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EFFECT OF WATER REGIME AND POTASSIUM FERTILIZER LEVELS ON YIELD OF SOYBEAN AND WATER USE EFFICIENCY AT NORTH DELTA

Saied, M.M.; H.A. Shams El-Din; E.H. Omar and A.A.S. Gendy
Soils, Water and Environment Res. Inst., Agric. Res. Center, Egypt

ABSTRACT

Two field experiments were carried out at Sakha Agric Res. Station in 2004 and 2005 seasons to study the effect of different soil moisture depletion, 35, 50 and 65% and potassium fertilizer levels; untreated 24 and 48 kg K_2O/fed. on soybean yield, some water relations and N, P, K concentrations of seeds.

The obtained results revealed that the irrigation at 50% soil moisture depletion surpassed the other two depletions (35 and 65%) in increasing the seed yield of soybean by 6.37 and 14.29% in the 1st season and 9.09 and 16.59 in the 2nd season. Application of 48, kg K_2O/fed. increased seed yield by 21.53 and 13.23% than application of 0.0 and 24 kg K_2O/fed. in the 1st season. While, in the 2nd season the seed yield increased by 21.43 and 10.36%.

The greatest amounts of water consumptive use were found to be 2007.43 and 1981.83 m^3/fed. in the 1st and 2nd seasons respectively under 35% depletion.

The most suitable water applied throughout the two seasons are 2646.4 and 2490.7 m^3/fed. in the 1st and 2nd seasons under irrigation 50% depletion of available soil moisture which produced the greatest seed yield.

The highest values of crop water use and field water use efficiencies were achieved from interaction between irrigation at 50% depletion of available soil moisture and application of 48 kg K_2O/fed. in both seasons.

INTRODUCTION

Soybean is the world's cultured plant as edible crop which is grown for its numerous utilizations and considered as important source of oil and protein. In Egypt increasing soybean productivity is urgently needed to meet the demands of both human and livestock. Proper irrigation and potassium fertilization are often critical factors in the success of the crop. As our share from Nile water is limited and the necessity of expanding cultivation in the newly reclaimed soil, there is a great need to make better use of our limited water resources.

The main problem have been observed during the summer season is the severe competition between the main crops growing in such period regarding irrigation water duty. It is of considerable importance to study the effect of rationalize the amount of irrigation water added to the unit cultivated area of land for significant without causing great reduction in yield. The effect of applied irrigation water on yield of soybean was studied by other investigators. Among them Sourour *et al.* (1988), Dornbos *et al.* (1989), El-Borai *et al.* (1993) and Shams El-Din *et al.* (1995), they reported that water stressed soybean plants produced fewer pods and lower weight of both 100 seed weight and seed yield.

Moreover El-Borai *et al.* (1993) measured 53 to 57% yield reductions in soybean resulting from water stress.

El-Awag *et al.* (1993), El-Refaie and El-Kabbany (1995) and El-Naggar *et al.* (1995) stated that the greatest yield obtained the most suitable water applied (increasing soil moisture tension) decreased consumptive use and water use efficiency which increased by decreasing the depletion of available soil moisture.

Eisa and Hanna (1997), concluded that the recommended treatment (seven irrigations) recorded both the highest amount of irrigation water applied and water consumptive use, while the lowest values were obtained from application of three irrigations in the two seasons. The best water use efficiency for seed production was obtained from irrigating soybean five times at 15, 30, 60, 75 and 105 days from sowing.

Also, substantial increases in soybean growth, yield quantity and seed quality were achieved by adding potassium fertilizer. In order to face the K-needs of grain legumes, soil and fertilizers might be able to supply K at a sufficient rate through all growth stages (Faucannier, 1980 and Abd El-Hady *et al.*, 1987).

Application of potassium fertilizer up to 36 kg K_2O/fed. had significant effect on the number of pods/plant, plant height and seed and straw yield of soybean (Derar and Saleep, 1997).

The objective of the present study was to investigate the effect of irrigation at different soil moisture levels and potassium fertilizer levels on soybean yields and its components, mineral composition in seeds and some water relations.

MATERIALS AND METHODS

Two field experiments were conducted at Sakha Agricultural Research Station in North Nile Delta region, during summer season of 2004 and 2005 respectively to study the effect of water regime and level of potassium fertilizer applied on seed yield of soybean, mineral composition of seeds and some water relations.

The soil of the experimental field was clayey in texture, non saline and non alkaline as shown in Table (1a). Soil chemical analysis in soil paste extract was determined according to Page (1982) and physical properties of soil were determined according to Klute (1986). While Table (1b) illustrates some soil-water features.

