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Effect of Deficit Irrigation on Potatoes Production

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Abstract. A field experiment was conducted in 1986/87 crop growing season to investigate the effects of deficit irrigation on potatoes production. The experiment consisted of three irrigation levels, 80%, 50% and 30% of available water (levels 1, 2 and 3) and two varieties of potatoes (Ajax and Miraka). The soil of the experimental site is sandy loam and the irrigation water used had an EC of 5.5 dS/m at 25°C. The accumulative water applied was 540, 440, and 390 mm for levels 1,2, and 3, respectively. The gross irrigation water required for the region using surface irrigation and irrigation water with EC of 5.5 dS/m was calculated as 960 mm. At the highest level of irrigation, maximum average yield of 2.717 and 2.433 g/m^2 were obtained for Ajax and Miraka, respectively. The yield was a function of the quantity and quality of irrigation water. It could be suggested that the inhibiting effect of the saline water on potatoes yield can be decreased by frequent irrigation, and increasing the leaching fraction.

Introduction

In the late seventies several varieties of potatoes (*Solanum tuberousm*) were introduced by the Ministry of Agriculture and Water. Potatoes are now grown in different regions of the Kingdom [1] with most, being grown in the Eastern Province of Saudi Arabia where production of wheat is insignificant.

The use of medium to saline water for irrigation is a subject of vital importance in the Kingdom where most of underground water is classified as medium to saline water [2]. The tuber yield of potatoes response to irrigation has been reported in many irrigation experiments and show that tuber yields have been affected by water stress at different stages of growth [3-6]. The objective of this study was, therefore, to determine the effect of deficit irrigation on tuber yield of two varieties using ground water with an ECw of 5.5 dS/m at 25°C.

Materials and Methods

A field experiment was conducted at the Agricultural Experimental Station of King Saud University at Deirab during the 1986/87 growing season. The experimental site was planted on Oct.6, 1986, and harvested on Jan. 26th, 87. The soil of the experimental site is coarse-loamy, mixed (calcareous), hyperthermic Type Torrifluvents with 62% sand, 19% silt and 19% clay. The soil water characteristic curve is shown in Fig. 1. Selected properties of the soil and irrigation water were determined by standard procedures [7] and reported in Table 1.

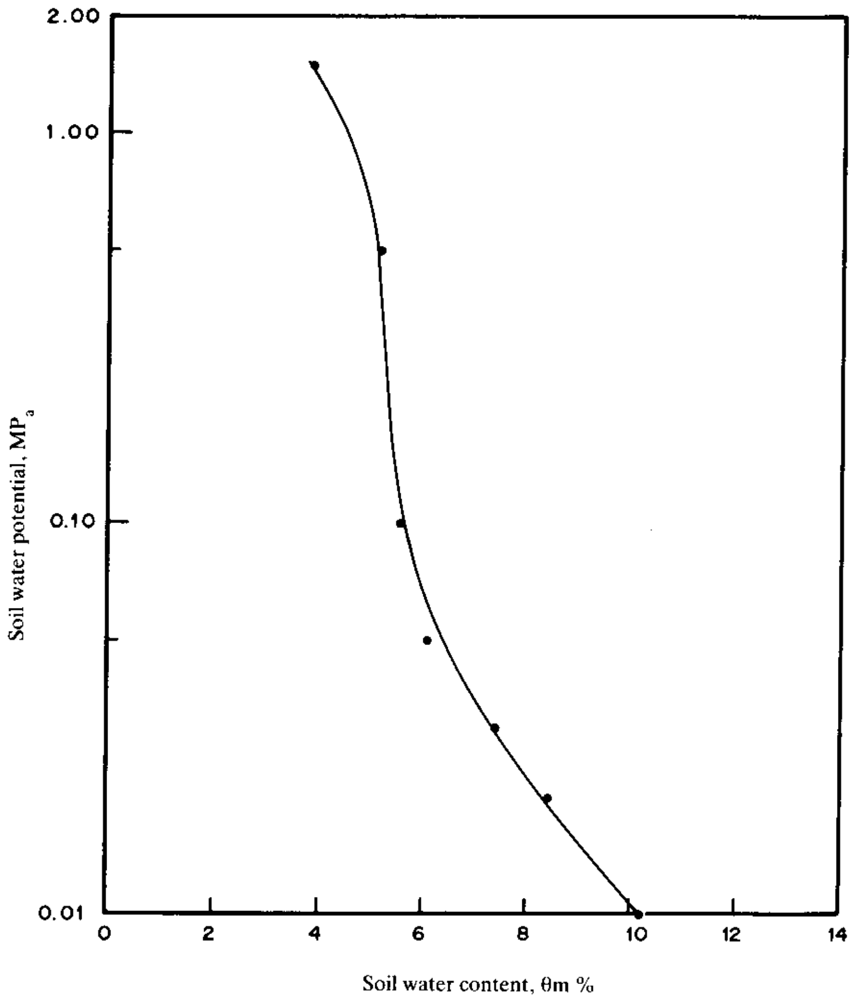

Fig. 1. Soil water content related to soil water potential (θm is grvimetric water content).

