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EFFECT OF SOME IRRIGATION REGIMES ON WATER CONSUMPTIVE USE AND GROWTH ANALYSIS FOR SOME SOYBEAN CULTIVARS.

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ABSTRACT

The effect of controlled irrigation regimes at 25 , 50 and 75% available soil moisture depletion on some growth characteristics and water consumptive use by three soybean cultivars (Clark, Williams and Crawford) was studied during 2000 and 2001 seasons.

Increasing soil moisture depletion before irrigation significantly decreased plant height, leaf area / plant, dry matter accumulation and relative growth rate throughout of the growing season. Wherever specific leaf area and leaf area ratio were significantly affected by moisture stress only after 7 week from planting. On the other hand, root / top ratio increased with increased soil moisture depletion. Crawford cultivar surpassed significantly in plant height, dry matter accumulation, leaf area, specific leaf area and leaf area ratio, while Williams was superior in root / top ratio. As well as relative growth rate.

Water consumptive use decreased as moisture depletion increased. Crawford cultivar consumed more water compared with Clark and Williams cultivars. Clark, Williams and. Crawford cultivars water consumptive use were 45.3, 44.6 and 53.0 cm in 2000 season and 44.5, 33.4 and 45.3 cm in 2001 season, respectively. The cubic meter of capillary water produced 0.52, 0.53 and 0.44 kg seeds in 2000 and 0.40 , 0.42 and 0.39 kg seeds in 2001 for irrigation at 25 , 50 and 75 % soil moisture depletion, respectively. Clark cultivar was more efficient in utilizing soil moisture followed by Williams and Crawford cultivars.

INTRODUCTION

Knowledge of how different factors influence the time and rate of dry matter accumulation in different parts of any crop plant is basic to the development of improved varieties and to increase crop yields through improved cultural practices. Literature for soybean (*Glycine max, L. Merr.*) with quantitative determination of difference among plant varieties in their reaction to soil moisture stress is limited (Mason *et al.*, 1981). Some investigators reported that limited soil water potential influenced soybean performance by reducing plant height, size of assimilating leaf area and dry matter accumulation, but the root / top ratio was increased (Momen *et al.*, 1979 and Hudak and Patterson 1995). Morever Adjei-Twum and Splittstoesser (1976) and Mason *et al.* (1981) they found that photosynthetic efficiency and leaf number were greatest at four bar leaf water potential. Leaf area, number of internodes, plant height and dry weight of different plant parts decreased as leaf water potentiai changed from 2 to 19 bar. Sivakumar *et al.* (1977) and Mohamed *et al.* (1994) reported that leaf dry matter reached to the maximum levels at 79 days after planting. while leaf area index and root / top ratio reached to the maximum levels at 86 days after planting. Meanwhile crop growth rate was higher during pod filling stage than at any other stages.

Evepotranspiration measurements give better estimates of irrigation water requirements. Consequently, water requirement must be carefully determined. Tanner *et al.* (1960) reported that the capillary movement of water to the soil surface limits evaporation as the soil surface dries. Israelsen and Hansen (1962) and Kanemasu *et al.* (1976) reported that, roots of plants in moist soil extract more water than roots of the same plants grown in the drier soil. In normal irrigation practice, values of 40, 30 , 20 and 10 % from the surface , second, third and fourth feet of soil, respectively, will be extracted to provide the consumptive use for plants. Russell *et al.* (1973) demonstrated that rate of water can move through the soil to the roots decreased as the soil dried due to rapid drop in the capillary conductivity of the soil. Brady *et al.* (1974) and Konam *et al.* (1994) found that water use efficiency was highest when irrigation was given at 60-65% soil moisture depletion. Doss and Thurlow (1974) and Rondall *et al.* (1982) found the average rates of water use efficiency by soybean to be from 0.05 to 0.84 cm / day depending on the amount of the available water in the soil. The objective of this study was to relate growth characteristics and soil moisture stress, simultaneously, at different growth stages and attempted to provide quantitative data for analyzing growth patterns of soybean plants in field environments and for determining water consumptive use and water use efficiency by some soybean cultivars.