Table (1a): Some physical and chemical properties of the experimental field.

Depth, cm	Particle size distribution			Texture	EC	SAR	pH	Cations meq/L				Anions meq/L			
	Sand %	Silt %	Clay %	class	dS/m			Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
0-30	28.0	29.1	42.9	Clayey	3.38	4.28	7.81	13.4	0.8	12.5	7.1	0.0	3.3	11.9	21.0
30-60	27.1	29.6	43.1	Clayey	3.6	4.91	7.93	16.1	0.7	13.0	8.5	0.0	3.3	20.4	14.6
60-90	27.9	28.7	43.4	Clayey	3.79	4.31	7.96	14.6	0.7	15.8	6.8	0.0	3.0	14.5	20.4

Table (1b): Soil moisture characteristics of the experimental field.

Depth, cm	Field capacity %	Wilting point %	Available water %	Bulk density, g/cm^3
0-15	43 9	23.96	20.04	1.24
15-30	39.0	21.2	17.8	1.36
30-45	37.0	20.11	16.89	1.39
45-60	36.2	19.67	16.53	1.47
Average	39.03	21 21	17.82	1.37

A split plot design with four replicates was used and the experimental treatments were as follows:

The main plots: (Water depletion)

D_{35} : Irrigation at 35% depletion of soil available water.

D_{50} : Irrigation at 50% depletion of soil available water.

D_{65} : Irrigation at 65% depletion of soil available water.

Sub plots-(potassium fertilizer levels).

K_0 Untreated

K_1 Application of 24 kg K_2O/fed.

K_2 Application of 48 kg K_2O/fed.

Soybean (*Glycine max* L.) variety Giza 21 was sowed in the first week of June and harvested on the 20 and 25^{th} Sep. 2004 and 2005 for the two seasons, respectively.

Fertilizers were applied to all plots as recommended practices at the rate of 20 kg N/fed. as urea (46% N) and 15 kg P_2O_5/fed. as calcium superphosphate (15.5% P_2O_5). Potassium fertilizer was added in the form of potassium sulphate (48% K_2O). Irrigation scheduling was based on soil moisture content which was gravimetrically determined in soil samples taken from successive layers before and after each irrigation of 15 cm depth down to 60 cm for scheduling irrigation.

Studied characters:

1. Yield and its components: The total plot area (10.5 m^2) was harvested, 100 seeds weight and seed yield (ton/fed.) was determined . All the data were statistically analyzed according to Snedecor and Cochran (1967).
2. Plant height, number of tillers and pods per plant.
3. Mineral composition of seeds: Nitrogen, phosphorus and potassium were determined according to methods introduced by Jackson (1967).
4. Amount of irrigation water applied (Wa) to each treatments was measured using cutthroat flume 10 x 90 cm (Early, 1975).
5. Water consumptive use by growing crop was calculated in m^3/fed. from sowing until harvesting according to the following equation:

$$Cu = \sum_{i=1}^{i=n} \frac{\theta_2 - \theta_1}{100} \times DB \times \frac{60}{100} \times 4200$$ (Israelsen and Hansen, 1962)

Where:

Cu : Water consumptive use m^3/fed.

n : Number of irrigations

θ_2 : Soil moisture content (%) after irrigation
θ_1 : Soil moisture content (%) before the next irrigation
DB : Bulk density (g/cm^3).
4200 : Area of feddan 0.42 ha.

6. Field water use efficiency (kg/m^3) = yield (kg/fed.)/amount of water applied (m^3/fed.), (Jensen, 1983).
7. Crop water use efficiency (kg/m^3) = yield (kg/fed.)/actual water consumption use (m^3/fed.), Jensen 1983.

RESULTS AND DISCUSSIONS

Seed yield of soybean:

A. Effect of soil moisture depletion levels:

Data in Table (2) show the effect of irrigation treatments on seed yield of soybean and yield components during the two successive seasons. The obtained results revealed that all estimated characters were significantly affected by the tested depletion treatments except for plant height which was higher under 35% depletion. Irrigation at 50% soil moisture depletion surpassed the other two depletion treatments (35 and 65%) in increasing the seeds of soybean by 6.37 and 14.29% in the 1st season and 9.09 and 16.59% in the 2nd season. The highest average values (1062.94 and 1096.23 kg/fed.) for seed yield, (4.42 and 5.25) for number of tillers, (88.75 and 77.75) for number of pods/plant and (18.39 and 17.33 gm) for weight of 100 seeds in the 1st and 2nd seasons, respectively were obtained under irrigation at 50% depletion of available soil moisture. The more droughted soybean plants which irrigated at 65% depletion of available water produced the lowest average seed yield and yield parameters in the two growing seasons. These results are in agreement with those of El-Borai *et al.* (1993) and Shams El-Din *et al.* (1995), they reported that water stressed soybean plants produced lower pods and lower weight of both 100 seed and seed yield.

