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Effect of Water Potentials on Growth and Yield of Cowpea (*Vigna Unguiculata* [L] Walp)

Abdelshakoor H. suliman and Faisal Elgasim Ahmed

Dept. of Crop Sciences, Fac. Of Agric. University of Zalingei, Darfur-Sudan

Abstract: A field experiment was conducted for two consecutive seasons during 2003/2004 and 2004/2005 in the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat to study the effect of different water stress levels on growth and yield of cowpea (*Vigna unguiculata* L. [Walp]) cultivars. Two cowpea cultivars were used in this study, namely: Ein el Ghazal (Line 1-12-3) and Dahab el Goz (IT84s-2163). Six water stress levels (-2.5, -5.0, -7.5, -10.0, -12.5, and -15.0 bars) as estimated by predawn leaf water potential using pressure chamber was applied. The results showed that water stress treatments significantly reduced the number of leaves per plant, leaf area index, leaf area ratio, shoot\root ratio and biomass production. Similarly, seed yield was significantly reduced by water stress treatments, particularly at lower soil water potentials (-12.5 and -15.0 bar). The reduction in yield was associated with substantial reductions in yield components. Significant differences were observed between the two cultivars in the different characters studied. In this respect, Dahab el Goz (V2) exhibits vigorous growth (greater number of leaves per plant, leaf area index, leaf area ratio and deep root system) and seed yield compared to Ein el Ghazal (V1). The critical water stress levels as estimated by soil water potentials for cowpea growth and yield were found to be lower than -10.0 bars.

Key words:

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp) is one of the ancient human food sources and has probably been used as a crop since Neolithic times [22]. A lack of archaeological evidence has resulted in contradicting views supporting Africa, Asia, and South America as origin [22,4,10]. Presently, cowpea is grown throughout the tropic and subtropics areas around the whole world where rainfall resources are characteristically low (300-600 mm) and variable [6]. Generally, cowpea is better adapted to drought, high temperatures and other biotic stresses compared with other crops [5,12,15].

Many cultivars of cowpea are, however, damaged by drought and high temperatures, especially during reproductive development. For instance, the combination of high temperature, drought and long days can slow down or inhibit floral bud development, resulting in few flowers being produced and substantially reduced cowpea productivity [1]. This low productivity has been attributed to water deficit, the persistent of the traditional cropping systems, pests and diseases. Generally, under adequate soil moisture conditions, the indeterminate cowpea flowers over along period, produces more seeds, and yield loss is limited. On the contrary, under water deficit conditions, as is often the case in the semi-arid zones, the flowering period is cut short and the seed matures earlier. Moreover, the formation of new floral nodes and flowers are delayed and/or aborted, thus leading to low productivity [24]. In addition, cowpea is also sensitive to drought at different stages of growth.

According to Shouse [20], the crop response to water stress at various stages of growth is related to crop species, stage of growth, economic portion of the crop, and the duration of the stress. Earlier studies indicated that cowpea could maintain seed yield when subjected to vegetative stage drought provided subsequent conditions were conducive for flowering and pod set [28,21]. However, Akyeampong [2] showed that, the crop is highly sensitive to water deficits during flowering and pod filling stages. Therefore, stability in yields of agronomically acceptable cultivars is generally regarded as the ultimate goal in cowpea improvement and a cornerstone in achieving sustainability. One way to achieve this is to identify genotypes with adequate levels of resistance to drought, heat and other stresses. The objective of this investigation was to study the effect of water stress on growth and yield of cowpea cultivars.

MATERIALS AND METHODS

A field experiment was conducted for two

Corresponding Author: Abdelshakoor H. suliman, Dept. of Crop Sciences, Fac. Of Agric. University of Zalingei, Darfur-Sudan

consecutive seasons during 2003/2004 and 2004/2005 at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (Latitude 15° 40' N, Longitude 32° 32' E, and Altitude of 280 meters *asl*). Two cultivars of cowpea were used in the experiment; namely, line 1-12-3 (V1) and IT84s-2163 (V2), locally known as Ein elGhazal and Dahab elGoz, respectively.