MATERIALS AND METHODS

Two field experiments were layed out at the Experimental Farm of Faculty of Agriculture, Cairo University, Giza during the two seasons 2000 and 2001.

The cultivars used were Clark and Williams (early maturing varieties) and Crawford (medium maturing varieties). Three irrigation regimes i.e. irrigation at 25, 50 and 75 percent available soil moisture depletion were used in both seasons.

A split-plot design with four replications was used with irrigation regimes as main-plot and cultivars as sub-plots. The sub-plot area was 14.7 m^2. Seeds were sown on 9^{th} and 16^{th} of May in 2000 and 2001, respectively. The common known (Herati) method of sowing was used. Seeds were drilled in rows 60 cm apart . Forty kg N / feddan in the form of Ammonium sulfate (20 % N) was added two times in equal rates, the first at sowing and the second three weeks after sowing. Water was controlled and measured volumetrically using a big tank having a continuous water flow. Irrigation water was measured by a calibrated water meter. The first irrigation took place 21 days after sowing using equal amounts of water for each sub-plot, after which the three irrigation regimes under test were practiced. Water was add when plants consumed approximately 25, 50 and 75 percent of the available moisture within the root zone. Soil water contents were measured gravimetrically at several times to predict time of irrigation, also to compute the amount of irrigation water. Soil samples were taken at three depths i.e. 0-20 , 20-40 and 40-60 cm. Irrigation water was applied by raising the soil moisture to its field capacity when it reached the available soil moisture depletion. Some soil mechanical and chemical characteristics of the plot area are listed in table 1.

Table 1: Mechanical, chemical analysis and some physical properties of the soil.

Mechanical analysis		Chemical analysis Available (ppm)		Physical properties				
				Depth cm	Field Capacity %	Welting %	Available water	Bulk density
pH	8.1	N	48.3	0-20	47.46	25.95	21.81	1.16
Sand	21.9	P	12.9	20-40	35.48	19.28	16.20	1.29
Silt	30.4	K	200.0	40-60	34.49	18.74	15.75	1.33
Clay	47.7							

The growth attributes, i.e. relative growth rate (RGR, g /g / week), specific leaf area (SLA) and leaf area ratio (LAR) were computed according to the following formulae (Watson, 1985).

$RGR = Log_e W_2 - Log_e W_1 / t_2 - t_1$

$SLA = \text{Leaf area } (cm^2) / \text{Leaf dry weight (g)}$

$LAR = \text{Leaf area } (cm^2) / \text{plant dry weight (g)}$

Where W_1, A_1 and W_2, A_2, respectively, refer to dry weight and leaf area at time t_1 and t_2 in weeks.

Only three rows out of the central five rows devoted for yield determination were sampled. Ten random guarded plants from each sub-plot were separated into leaves, stems and roots. Plant fractions were washed, dried at 90°C and weighed.

Water consumptive use (U) and soil moisture percentage (S) for each depth (20 cm) were determined according to Israelsen and Hansen (1962) as follows:

$U = (e_2 - e_1) / 100 \times D_b \times d \times 4200.8$

$S = (e_2 - e_1) \text{ for each depth} / (e_2 - e_1) \text{ for all depths} \times 100$

Where e_1 and e_2 = soil moisture percent before and after irrigation, respectively. d = depth of irrigation. D_b = bulk density in gm / cm^3 of the choice depth.

Water use efficiency in kg seeds / m^2 was calculated by the following formula :

Seed yield (kg/feddan) / Water consumptive use (m^3/faddan)

At the end of both seasons, means of the traits studied were subjected to analysis of variance, where they were compared by L.S.D. method at 0.05 level of significance, according to Sendecor and Cochran (1981).

RESULTS AND DISCUSSION

A- Growth characteristics

Results in table 2 indicate the significant effect of both soil moisture stress and cultivars on plant height in both seasons. Plant height was depressed by increasing soil moisture depletion. The shortest plants resulted from irrigation 75% depletion. Such results may be interpreted by the fact rate of cell enlargement and stem elongation can be inhibited by water deficits.

Similar results were obtained by Momen *et al.* (1979) and Hudak and Patterson (1995).