The increase in seed yield under irrigation at 50% depletion of available soil water is mainly attributed to the suitable soil moisture in the root zone and to the presence of water supply continuously to plants in the different growth stages.

B. Effect of potassium levels:

Results in Table (2) show significant differences among levels of potassium fertilization for seed yield, plant height, number of tillers, number of pods per plant and weight of 100 seeds in both growing seasons. Increasing the K rate from 24 to 48 kg K_2O/fed. increased seed yield and yield components in the two studied seasons. The high level of potassium fertilizer had the highest average values of these traits followed by the recommended level of 24 kg K_2O/fed. These results show that 48 kg K_2O/fed. may be gained the balance nutrition in the plants and reflected on the yield and its components. In this respect, Derar and Saleep (1997) stated that application of potassium fertilizer up to 36 kg K_2O/fed. had significant effect on the number of pods/plant, plant height and seed and straw yields of soybean.

Table (2): Soybean yield and yield components as influenced by moisture depletion and potassium fertilization.

Treatments	Seed yield, kg/fed.	Plant height, cm	Number of tillers	Number of pods/ plant	Weight of 100 seeds, gm	Seed yield, kg/fed.	Plant height, cm	Number of tillers	Number of pods/ plant	Weight of 100 seeds, gm
	First season (2004)					Second season (2005)				
Depletion level										
D_{35}	995.24	97.75	3.75	75.58	17.26	996.62	100.01	3.83	57.58	16.32
D_{50}	1062.94	92.01	4.42	88.75	18.39	1096.23	95.98	5.25	77.75	17.33
D_{65}	911.05	91.83	3.00	47.08	16.45	914.32	91.08	3.33	51.33	15.12
F-test	**	*	**	**	**	**	*	**	**	**
L.S.D. 0.05	9.52	5.14	0.32	8.96	0.79	8.75	8.39	0.75	8.09	0.73
0.01	13.18		0.48	13.09	1.13	12.18		1.14	11.30	1.05
Potassium fert.										
K_0	878.47	83.83	3.17	47.33	16.92	880.62	83.08	3.25	58.02	16.11
K_{24}	971.32	89.08	3.67	78.47	17.29	1005.19	87.83	4.25	60.58	16.22
K_{48}	119.44	108.67	4.33	85.17	17.88	1121.36	115.75	4.92	68.08	16.45
F-test	**	**	**	**	**	**	**	**	*	*
L.S.D. 0.05	10.96	4.22	0.37	6.43	0.72	9.77	8.79	0.31	8.83	0.33
0.01	15.02	5.78	0.51	8.81	0.95	13.39	12.05	0.42		
Interaction D x K	**	**	ns	**	**	**	**	ns	**	**

The interaction between irrigation and potassium fertilizer levels gave a high significant effects on seed yield and yield components except number of tillers in the two studied seasons.

These results are in coincide with those of Faucannier (1980), Abd El-Hady *et al.* (1987) and Derar and Saleep (1997).

Some water relations:

1. Water consumptive use:

The water consumptive use values for different treatments of soil moisture depletion and potassium fertilizer levels are presented in Table (3). The greatest amount of water consumptive use were found to be 2007.43 and 1981.83 m^3/fed. in the first and the second season, respectively under 35% depletion of available soil moisture. It was followed by 50% depletion, while the lowest values (1785.8 and 1780.1 m^3/fed.) for both seasons were obtained under 65% depletion available soil moisture. As for the effect of potassium fertilizer levels, data in Table (3) show that as potassium fertilizer increased from 24 to 48 kg K_2O, the water consumptive use was increased under different soil moisture depletion. Increasing water consumptive use as application of potassium fertilization increased is mainly due to its effect on increasing transpiration.

Obtained results agreed with those of El-Naggar *et al.* (1996) who reported that increasing K_2O from 0 to 72 kg/fed. increased water consumptive use in maize and soybean.