The experiment was designed to study the effect of six watering regimes on the performance of two cowpea cultivars under irrigated conditions. The watering treatments corresponded to the following soil water potentials: -2.5 bars (W1), -5.0 bars (W2), -7.5 bars (W3), -10.0 bars (W4), -12.5 bars (W5), and -15.0 bars (W6). The soil water potentials were estimated by measuring the predawn leaf water potential using the pressure chamber (Model Skye, SKPM 1400, UK) as described by Lawn (1982). Before the commencement of the treatments (three weeks after sowing), the plants received equal quantities of water (450 mm) using a calibrated pump. Pre-irrigation soil moisture content was determined using both the gravimetric method and tensiometers (Gallenkamp, Growers Model 080, 1968).

The experimental treatments were arranged in 6 x 2 split-plot design with four replications in both seasons. The main plots were allotted for the cultivars and the subplots for watering treatments. The spacing between holes was 25 cm, and the individual plot size was 20 meter square consisting of five ridges of four-meter in length. Sampling was carried out from ten plants in each plot randomly selected. Data collected was subjected to analysis of variance (ANOVA) and LSD was used for means separation and correlation analysis was also applied using SPSS.

RESULTS AND DISCUSSION

The statistical analysis showed that watering treatments and cultivars had significant effects ($P \geq 0.05$) on mean number of leaves per plant particularly in the last two sampling occasions (fig. 1 and 2), leaf area index (Fig. 3 and 4), shoot/root ration (Table 1), specific leaf weight (Fig. 5 and 6), leaf area ratio (Table 2). In these growth parameters low levels of water potential had a significantly effect. V2 showed vigorous growth in the mentioned attributes compared to V2. On the other hand yield components were significantly decreased as a result of water stress In this regard; number of pods per plant (Table 3), number of seeds per pod (Table 4) and seed weight (Table 5) were significantly reduced by low water potential levels. The final seed yield was substantially decreased by water stress (Table 6). V1 showed heavier seeds and thus higher yields compared to V2. On the other hand V2 showed greater number of pods per plant and seeds per pod. Correlation analysis carried out for both growth and yield parameters versus water potential showed negative values with water potential but positively correlated with each other (Table 7 and 8).

Discussion: In the present study, growth attributes were significantly affected by watering treatments especially after flowering in both seasons. This may be attributed to the fact that water stress had no or little effect on vegetative development. Supporting evidences were reported by Bates and Hall (1982) who showed that under field conditions cowpea exhibits extreme drought avoidance at the vegetative stage to the extent that water conservation by the remaining tissue ensures plant survival. Similarly, many researchers reported no or little effect of drought on the vegetative growth attributes of cowpea [24,27,22]. Since source strength depends on total leaf area, the reduction in leaf growth ultimately reduces carbon supply as reported by many workers [11,14] and Anyian and Herzog [3] reported that under water deficit conditions, leaf area was sharply reduced as a result of leaf growth reduction and abscission. The reduction in leaf area reduces crop growth and thus biomass production. Seed production, which is positively correlated with leaf area [18], may also be reduced by leaf area reductions induced by drought stress. Similarly, the reduction in leaf area index, leaf area ratio and specific leaf weight observed in this study, may be attributed to the effect of water stress on leaf growth and expansion. Supporting evidences were reported by many researchers [13,18,9,3]. This was further substantiated by the result of the correlations where most of these parameters were negatively correlated with leaf water potentials.

The reduction in number of nodules per plant observed in the present study may be attributed to the effect of drought on the process of nodulation and the activity of nitrogenase enzyme as has been reported by Wansnik *et al.* [27] and Reppela and Beck [19]. In grain legumes, nitrogen accumulation is closely related to biomass accumulation and seed growth. In this study, plant nodulation was positively correlated with biomass production. However, it is not obvious which particular physiological process of the stressed plant actually affect nodule growth and metabolism [8]. Furthermore, Rapela and Saxena [16] showed that, the nodules of annual plants tend to die at flowering and seed set presumably because at this time flowers and developing seeds are the major sinks of the resources thus causing nodule disintegration. This might explain the higher number of nodules per plant at the end of the vegetative period and at the beginning of flowering observed in this study.