Crawford had the tallest plants among cultivars followed by Clark and Williams indicating that it was more tolerant to drought. The moisture stress x cultivars interaction was not significant.

Moisture stress treatments had a significant effect on dry matter accumulation at all sampling dates in both seasons Table 3 and 4. Drought critically decreased dry matter accumulation. Such effect was more pronounced as the plants advanced towards maturity. This may be attributed to the fact that mineral nutrient uptake is frequently reduced to a considerable degree in stressed plants, which in turn reduced photosynthetic efficiency and consequently dry matter accumulation. These results agree with those by Adjei-Twum and Splittstoesser (1976), Sivakumar *et al.* (1977) and Mohamed *et al.* (1994).

Cultivars exhibited significant differences only at the first and second sampling dates of 2001 season Table 4. Crawford accumulated more dry matter than the other two cultivars. Significant moisture stress x cultivars interaction was recorded at all sampling dates in 2001. Crawford was the most tolerant cultivar to drought throughout the growing season.

Table 2: Soybean plant height at harvest time in 2000 and 2001 seasons.

Cultivars	2000					2001				
	Available soil moisture depilation %									
	25	50	75	Mean	L.S.D0.05	25	50	75	Mean	L.S.D0.05
Clark	94.3	88.7	74.9	86.0	4.3	78.9	77.3	75.0	77.2	9.2
Williams	83.3	78.7	76.5	79.5		74.8	61.6	55.4	63.9	
Crawford	93.6	90.9	85.4	89.9		90.3	88.6	88.4	90.6	
Mean	90.4	86.1	78.9	85.1		82.6	76.1	72.9	77.2	
L.S.D 0.05	7.6					5.4				
W. S. x CVS L.S.D. 5%	n.s.					n.s.				

In both seasons, root / top ratio significantly increased as the available soil moisture depletion increased and such effect was more pronounced at the early stage of growth. Table 3ano 4 Similar resulted were obtained by Sivakumar *et al.* (1977).

Williams had the highest root / top ratio at all sampling dates in both seasons. Root / top ratio decreased as plants advanced towards maturity. The moisture stress x cultivar interaction was significant throughout the growing season of 2001. The highest ratio resulted from Crawford when irrigated at 75% moisture depletion indicating its tolerance to drought followed Clark and Williams in a descending order.

A gradual decreased in leaf area / plant as available soil moisture depletion increased was recorded.

Differences were significant at all sampling dates Table 4 this may be due to a decreased in water absorption as well as nutrient uptake. Adjei-Twum and Splittstoesser (1976) and Sivakumar *et al.* (1977) obtained similar results.

Crawford surpassed significantly Clark and Williams in leaf area throughout the growing season. Leaf area in all cultivars increased with age.

Table 3: Dry matter accumulation and root / top ratio in 2000 season.

Cultivars	45 days after planting					66 days after planting				
	Available soil moisture depilation %									
	25	50	75	Mean	L.S.D0.05	25	50	75	Mean	L.S.D0.05
	Dry matter soil accumulation / plant (gm)									
Clark	11.1	7.2	6.1	8.1		57.6	38 5	28.7	41.6	
Williams	9.0	7.5	6.1	7.5	n.s.	72.7	39.1	29.4	47.1	n.s.
Crawford	7.4	5.9	4.9	6.1		62.9	27.7	14.9	36.9	
Mean	9.1	6.9	5.7	7.2		64.4	35.1	26.0	41.8	
L.S.D0.05			0.9				7.8			
W. S. x CVS L.S.D. 5%			n.s.				n.s.			
	Root / top dry weight ratio									
Clark	0.17	0.19	0.23	0.20		0.14	0.15	0.18	0.15	
Williams	0.17	0.18	0.26	0.20	n.s.	0.14	0.16	0.19	0.17	0.011
Crawford	0.15	0.16	0.18	0.16		0.13	0.14	0.16	0.15	
Mean	0.16	0.18	0.23	0.19		0.14	0.15	0.17	0.15	
L.S.D0.05			0.021				0.009			
W. S. x CVS L.S.D. 5%			n.s.				n.s.			

Table 4: Dry matter accumulation, root / top ratio and leaf area / plant in 2001 season.