Table 1. Chemical analysis of soil and water

SP	Soil* pH	EC	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	$SO_4^=$	SAR
		dS/m				meq/100g soil				
25	7.7	4. 9	20. 3	13.27	37.61	4.74	1.63	23. 9	50.39	
	Water **									
	pH	EC	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	Cl^-	$SO_4^=$	SAR
	7.8	5.50	18.67	14.33	28.3	0.38	2.84	23.93	34.91	7.0

* Means of six samples taken at the end of the experiment (at depth of 20-40 cm).
** Means of six samples taken during the experiment.

A factorial experiment in a randomized complete block design was used in this study with two factors, three irrigation levels and two varieties with three replications. The amount of water applied during the growing season is presented in Table 2. The irrigation water was applied when the mean electrical resistance of gypsum blocks of the plots, placed at depth of 30 cm, reached approximately 900 ohms (80% of the available water), 2600 ohms (50% of the available water) and 8000 ohms (30% of the available water) for levels 1,2 and 3 respectively (Figs. 1,2). Five cm of water were applied at each irrigation, one plot at a time using a hose with a meter attached. This provided a furrow irrigation system as described in earlier work [8]. The two varieties used in this study recommended by the Ministry of Agriculture and Water for their high production in the Kingdom, were Ajax and Miraka.

Table 2. Cumulative water applied

Date of water applied	Level 1 cm	Level 2 cm	Level 3 cm
From 5/10 to 11/11	30.0	30.0	30.0
30/11	5	-	-
4/12*	0.5	0.5	0.5
9/12	-	5.0	-
16/12	5.0	-	-
20/12*	3.3	3.3	3.3
13/1	-	5.0	5.0
12/1	-	-	-
Total	53.8	43.8	38.8

* Rainfall.

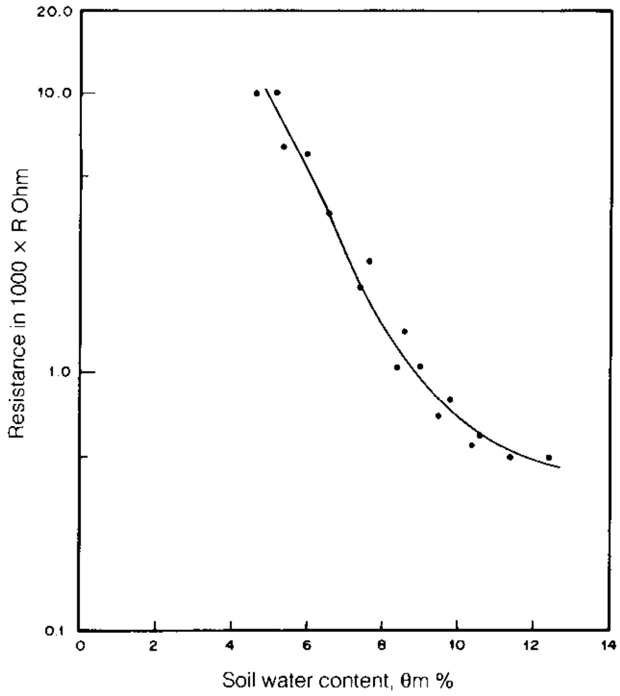

Fig. 2. Soil water content related to resistance (θm is gravimetric water content).

The most common methods for estimation of evapotranspiration are presented in FAO publication No. 24 [9]. These methods are Blaney-Criddle, radiation, modified penman and pan evaporation. In this study an estimation of evapotranspiration for the four methods have been carried out using Dierab Experimental Station meteorological record (1979-1986) (Fig. 3). The actual evapotranspiration (ETa) was estimated using the Blaney-Criddle equation only. The leaching requirements (LR) can be estimated using the following equation:

$$LR = ECw/5\ ECe - ECw$$

where ECw is the electrical conductivity of irrigation water (dS/m), ECe is the electrical conductivity of the saturation extract [10]. The gross irrigation water required (GWR) can be estimated as follows:

$$GWR = ETa\ /\ (1\text{-}LR)Ei$$

where Ei is the irrigation efficiency of the system and in our study this can be estimated as 60% for furrow irrigation system.

