exception of treatment W_2 in the second season during which this ratio increased slightly until the age of 72 days for 'Lubia Hilo'.

Dry matter accumulation A.G.R. and WUE: For the two seasons, dry matter accumulation under W_1 was higher than that under W_2, (Table 1).

A.G.R. was calculated to compare increments in dry matter (W_2-W_1) for the three crops and irrigation treatments during the time period (T_1 and T_2) by the relation:-

$$A.G.R. = (W_2-W_1) / (T_2-T_1)$$

A.G.R., as expected, had a similar trend as dry matter accumulation (Table 2). In the first experiment, WUE of the three crops, grown under the short or long irrigation intervals, was similar by reason of the similarity of the ratio of water used to the obtained yield. In the second season, the pattern was not consistent. This was most probably due to failure to control insect damage.

WUE of the two *Vigna* species under the conditions of this experiment were lower than the value found for haricot beans (El Nadi 1975), and also lower than that of broad beans (El Nadi 1970). The relatively low yields of the two species of *Vigna* also account for their low WUE.

Effect of water regime on the content of crude protein in the seeds: Water stress has been known for a long time to have adverse effects on a

number of physiological processes, including high rate of respiration and enhanced hydrolytic reactions which deplete the carbohydrate reserves in plant structures affected by the stress.

The two main food reserves stored in seed legumes are crude proteins and carbohydrates. Enhanced hydrolysis of carbohydrates and their depletion, due to the increase in the respiration rate under conditions of water stress, result in increase in the ratio of crude proteins, coupled with decrease in seed weight of stressed plants. This fact was also reported by Husman *et al*. (2000).

The percentage of crude protein was 25.3 and 32.8 in the seeds of *V. unguiculata*, 22.1 and 37.9 in the seeds of *V.sinensis* and 26.1 and 30.4 in the seed of *Lablab purpureus* for W_1 and W_2, respectively.

Effects of water stress on seed weight and harvest index (H.I.): Table 3 depicts clear reduction in 100-seed weight due to water stress, induced by prolonged irrigation until 14 days. Reduction in this parameter was established by the findings of several workers on different crops, e.g., broad beans (El Nadi 1970), haricot beans (El Nadi 1975) and soybean (Mingcai *et al* 2004).

The H.I. and seed yield were higher under irrigation of 14 days than irrigation every seven days for the three crops (Table 4). This finding indicates that frequent irrigation (W_1) was more favourable for vegetative growth than for reproductive growth. The seed yield of *V. ungiculata* and *V. sinensis* in the first season was comparable with the productivity reported by FAO (1984). However, under irrigation, Abdel Bagi (1985), reported higher yields.

Water use efficiency (WUE): The results of the first season showed that the total yield of fodder and seeds of *Lablab purpureus* were associated with the highest WUE (small numerical value of 0.84 for W_1 and 0.98 for W_2), *V. unguiculata* was second and *V. sinensis* was third. The reason for the superiority of *Lablab purpureus* is attributable to the fact that both the dry shoots and seeds are of economic value.

Table 1. Effect of water regime on the ratio of leaf/stem and accumulation of dry matter of three indigenous pulse crops

Crop and water regime	Crop age (days)					
	1st season			2nd season		
	58	72	86	58	72	86
	Leaf: Stem ratio					
'Lubia Hilu'						
W1	3.03	1.43	1.26	2.90	1.60	1.57
W2	2.80	1.33	1.13	2.17	2.20	1.83
'Lubia Kordofani'						
W1	2.37	2.07	1.57	5.23	3.87	2.07
W2	2.17	1.93	1.50	4.27	2.73	2.23
'Lubia Afin'						
W1	2.73	1.97	1.30	3.23	15.0	0.98
W2	2.30	1.83	1.27	2.37	10.7	0.90
L.S.D.(0.05) (W)	1.92	1.89	0.14	1.29	1.41	0.50
L.S.D.(0.05) (C)	0.47	1.04	0.31	1.25	0.53	0.24
	Dry matter (tons/ha) accumulation					
'Lubia Hilo'						
W_1	0.78	1.78	2.68	0.048	0.091	0.129
W_2	0.50	1.26	2.39	0.035	0.055	0.068
'Lubia Kordofani'						
W_1	0.55	0.90	1.37	0.037	0.059	0.089
W_2	0.29	0.76	1.22	0.019	0.038	0.049
'Lubia Afin'						
W_1	0.60	1.63	2.85	0.040	0.073	0.125
W_2	0.37	1.15	1.93	0.039	0.059	0.049
L.S.D. (0.05) (W)	0.06	0.33	0.04	0.004	0.048	0.077
L.S.D. (0.05)(C)	0.09	0.40	0.66	0.015	0.027	0.043

W_1 = irrigation every seven days; W_2 = irrigation every 14 days

Table 2. Effect of the water regime on average growth rate (A.G.R.) of three indiginous pulse crops for two successive 14 days.