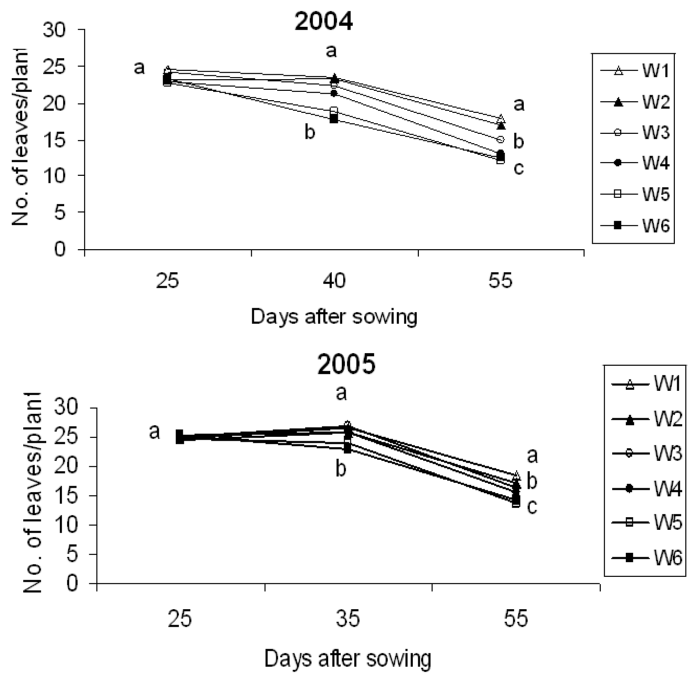

Fig. 1: Effect of water stress on mean number of leaves/plant during 2004 and 2005 seasons

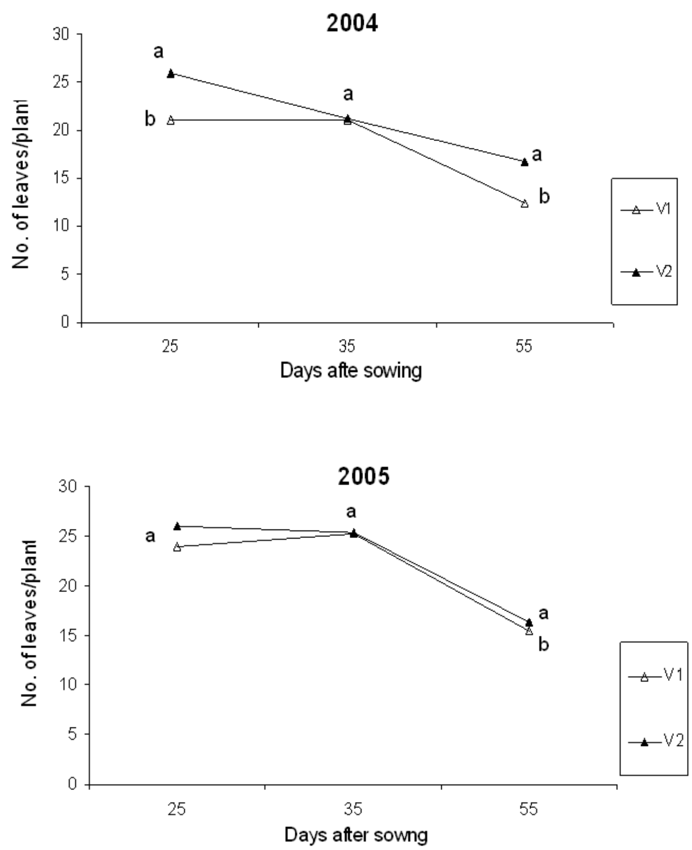

Fig. 2: Effect of cultivars on mean number of leaves/plant during 2004 and 2005 seasons