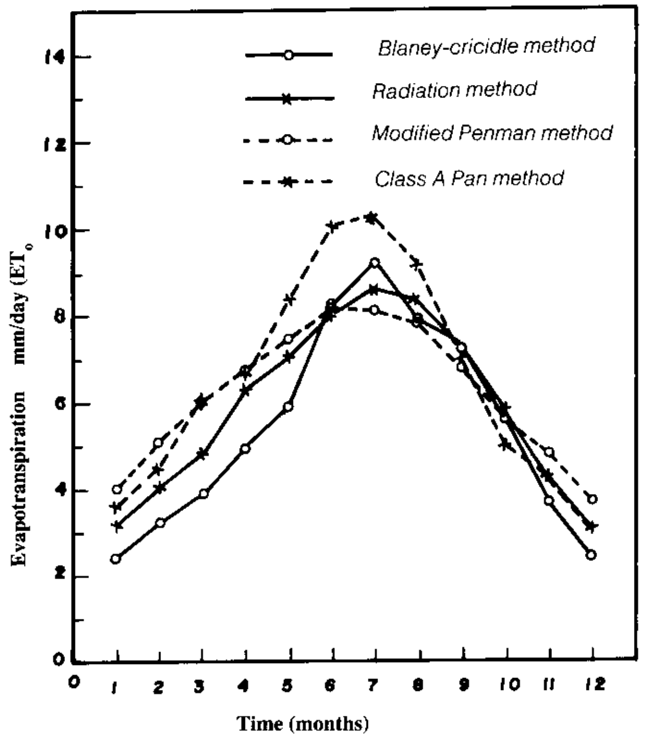

Fig. 3. Mean monthly potential evapotranspiration at Deirab (1979 - 1986)

The area of the experimental plot was 27.5 m^2 and the distance between rows was 70 cm and between the plants was 35 cm. At the end of growing season the tuber yield was determined and analysis of variance was carried out.

Results and Discussion

The effect of irrigation water on the tuber yield is shown in Table 3. The interaction between the level of irrigation and variety was not significant. The effect of the amount of irrigation water was highly significant, the higher the irrigation level, the higher the yield. Varietal differences were also significant. Ajax variety had exceeded Miraka in yield, and this is in agreement with the results reported by the Ministry of Agriculture and Water [1].

An estimation of the actual evapotranspiration (ETa) was calculated using FAO Blaney-Criddle method [9], and was found to be equal to 410 mm for the growing season of the potatoes (Oct. 6-Jan.26). The gross irrigation water was 960 mm with leaching fraction of 30% and irrigation system efficiency of 60%. Thus the gross

Table 3. **Analysis of variance for tuber yield of potatoes**

Source	D.F	F. value	P>F	Remarks
Treatment	5	20. 6*	.0001	R = .89
Irrig. level	2	45.47*	.0001	C.V = 12.63
Variety	1	9.74*	.0089	
LevelxVar.	2	1.01	.3919	
Error	12			
Total	17			

* Significant at 1%.

water required for irrigation is much higher than the actual applied for all the three levels in the experiment which was 538 mm for high water level treatments.

The average tubers yield of the two varieties is plotted in Fig. 4., as a function of seasonal water applied. For complete data a regression analysis was carried out for the varieties. The results were as follows:

$Y = -14409.02 + 4315.78 \ln AW$ R= 0.85,* for Ajax and
$Y = -10904.81 + 3309.16 \ln AW$ R= 0.77**,* for Miraka and
$Y = -12666.48 + 3816.62 \ln AW$ R= 0.74**,* for both varieties.

where Y is tuber yield in g/m^2 and AW is the water applied. The tuber yield was plotted against the water applied with the above mentioned models (Fig. 5). The non-linearity relationship shown here has been reported in several studies [10]. They suggested that in irrigated crops, it is useful to express yield as a function of gross water use rather than the actual evapotranspiration (ETa). In level 3 treatments, where the applied water is less than the ETa, the yield was reduced to an average of 1179 g/m^2. This implies that the reduction in tuber yield can be attributed to the amount of irrigation and the quality of irrigation water used. Since the increase in yield was related to the water applied, it could be suggested that the inhibiting effect of irrigation water quality (saline water) on tuber yield of the potato can be decreased by increasing the frequency and amount of water applied, thereby preventing the salts accumulation around the roots and maintaining high water content in the soil. The presence of salt in the soil or in the irrigation water requires plants to exert enough energy to overcome the value of low total soil potential to obtain adequate water [11,p. 235,12].

The water use efficiency (yields per unit of water applied) of the treatments, for Ajax variety, was 5.05, 4.95 and 3.20 kg/m^2 for levels 1,2 and 3, respectively. That of Miraka was 4.15, 3.95 and 2.88 kg/m^2 for levels 1, 2 and 3, respectively.