Cultivars	Days after planting														
	62					83					97				
	Available soil moisture depilation %														
	25	50	75	Mean	L.S.D 5%	25	50	75	Mean	L.S.D 5%	25	50	75	Mean	L.S.D 5%
	Dry matter soil accumulation / plant (gm)														
Clark	20.8	20 5	18.5	19 9		31.4	27.5	21.3	26.7		56.6	48.7	31.6	45.6	
Williams	19.6	13.3	12.4	15 1	2.9	45.9	25.1	20 7	30 6	5.2	62.2	34 4	27 0	41 2	n.s.
Crawford	32.8	22.7	20.3	25 3		43.6	37.3	32.3	37.7		63.2	53.6	42.1	53.0	
Mean	24.4	18.8	17 0	20.1		40.3	29.9	24 8	31.7		60 7	45.6	33.6	46 8	
L.S.D5%			3.1				3.7					8 6			
W. S x CVS L.S.D 5%			4.2				1.3					3.0			
	Root / top dry weight ratio														
Clark	0.106	0 115	0.128	0 116		0.096	0 111	0.117	0 108		0.085	0 091	0.101	0 092	
Williams	0.094	0 106	0.116	0 105	n.s.	0 073	0 081	0.088	0 081	0 006	0 072	0 077	0.083	0 077	0 01
Crawford	0 084	0 098	0 149	0 110		0 084	0 101	0.112	0 099		0 082	0.100	0 109	0.079	
Mean	0.095	0.103	0.131	0.110		0.084	0 098	0 106	0 096		0.079	0 089	0 097	0.088	
L.S.D5%			0.006				0.005					0 003			
W S x CVS L.S.D 5%			0.009				0.007					0.008			
	Leaf area / plant dc^2														
Clark	19.38	12.96	10.97	14 44		19.96	16.49	13.24	16.56		21 79	18.59	14 05	18.19	
Williams	18 74	12 56	11.48	14 26	6.4	20.11	14.25	12.54	15.63	5.1	22.29	15.19	13.22	16 90	4.21
Crawford	36.47	26.79	17.48	26.91		48.65	38 76	27 05	38.22		57 24	46.12	37.04	46 80	
Mean	24 86	17.43	13.30	18.53		29.64	23 16	17.61	23 47		33.77	26.63	21 44	27 28	
L.S.D5%			3 42				3 58					2.81			
W. S. x CVS L.S.D 5%			4.17				5.31					n.s.			

The interaction had a significant effect on leaf area at the first and second growth stages in favors of Crawford irrigated at 25 percent available soil moisture depletion. The depressing effect of drought was more pronounced in Crawford at the early stages of growth than the other two cultivars.

Results in table 5 indicated that RGR seemed to be quite sensitive to moisture stress, because it gradually decreased as soybean plants were subjected to drought. The differences between 50 and 75 % available soil moisture depletion were not significant in both season. RGR increased as plants advanced towards maturity. Such results may support the effect on dry matter accumulation. Similar results were obtained by Sivakumar *et al* (1977) and Mason *et al.* (1981).

Table 5: Relative growth rate (RGR), Specific leaf area (SLA) and leaf area ratio (LAR).