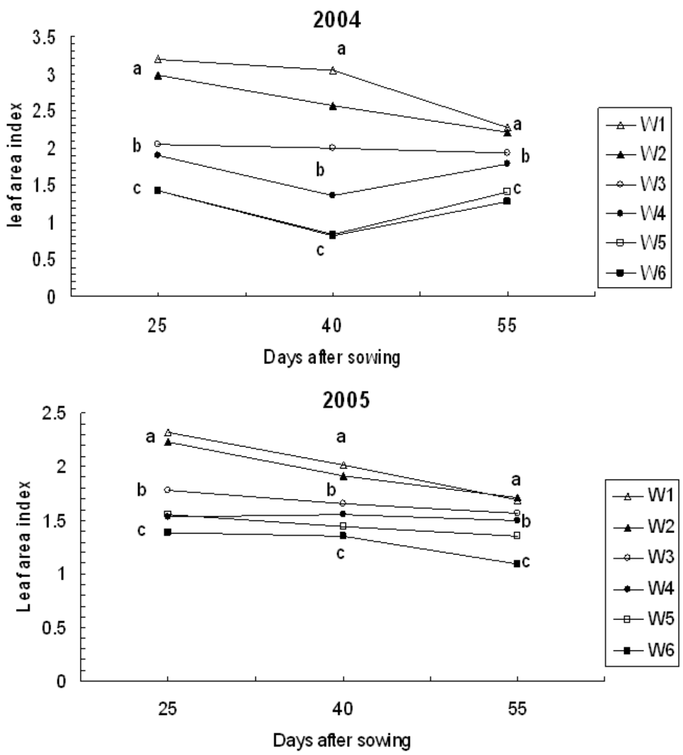

Fig. 3: Effect of water stress on mean leaf area index during 2004 and 2005 seasons