2. Amount of water applied:

The amount of irrigation water delivered to each treatment was measured and recorded in Table (3). The data indicated that the irrigation at 35% depletion of available soil moisture under application of 48 kg K_2O/fed. received the highest amount of irrigation water followed by interaction between irrigation at 50% depletion and application 48 kg K_2O/fed. for both seasons. On the other hand, the irrigation at 65% depletion of available soil moisture under untreated treatments (K_0). received the lowest amount of irrigation water. It can be seen that from Table (3) the most suitable water applied throughout the two seasons are 2646.6 and 2490.7 m^3/fed. in the first and the second seasons which produced the greatest seed yield. The listed values are obtained as irrigation events was based on 50% depletion from available water and 48 kg K2O/fed. In addition, these values of irrigation water consists of watering excluding the sowing one. Similar results were obtained by El-Awag *et al.* (1993) and El-Naggar *et al.* (1996).

3. Field and crop water use efficiencies:

Data in Table (3) indicated that the values of field water use efficiency were lower than that of crop water use efficiency. Both efficiencies are dealing with the capability of each unit of both water consumed and water applied in producing the crop yield.

It was noticed that the highest values of crop water use and field water use efficiencies were achieved from combination between irrigation at 50% depletion of available soil moisture and application 48 kg K_2O/fed. in both seasons.

Table (3): Some water relations for soybean as affected by soil moisture depletion levels and potassium fertilization.

Treatments		First season, 2004					Second season, 2005				
Soil moisture depletion	Potassium fert. levels	Seed yield, kg/fed.	Water consumptive use, m^3/fed.	Water applied, m^3/fed.	CWUE, kg/m^3	FWUE, kg/m^3	Seed yield, kg/fed.	WCU, m^3/fed.	Wa, m^3/fed.	CWUE, kg/m^3	FWUE, kg/m^3
D_{35}	K_0	875.43	1948.4	2824.6	0.45	0.31	878.73	1939.6	2492.4	0 45	0 35
	K_{24}	964.3	1990.3	2905.4	0.48	0.33	965.45	1981.5	2546.23	0.49	0.38
	K_{48}	1146.0	2083.6	3041.2	0.55	0 38	1145.68	2024.4	2601.4	0.57	0 44
	Mean	995.24	2007.43	2923.73	0.5	0.34	996.62	1981.83	2546.6	0.5	0 39
D_{50}	K_0	975.57	1871 5	2507.1	0.52	0.39	976.45	1846 6	2372.9	0.53	0.41
	K_{24}	1031.25	1910.2	2578.5	0.54	0.4	1128.28	1902.5	2444.7	0.59	0.46
	K_{48}	1182.0	1959.7	2646.6	0.6	0.45	1183.95	1938.3	2490.7	0.61	0 48
	Mean	1062.94	1913.8	2577.4	0.55	0.41	1096 23	1895.8	2436.1	0.58	0.45
D_{65}	K_0	784.4	1748.4	2272.0	0.45	0.35	786.68	1731.2	2224.6	0.45	0.35
	K_{24}	918.4	1785.8	2356.2	0.51	0.39	921 85	1788.4	2298.1	0.51	0 40
	K_{48}	1030	1823.2	2424.6	0.56	0.42	1034.45	1820.7	2339.6	0 57	0.44
	Mean	910.93	1785.8	2350.93	0 51	0.3	914.33	1780 1	2287.4	0.51	0 4

While the lowest values were obtained from interaction between irrigation at 35% depletion of available soil-moisture without K application

The clear increase in crop and field water use efficiencies values could be attributed to the higher yield of soybean.

The present results are in general agreement with those obtained by El-Refaie and El-Kabbany (1995) and El-Naggar *et al.* (1995).

Mineral composition of seeds:

Data in Table (4) show the effect of available soil moisture depletion levels and potassium fertilizer levels on mineral composition of seeds.

Table (4): Contents of NPK (%) in seeds of soybean as affected by soil moisture depletion levels and potassium fertilizer rates.

Irrigation level	Potassium fert.	First season			Second season		
		N	P	K	N	P	K
D_{35}	K_0	3.00	0.63	0.78	3.14	0.61	0.76
	K_{24}	3.10	0.66	0.90	3.18	0.67	0.93
	K_{48}	3.20	0.66	0.93	3.23	0.69	0.96
	Average	3.10	0.65	0.87	3.18	0.66	0.88
D_{50}	K_0	3.08	0.58	0.86	3.11	0.53	0.84
	K_{24}	3.16	0.60	0.98	3.14	0.62	1.02
	K_{48}	3.22	0.64	1.01	3.26	0.66	1.13
	Average	3.15	0.61	0.95	3.17	0.60	1.00
D_{65}	K_0	3.22	0.54	0.90	3.25	0.58	0.88
	K_{24}	3.30	0.58	1.06	3.35	0.63	1.11
	K_{48}	3.34	0.62	1.12	3.38	0.65	1.16
	Average	3.29	0.58	1.03	3.33	0.62	1.05
K average	K_0	3.10	0.58	0.85	3.17	0.57	0.83
	K_{24}	3.19	0.61	0.98	3.22	0.64	1.02
	K_{48}	3.25	0.64	1.02	3.29	0.67	1.08

Data indicated that nitrogen and potassium percentage in seeds of soybean increased with increasing the water stress for both seasons. On the other hand, phosphorus percentage decreased with decreasing water stress in both seasons.