Cultivars	Available soil moisture depilation %														
	25	50	75	Mean	L.S.D 5%	25	50	75	Mean	L.S.D 5%	25	50	75	Mean	L.S.D 5%
	(45-66) days (2000)					(62-83) days (2001)					(83-97) days (2001)				
	RGR g / g / week														
Clark	0.67	0.55	0.53	0.58		0 13	0.09	0.03	0.09		0.28	0.27	0.28	0.25	
Williams	0.69	0 55	0.53	0.59	n.s.	0.30	0.17	0.17	0.21	0.02	0.15	0 13	0.13	0 14	0.06
Crawford	0 76	0.51	0.46	0.56		0.16	0.15	0.14	0.15		0.20	0.18	0.13	0.17	
Mean	0.71	0.54	0 51	0.58		0.20	0.14	0.11	0 15		0.21	0.20	0.15	0.19	
L.S.D5%			0.05					0.04					n.s.		
W. S. x CVS L.S.D 5%			n.s.					n.s					n.s.		
	SLA cm² / g														
Clark	220 5	199.5	190 0	203.3		208 0	243 0	222.0	224.3		209.0	228.0	212.0	216.0	
Williams	281.0	230.5	227.5	246.3	13.2	219.0	250 0	273.0	237.3	19	234.0	258 0	244.0	245.0	24.2
Crawford	269 0	310 5	258.7	279.4		294.0	317.0	298.0	303.0		310 0	317 0	328.0	318 0	
Mean	256.8	246.8	225.4	243.		240 3	270.0	254.3	254.8		251.0	268.0	261 0	260.0	
L.S.D5%			9.1					n.s.					n.s.		
W. S. x CVS L.S.D. 5%			18.2					n.s					n.s.		
	LAR cm² / g														
Clark	93.9	63.5	50.6	72.3		64 7	60.7	61.1	62.2b		40.3	39.7	44.5	41.5	
Williams	98.9	93 8	96.0	96.2	16.3	44.0	56.7	61.1	53.9b	t	35.5	45.5	49 1	43.3	6.7
Crawford	126.3	118.0	86.3	110.2		113.9	104.5	83.4	100.6a	2	90.6	87.5	88.5	88.8	
Mean	109.4	91.7	80.6	92.9		74.2	73 9	68.5	72.2		55.4	57.4	60.7	57.8	
L.S.D5%			8.4					n.s.					n.s.		
W. S x CVS L.S.D 5%			5.8					9.7					n.s.		

Difference in RGR among cultivars were significant in only 2001 season. Williams showed the highest RGR during the first period (62-83 days), while Clark was superior in the second period (83-97 days) after planting. Significant moisture stress x cultivars interaction was absent in both seasons. Irrigation regime had no significant effect on SAL or LAR at all stages, except at 62 days after planting, where such traits decreased progressively with increasing soil moisture depletion, indicating that water deficits critically affected both weight and size of the assimilating leaf area.

Crawford significantly surpassed Clark and Williams in SLA and LAR at all growth stage in both seasons. Clark lowest in this respect. The moisture stress x cultivars interaction had a significant affect on SLA at the first sampling date and LAR at the first two sampling dates.

B- Water relations:

The knowledge of water consumptive use is a prerequisite for proper scheduling of irrigation and improving irrigation practices. It is evident from table 6 that water consumptive use gradually increased as the availability of soil moisture increased in the root zone. This could be explained on the basils that at 25% moisture depletion there was a more luxuriant use for water, which ultimately resulted in increased transpiration. On the other hand, the sparsely spaced irrigation in the case of 75% depletion resulted in poor growth, with small leaf area for transpiration, but it undoubtedly gave more support to losses by soil surface evaporation. The present results confirmed those Doss and Thurlow (1974) and Rondall *et al.* (1982).

Crawford had the highest value of water consumption, while Clark and Williams were nearly the same in this respect. It seems that water consumptive use was highly related to variation in length of growing season.

Figure 1 indicates that most of the water consumed by soybean plants was removed from the upper 40 cm. It is clear that water consumption from the first layer (0-20cm) decreased with increasing soil moisture depletion before irrigation compared with the second and the third ones, where water consumption increased with increasing soil moisture depletion. This means that plants tented to extract their water requirements from deeper soil layers as soil moisture content of the surface soil layer decreased as a result of drought during the growing season. Similar results obtained by Brody *et al.* (1974) and Kortam *et al.* (1994).

Efficiency of water use may be used as a criterion for establishing the relation between water evapotranspiration yield productions of different cultivars as influenced by soil moisture stress. Results in Table 5 indicated that best water use efficiency for seed production was attained when plants were irrigated at 50% moisture depletion. Clark was more efficient utilizing available water followed by Williams and Crawford. It was previously found that the highest seed resulted from irrigation at 25 percent soil moisture depletion. However, the greatest water use efficiency was obtained at 50% percent followed by 25 percent soil moisture depletion. These results are similar to those obtained by Brady *et al.* (1974) who concluded that water use efficiency was when irrigation was given at 60-65 percent soil moisture depletion. '

The results obtained in this investigation that limited soil moisture critically influenced performance of soybean plant by reducing its highest, weight and size of assimilating leaf area and dry matter accumulation. The interaction between moisture stress x cultivar would indicate that cultivars responded differently to water stress. The results suggest that for best growth and water use efficiency soybean should be irrigated at 25-50% available soil moisture depletion.