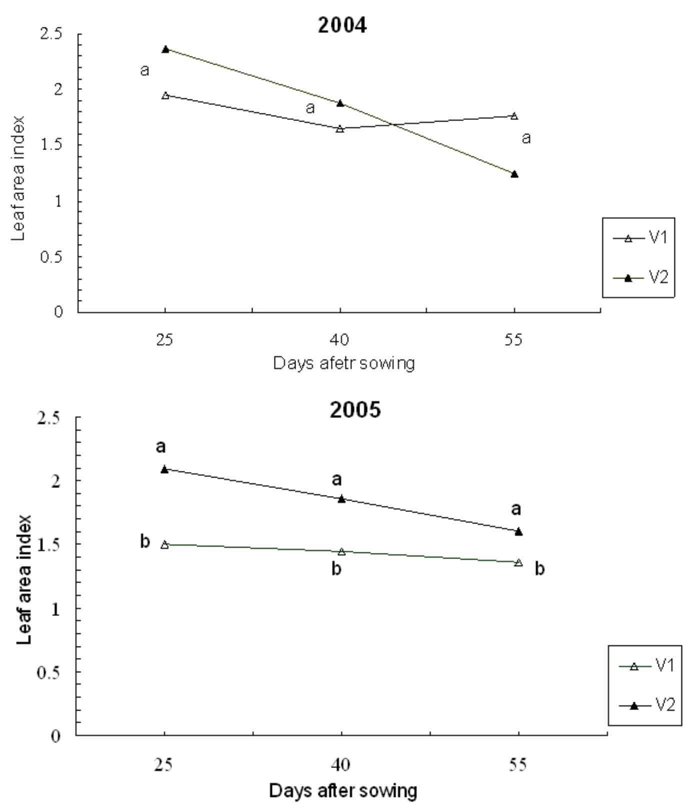

Fig. 4: Effect of cultivars on mean leaf area index during 2004 and 2005 seasons

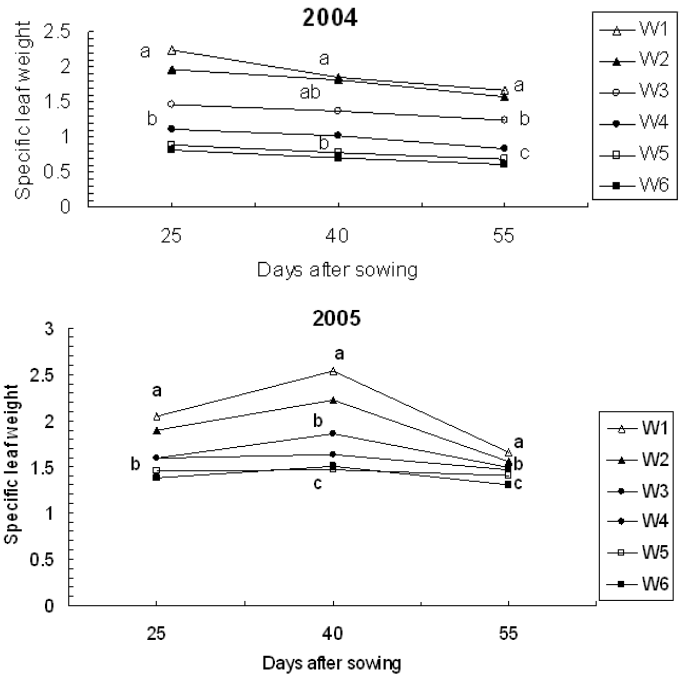

Fig. 5: Effect of water stress on mean specific leaf weight during 2004 and 2005 seasons

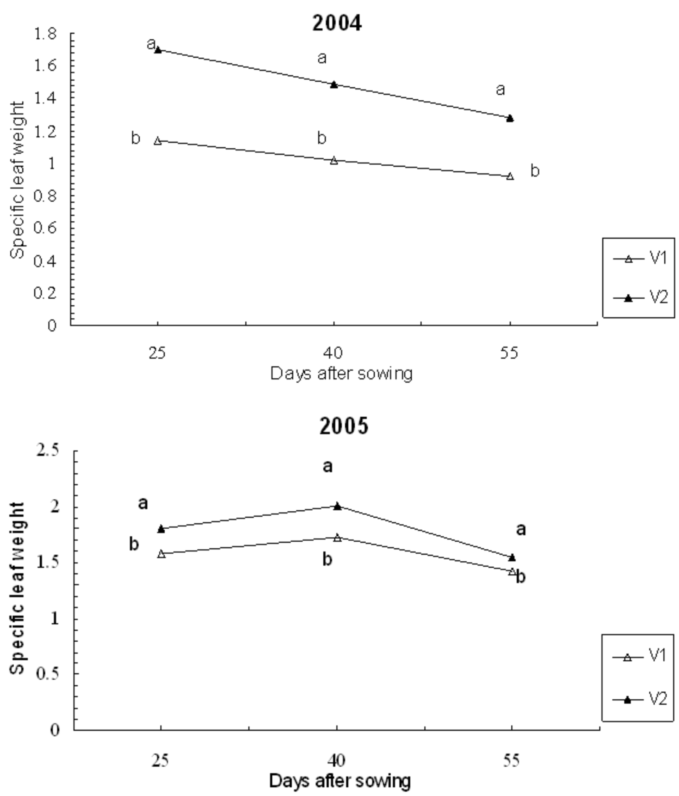

Fig. 6: Effect of cultivars on mean leaf area index during 2004 and 2005 seasons

Table 1: Effect of drought stress and cultivars on mean shoot/root ratio during 2004 and 2005 seasons

Treatments	2005			2005		
	V1	V2	Mean	V1	V2	Mean
P1	6.44	4.92	5.68[a]	7.16	4.34	5.75[a]
P2	7.01	4.82	5.91[a]	7.01	3.90	5.45[a]
P3	5.19	4.21	4.70[b]	6.23	4.47	5.35[a]
P4	5.04	3.87	4.45[b]	4.82	5.26	5.04[a]
P5	3.77	2.95	3.36[b]	3.53	5.50	4.51[a]
P6	2.59	2.55	2.57[c]	2.90	3.55	3.22[b]
Mean	5.01[a]	3.89[b]		5.27[a]	4.50[b]	
LSD A (0.01)	0.38	0.40				
LSD B (0.01)	1.18	1.73				
LSD A x B (0.01)	-----	2.45				