The highest mean value of nitrogen (3.29 and 3.33%) and (1.03 and 1.05%) for potassium was obtained at irrigation 65% depletion of available soil moisture in the 1st and 2nd seasons respectively. On the contrary to this, the highest mean values of phosphorus percentage 0.65 and 0.66% were obtained with irrigation at 35% depletion of available soil moisture in both seasons.

The increase in phosphorus percentage in seeds may be due to the effect of high soil moisture content on the solubility of phosphorus compounds in soil. Concerning the effect of potassium fertilizer levels on N, P and K, data revealed that application of K up to 48 kg K_2O/fed. increased the N, P and K in seeds of soybean.

Barbariuck (1985) pointed out that the increase of N uptake as a result of K application was not nutritional response to K but resulted from the suppression of N uptake.

Simiiar results were obtained by Abd El-Mawly (1987) who reported that K addition increased NPK in soybean plant.

Finally, to achieve the highest seed yield of soybean and its water use efficiency, it could be recommended by irrigation at 50% depletion of soil available water and application of 48 kg K_2O/fed.

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تأثير مستويات استنفاذ الرطوبة الأرضية ومعدلات التسميد البوتاسى على محصول فول الصويا وكفاءة استخدام المياه بشمال الدلتا

محمود محمد سعيد ، حسن على شمس الدين ، السعيد حماد عمر ، الجندى عبدالرازق سليمان جندى

معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر

أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بسخا في الموسمين الزراعيين ٢٠٠٤ ، ٢٠٠٥م لدراسة تأثير ثلاثة مستويات من استنفاذ الرطوبة الأرضية الميسرة وهي ٣٥ ، ٥٠ ، ٦٥% وثلاثة معدلات من التسميد البوتاسي صفر ، ٢٤ ، ٤٨كجم بو٢أ/فدان على محصول فول الصويا ومكوناته وبعض العلاقات المائية وعلى تركيز النيتروجين ، الفوسفور ، والبوتاسيوم في بذور فول الصويا.

وقد أظهرت النتائج المتحصل عليها أن معاملة الرى عند ٥٠% استنفاذ من الرطوبة الأرضية الميسرة تفوقت على معاملتي رى ٣٥% ، ٦٥% في زيادة محصول بذور فول الصويا بنسبة ٦,٣٧% ، ١٤,٢٩% في الموسم الزراعى الأول ، زيادة بنسبة ٩,٠٩% ، ١٦,٥٩% في الموسم الزراعى الثانى.

أيضا إضافة البوتاسيوم بمعدل ٤٨كجم بو٢أ للفدان أدى إلى زيادة محصول البذور بنسبة ٢١,٥٣% ، ١٣,٢٣% مقارنة بالكنترول بدون اضافة ومعدل الإضافة ٢٤ كجم بو٢أ/فدان فى الموسم الزراعى الأول بينما كانت الزيادة فى الموسم الزراعى الثانى هى ٢١,٤٧% ، ١٠,٣٦% مقارنة بنفس المعاملات المذكورة.

اتضح من النتائج أيضا أن أعلى القيم للاستهلاك المائى كانت ٢٠٠٧,٤٣ ، ١٩٨١,٨٣م٣/فدان فى الموسمين الأول والثانى مع المعاملة التى تروى عند فقد ٣٥% من الرطوبة الميسرة ، وأن أنسب كمية لمياه الرى المضاف فى الموسمين كانت ٢٦٤٦,٤ ، ٢٤٩٠,٧م٣/فدان مع المعاملة التى تروى عند استنفاذ ٥٠% من الرطوبة الأرضية الميسرة وهى التى أعطت أعلى محصول من بذور فول الصويا وأن أعلى القيم لكفاءات استخدام المياه تحققت من التفاعل بين الرى عند ٥٠% استنفاذ من الرطوبة الأرضية الميسرة وإضافة ٤٨ كجم بو٢أ/فدان في كلا الموسمين.