Table 6:Water consumptive use (cm) and water use efficiency in kg seeds / m^3 water.

Cultivars	2000 season				2001 season			
	Available soil moisture depilation %							
	25	50	75	Mean	25	50	75	Mean
	Water consumptive depletion %							
Clark	54.3	42.1	39.5	45.3	52.0	43.5	37.9	44.5
Williams	50.2	45.5	38.6	44.6	48.5	42.7	38.8	43.4
Crawford	65.1	50.3	43.5	53.0	68.1	51.4	43.2	54.3
	56.3	46.0	40.3	47.6	56.2	46.0	39.9	47.4
	Water use efficiency							
Clark	0.57	0.62	0.46	0.55	0.43	0.49	0.45	0.46
Williams	0.58	0.50	0.48	0.52	0.47	0.41	0.36	0.41
Crawford	0.41	0.47	0.44	0.44	0.31	0.37	0.35	0.34
	0.52	0.53	0.46	0.50	0.40	0.42	0.39	0.40

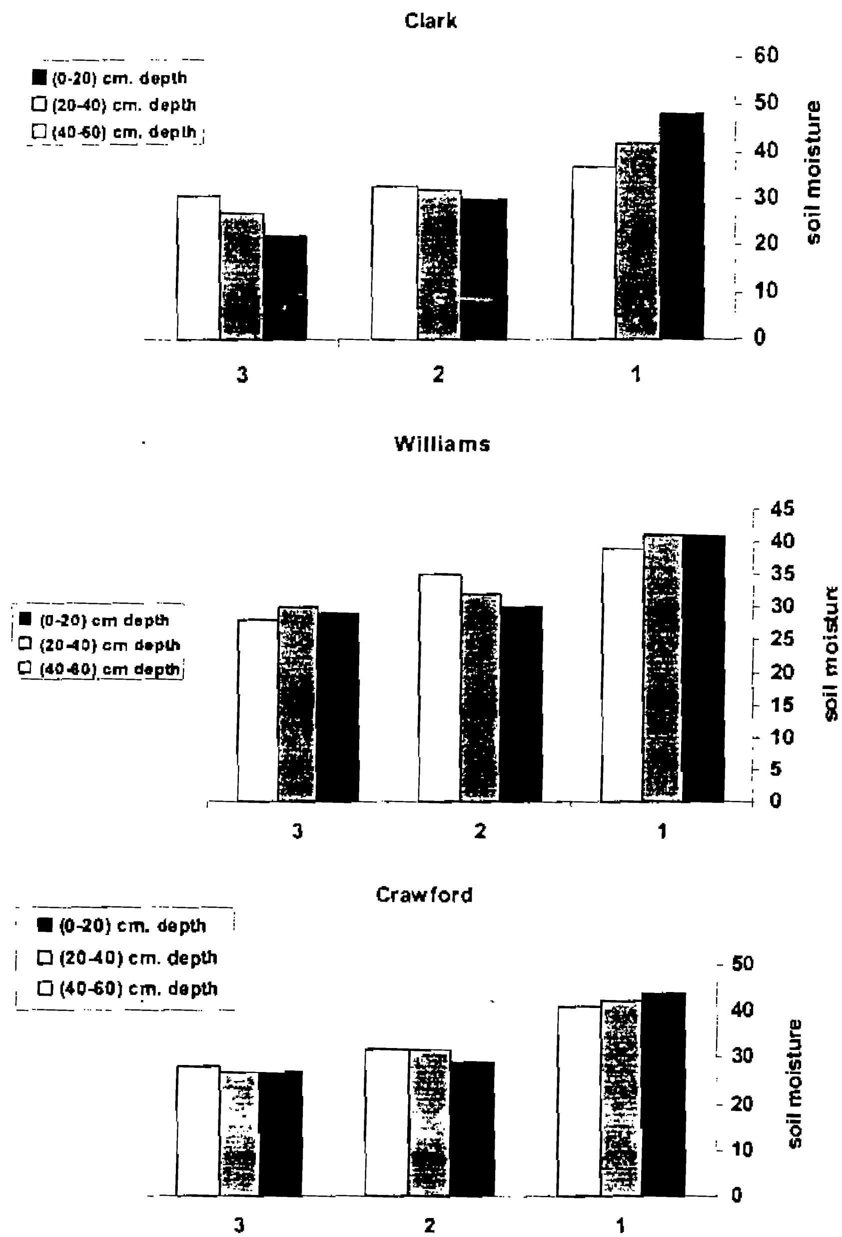

Fig. (1): Soil moisture extraction patterns as influenced by soil moisture depletion and cultivars in 2001 seasons.

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تأثير بعض نظم الرى على الاستهلاك المائى و تحليل النمو لبعض أصنـــاف فـــول الصويا.

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قسم العلاقات المائية والري الحقلي – المركز القومي للبحوث– القاهرة – مصر

أجرى هذا البحث خلال موسمى ٢٠٠٠، ٢٠٠١ لدراسة تأثير ثلاث نظم للرى و هى الـــرى عند استنفاذ ٢٥ ، ٥٠ ، ٧٥ % من الماء الميسر بمنطقة الجذور على بعض صفـــات النمـــو و الاستهلاك المائى لثلاث أصناف من فول الصويا و هى كلارك ، وليامز ، كرافورد.