Table 2: Effect of drought stress and cultivars on mean leaf area ratio (cm^2**g** $^{-1}$) during 2004 and 2005 seasons

Treatments	2005			2005		
	V1	V2	Mean	V1	V2	Mean
P1	0.98	1.11	1.04[a]	0.98	1.03	1.00[a]
P2	0.90	1.05	0.97[b]	1.01	1.01	1.01[a]
P3	0.98	0.95	0.96[b]	0.90	0.92	0.91[a]
P4	0.87	0.92	0.89[c]	0.90	0.94	0.92[a]
P5	0.90	0.86	0.88[c]	0.81	0.97	0.89[b]
P6	0.61	0.79	0.70[c]	0.87	0.86	0.86[b]
Mean	0.87	0.95		0.91	0.95	
LSD A (0.01)	-----		-----			
LSD B (0.01)	0.24	(0.05)	0.11			
LSD A x B (0.01)	-----		---			

Table 3: Effect of drought stress and cultivars on mean number of pods per plant during 2004 and 2005 seasons:

Treatments	2005			2005		
	V1	V2	mean	V1	V2	Mean
P1	15.47	20.5	17.98[a]	15.30	18.35	16.82[a]
P2	15.03	19.70	17.36[a]	14.97	18.20	16.58[a]
P3	13.15	18.37	15.76[b]	14.20	16.10	15.15[b]
P4	12.72	16.12	14.42[b]	13.60	15.30	14.45[b]
P5	9.20	14.15	11.67[c]	13.00	13.20	13.10[b]
P6	10.60	14.05	12.32[c]	10.20	12.70	11.45[b]
Mean	12.69[b]	17.15[a]		13.54[b]	15.64[a]	
LSD A (0.01)	1.92	1.50				
LSD B (0.01)	1.77	1.80				

Table 4: Effect of drought stress and cultivars on mean number of seeds per pod during 2004 and 2005 seasons

Treatments	2005			2005		
	V1	V2	Mean	V1	V2	Mean
P1	11.47	16.37	13.92[a]	10.80	15.70	13.25[a]
P2	10.52	14.17	12.34[a]	9.70	15.50	12.60[a]
P3	9.82	14.55	12.18[a]	10.00	13.10	11.55[ab]

Table 4: Continue

P4	9.00	14.05	11.52[b]	9.20	12.00	10.60[b]
P5	7.14	13.40	10.27[b]	7.00	9.50	8.25[c]
P6	5.98	12.37	9.17[b]	7.40	9.15	8.27[c]
Mean	8.98[b]	14.15[a]		9.02[b]	12.49[a]	
LSD A (0.01)	0.75	0.45				
LSD B (0.01)	1.34	2.28				

Table 5: Effect of drought stress and cultivars on mean 1000-seed weight (g) during 2004 and 2005 seasons

Treatments	2005			2005		
	V1	V2	mean	V1	V2	Mean
P1	246.52	114.17	180.34[a]	237.30	119.60	178.45[a]
P2	241.40	110.50	175.95[a]	244.20	118.60	181.40[a]
P3	232.12	102.45	167.28[a]	227.80	111.60	169.70[a]
P4	206.35	98.97	152.37[b]	215.80	104.10	159.95[b]
P5	209.85	100.40	155.12[b]	201.90	93.60	147.75[b]
P6	204.77	99.60	152.18[b]	201.30	91.40	146.35[c]
Mean	223.50[a]	104.35[b]		221.38[a]	106.48[b]	
LSD A (0.01)	17.73	12.39				
LSD B (0.01)	17.05	13.24				
LSD A x B (0.01)	24.12					

Table 6: Effect of drought stress and cultivars on mean final seed yield (tons/ha) during 2004 and 2005 seasons