It is interesting to observe that ECe of the soil was less than that of the irrigation water. The lower values of ECe as compared to EC of the irrigation waters prevailed because of the texture of the soil which is classified as sandy loam and to the rainfall event occurred at the end of the growing season before the samples were taken. This contributed to the leaching of salts.

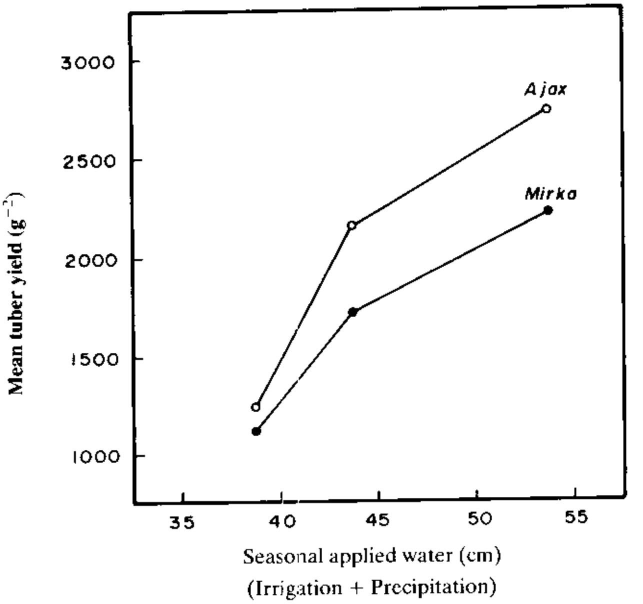

Fig. 4. Tuber yield as a function of seasonal water applied.

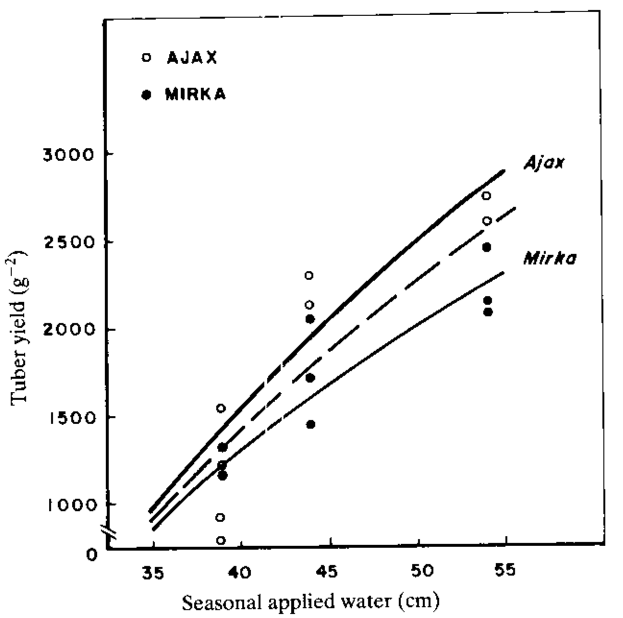

Fig. 5. Tuber yield as a function of seasonal water applied using the model Y = a + b ln X.

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تأثير قلة ماء الري على إنتاجية البطاطس

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ملخص البحث. أجريت دراسة حقلية خلال الموسم الزراعي ١٩٨٦/١٩٨٧م في الفترة من ٦ أكتوبر ١٩٨٦ ـ ٢٦ يناير ١٩٨٧م حول تأثير نقص ماء الري على إنتاجية البطاطس. استخدمت في التجربة ثلاثة مستويات للري (الري عند ٨٠٪، ٥٠٪ و٣٠٪ من الماء المتاح للنبات) وصنفين من البطاطس هما (أجاكس ومريكا) في تربة طميية رملية باستخدام مياه ري ذات توصيل كهربائي ٥,٥ ديسيسيمتر/م عند ٢٥°م.

إن كميةا لري المعطاة لكل وحدة زراعية كانت ٥٤٠ مم، ٤٤٠ مم و٢٩٠ مم للمستويات الأول، الثاني والثالث على التوالي. ولقد حسبت كمية الماء المفروض إضافتها في هذه المنطقة وباستخدام هذه المياه فكانت ٩٦٠ مم.

الري عند مستوى الماء المرتفع أعطى أعلى محصول للبطاطس فكان ٢٧١٧ و٢٢٣٣ جم/م^{2} لكل من أجاكس ومريكا. ولقد وجد أن هناك استجابة معنوية مرتفعة في المحصول لمستويات الري نتيجة لكمية ونوعية المياه المستخدمة في الري. ويمكن تقليل تأثير ملوحة ماء الري بزيادة عدد مرات الري وحساب نسبة الغسيل.