و قد أوضحت النتائج المتحصل عليها أن نظام الرى أثر تأثيرا معنويا على طول النبـــات و تراكم المادة الجافة و مساحة الأوراق و معدل النمو النسبى و كذلك نســـبة المجمـــوع الجـــذرى للخضرى و ذلك فى جميع مراحل موسم النمو بينما تأثرت المساحة النوعية للأوراق و النسبة بين مساحة الأوراق و الوزن الجاف للنبات معنويا بنظم الرى عند عمر ٩ أسابيع فقط. و قد تـــأثرت هذه الصفات جميعا سلبيا بزيادة استنفاذ الرطوبة الأرضية قبل الرى ما عدا نسبة المجموع الجذرى للمجموع الخضرى حيث تأثرت ايجابيا بتعرض النباتات للعطش فى كل من موسمى الدراسة.

و أوضحت النتائج أن الصنف كرافورد تفوق معنويا على الصنفين كلارك و ليامز فى طول النبات و تراكم المادة الجافة و مساحة الأوراق و كذلك المساحة النوعية للأوراق و النســـبة بيـــن مساحة أوراق النبات و وزنه الجاف فى كلا من موسمى الدراسة. فى حين أن الصنف كرافـــورد كان أعلى الأصناف فى معدل النمو النسبى و نسبة المجموع الجذرى للمجموع الخضرى.

و أوضحت النتائج أيضا زيادة معدل الاستهلاك المائى كلما توفرت الرطوبة الأرضية لمنطقة الجذور، و اظهر الصنف كرافورد معدل استهلاك مائى أعلى من الصنفين كلارك و وليـــامز ، و كان الاستهلاك المائى للأصناف هو ٤٥,٣ ، ٤٤,٦ ، ٥٣ ســـم فـــى موســـم ٢٠٠٠ ، و ٤٤,٥ ، ٣٣,٤ ، ٤٥,٣ سم فى موسم ٢٠٠١ ، و ذلك للأصناف كلارك ، و وليامز ، و كرافـــورد علـــى الترتيب.

و لقد أنتج المتر المكعب من الماء ٠,٥٢ ، ٠,٥٣ ، ٠,٤٦ كجم بذور فى موســـــم ٢٠٠٠، و ٠,٤٠ ، ٠,٤٢ ، ٠,٣٩ كجم بذور فى موسم ٢٠٠١ و ذلك للرى عند اســتنفاذ ٢٥ ، ٥٠ ، ٧٥ % من الرطوبة الأرضية على الترتيب. كما كان الصنف كلارك أعلا الأصناف استهلاكا للماء تـــلاه الصنفين وليامز و كرافورد.