Treatments	2005			2005		
	V1	V2	Mean	V1	V2	Mean
P1	2.84	1.38	2.11[a]	2.00	1.39	1.69[a]
P2	2.07	1.35	1.71[b]	1.97	1.44	1.70[a]
P3	1.80	1.16	1.48[b]	1.51	0.96	1.23[b]
P4	1.56	1.02	1.29[c]	1.05	0.69	0.87[c]
P5	1.35	0.89	1.12[c]	0.70	0.57	0.63[c]
P6	1.15	0.82	0.98[c]	0.98	0.62	0.80[c]
Mean	1.79[a]	1.10[b]		1.37[a]	0.94[b]	
LSD A (0.01)	0.05	12.39				
LSD B (0.01)	0.30	13.24				
LSD A x B (0.01)	0.43	0.30				

Table 7: Correlation analysis for growth attributes 30 DAS 2004

Parameters	Water potential	DM	SRR	LAR	LAI
Water potential					
DM	-0.90*				
SRR	-0.75	0.89*			
LAR	-0.64	0.81	0.90*		
LAI	-0.88*	0.98**	0.93**	0.80	
SLW	-0.91*	0.99**	0.92**	0.84*	0.98**

Table 7: Continue

	2005				
	Water potential	DM	SRR	LAR	LAI
Water potential					
DM	-0.96**				
SRR	-0.93**	0.90*			
LAR	-0.90*	0.81	0.91*		
LAI	-0.97**	0.99**	0.93**	0.80	
SLW	-0.98**	0.99**	0.93**	0.84*	0.98**

* and ** = Correlation is significant at 0.05 and 0.01 level of probability
DM = dry matter, SRR = shoot/root ratio, LAR = Leaf area ratio, LAI = Leaf area index, SLW = Specific leaf weight

Table 8: Correlation analysis of water potential and yield 2004

parameters	Water potential	Pods/plant	Harvested pods	Seeds/Pod	Seed weight	Seed Yield
Water potential No. Of						
pods/plant	-0.93**					
Harvested pods/plant	-0.95**	0.99**				
Seeds/Pod	-0.97**	0.93**	0.96**			
Seed weight	-0.92**	0.91*	0.90*	0.87*		
Seed Yield	-0.95**	0.94**	0.95**	0.96**	0.94**	
HI	-0.04	-0.05	-0.01	0.07	0.62	0.94**
			2005			
	Water potential	Pods/plant	Harvested pods	Seeds/pod	Seed weight	Seed yield
Water potential						
Pods/plant	-0.81*					
Harvested pods/plant	-0.87*	0.988**				
Seeds/pod	-0.91*	0.96**	0.97**			
Seed weight	-0.92**	0.96**	0.98**	0.98**		
Seed yield	-0.92**	0.89*	0.93**	0.94**	0.96**	
HI	-0.67	0.37	0.46	0.49	0.56	0.74

HI = harvest index

The significant differences in growth attributes, observed between the two cultivars, may be due to the growth habit of the cultivars used in this study as reported by Ehlers and Hall [5]. This might explain the superiority of Dahab el Goz on most of the growth parameters studied. Similar conclusions were reached by many other researchers [22,3,9].

Although cowpea is considered to be a drought-resistant crop, failure of rainfall or lack of irrigation is a frequent cause of yield fluctuation [27]. In the present study, seed yield of cowpea per unit area was significantly reduced under water stress treatments. The reduction was associated with significant reduction in yield components such as number of pods per plant, number of seeds per pod and seed weight. This was further confirmed by correlation analysis where seed yield was positively correlated with its components. Bala and Maheswari (1992) found few ontogenetically related whole plants physiological responses such as increase in leaf area, shift in dry matter partitioning in favor of leaf expansion, extended green leaf duration and increase in pod number to be related to productivity in cowpea after drought relief. However, Ravindra *et al.* [17] attributed the loss in seed yield as a result of drought to low fruiting efficiency and lack of filling time for pods. Moreover, Turk and Hall [24] attributed the reduction in seed yield of cowpea under drought to the secondary detrimental effects of drought avoidance on CO_2 assimilation. In the present study the difference between the two cultivars was significant for yield and yield components. In this regard V2 was superior over V1 in number of pods per plant, seeds per pod, and seed yield, while V1 had heavier seeds. This may be attributed to drought tolerance and/or resistance potential of each genotype. Singh *et al.* [21] showed that cultivars respond to drought in different manner.

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