Crop and water regime	A.G.R. (kg dry matter/ha/day)			
	1st season		2nd season	
	Between sample 1 and 2	Between sample 2 and 3	Between sample 1 and 2	Between sample 2 and 3
'Lubia Hilo'				
W_1	71.4	64.3	3.1	2.7
W_2	53.9	43.1	1.4	0.9
'Lubia Kordofani'				
W_1	34.0	33.1	1.5	2.1
W_2	25.2	32.9	1.3	0.9
'Lubia Afin'				
W_1	73.6	87.1	2.3	3.7
W_2	55.5	21.2	1.5	1.2

W_1 = irrigation every seven days; W_2 = irrigation every 14 days

Table 3. Effect of water regime on 100-seed weight for the three indiginous pulse crops for the first experiment.

Crop	100-seed weight(g)		Reduction (%) (W_2/W_1)
	W_1	W_2	
'Lubia Hilo'	8.6	8.0	9.3
'Lubia Kordofani'	25.6	21.3	8.3
'Lubia Afin'	17.0	15.3	9.0

W_1 = irrigation every seven days; W_2 = irrigation every 14 days
The seed yield of the second experiment was atypical because of insect attack that resulted in lower yield.

Table 4. Effect of water regime on dry weight of shoots, seed yield, harvest index (H.I.) and water use efficiency (WUE)

Crop and water regime	Seed yield (tons/ha)	Weight of dry shoots (tons/ha)	H.I. (%)	Total water used in season (M^3/ha)	WUE (M^3/kg yield)
			1st season		
'Lubia Hilo'					
W_1	0.66	3.75	15.0	4400	6.66
W_2	0.52	2.32	22.0	3290	6.32
'Lubia Kordofani'					
W_1	0.61	1.23	33.0	4310	7.06
W_2	0.40	0.77	34.0	3100	7.75
'Lubia Afin'					
W_1	0.07	5.17	1.3	4400	0.84
W_2	0.25	3.30	2.4	3290	0.98
LSD (0.05) Seed yield (W) = 0.26 and (C) = 0.31					
LSD (0.05) Dry weight of shoots (W) = 1.08 and (C) = 0.31					
			2nd season		
'Lubia Hilo'					
W_1	0.15	1.88	7.0	3370	22.46
W_2	0.07	0.65	10.0	2300	32.85
'Lubia Kordofani'					
W_1	0.14	1.12	11.0	4640	33.14
W_2	0.08	0.52	13.0	3020	37.75
'Lubia Afin'					
W_1	0.24	4.55	5.0	3370	0.70
W_2	0.20	2.20	8.33	2300	0.68
LSD (0.05) Seed yield (W) = 0.06 and (C) = 0.07					
LSD (0.05) Dry weight of shoots (W) = 1.30 and (C) = 0.43					

H.I. = Seed yield ÷ total weight of seeds + plus total dry weight of shoots
WUE for Lubia Hilo and Lubia Kordofani = M^3 water/kg seeds
WUE for Lubia Afin = M^3 water/kg seeds + dry weight of shoots

CONCLUSIONS

1. Irrigation interval of seven days and water use efficiency are better for vegetative and reproductive growth of the two *Vigna* sp. than irrigation every 14 days. The short irrigation interval is also better for dry fodder and seed production of *Lablab purpureus*, but the economics of this irrigation practice has to be investigated.
2. Although the seed yield was reduced under irrigation every 14 days, the percentage of crude protein was increased due to increase in the ratio of protein/carbohydrates.

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إستجابة ثلاثة من محاصيل البقول المحلية للإختلاف رطوبة التربه*

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موجز البحث: أجريت تجربة لموسمين (يناير - مايو 2005 وديسمبر 2005 - مايو 2006) في المزرعة التجريبية بكلية الزراعة - جامعة الخرطوم. وقد كان هدف التجربه دراسة تأثير فترة الرى (كل سبعة ايام وكل 14 يوما) علي نمو وانتاجية ثلاثة انواع من البقول المحلية هي 'لوبيا حلو' و *Vigna ungiculata* 'لوبيا كردفاني' *Vigna sinensis* و 'لوبيا عفن' *Lablab purpureus* . أدَى الرى كل 14 يوم الى نقص في المادة الجافة والانتاجية من البذور والي زيادة في نسبة البروتين الخام في بذور الانواع الثلاثة نتيجة لزيادة نسبة البروتين الي الكربوهيدرت.

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