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INFLUENCE OF NITROGEN FERTILIZER LEVELS AND WATER DEFICIT DURING SOME GROWTH STAGES ON WHEAT YIELD AT THE NORTH DELTA OF EGYPT

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ABSTRACT

Field trials were conducted at El-Serw Agricultural Research Station (North Delta) during the 1997/98 and 1998/99 winter seasons to investigate the influence of nitrogen fertilizer levels and irrigation water deficit during some growth stages on wheat yield, water consumptive use, water use efficiency and to develop wheat crop coefficient values for the North Delta area. Wheat cultivar Sakha 69 was used in this study. A split-plot statistical design with four replication was used. Four irrigation treatments (I_1 = full irrigation, I_2 = no irrigation at tillering, I_3 = no irrigation at heading, and I_4 = no irrigation at flowering) in the main plot and three N-fertilizer levels (N_1 = 30, N_2 = 60, and N_3 = 90 kg N/fed) in the sub-plots were tested. Results indicated that there was a significant effect of the tested variables on wheat grain and straw yields. Average grain yields were 2.03, 1.59, 1.78 and 1.75 t/fed for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. Water consumptive use values varied between 27.3 cm for the I_2 N_1 treatment to 39.66 cm for the I_1 N_3 treatment. Also, water use efficiency value of 1.57 kg grain/m^3 water consumed was obtained from the I_1 N_3 treatment. Average seasonal crop coefficient value of 0.78 was obtained for wheat crop grown at the North Delta area. Tillering stage of growth was the most sensitive stage for water deficit at El-Serw area.

INTRODUCTION

Wheat is the most important cereal crop grown in Egypt. It is now cultivated in about 2.5 million feddans (1feddan = 0.42 hectare) of which 2.1 million feddans are cultivated in the Nile Valley and Delta (Old Lands) and 0.4 million feddans in the newly reclaimed and rainfed soils. The national production in the 1998/99 season reached about 6.3 million tons.

The agricultural sector is the largest user of water in Egypt with its share exceeding 80% of the total demand of water. With increasing demands for municipal and industrial uses of water, the share of agricultural use of water will be steadily decreased. The development of agricultural production of Egypt's economy strongly depends on its ability to conserve and manage its water resources (Abu Zeid, 1999).

One way to conserve water is the use of less irrigation water when crops are purposely irrigated less during plant growth stages that are relatively not sensitive to water stress. Identifying growth stages of particular cultivars under local climate and soil conditions allows irrigation sceduling for both maximum crop yield and most efficient use of scarce water resouces

(Dargie, 1999). Doorenbos and Kassam (1979) indicated that irrigation in the early growth periods of wheat crop resulted in higher head numbers per m^2 compared to no irrigation. They stated also that flowering period is the most sensitive to water deficit. Mc Master *et al.* (1994) examined the effects of irrigation, based on stage of crop development, on winter wheat yield, yield components and specific culm responses. Results showed that if only one irrigation to be applied, the irrigation at late jointing is recommended due to its greater effect on tiller survival. Kirda *et al.* (1999) found that wheat gives good yield response, depending on wheather conditions, if irrigated at booting, heading and milking stages of growth.

In Egypt, Seif El-Yazal, *et al.* (1984) studied the effect of withholding irrigation on wheat cultivated at Sakha, Giza, Sids and Mallawi Agric. Res. Stations. Their results indicated that withholding one irrigation either at milk, heading, booting or at tillering stages decreased the grain yield by 11, 14, 16 and 20%, respectively as compared to the check treatment receiving six irrigations. Withholding two or three irrigations decreased the yield by 25 and 34% less than the yield of control treatment. Osman *et al.* (1996) examined the effect of water deficit at some growth stages of Sakha 69, Sakha 92 and Giza 162 wheat cultivars at the calcareous soils of Nubaria region. Their results indicated that four irrigations (at sowing, tillering, heading and milk stages of growth) are enough to produce wheat crop at the Nubaria area. They concluded also that Sakha 69 wheat cultivar proved to perform well in the calcareous soils of this region. Abdel Monem *et al.* (1997) studied the effect of number of irrigations and three N-fertilizer rates on wheat yield, water consumptive use and water use efficiency at El-Serw area. Results indicated that highest grain yield was obtained at 90 kg N/fed level. Also, there was no significant difference between the yield obtained from four and five irrigations.

The objectives of this study were to test the effect of different levels of N-fertilizer and skipping irrigation at some growth stages of wheat cultivar Sakha 69 on grain and straw yields, water consumptive use and water use efficiency, also, to develop the appropriate wheat crop coefficient for the Northern Delta area of Egypt.

MATERIALS AND METHODS

Field experiments were conducted at El-Serw Agricultural Research Station, Agricultural Research Center (ARC) at the North Delta of Egypt during the 1997/98 and 1998/99 winter seasons to investigate the effect of nitrogen fertilizer levels and water deficit at some growth stages on wheat grain and straw yields, water consumptive use and water use efficiency. Also, to develop the proper wheat crop coefficient value for the North Delta region.

The main soil physical and chemical characteristics at El-Serw experimental farm are presented in Table (1).

Table 1: Main soil physical and chemical characteristics at the experimental site.

Depth (cm)	Particle size distribution			Texture Class	OM (%)	$CaCO_3$ (%)	CEC meq/100g soil	PH (1 :2.5)	EC (dS/m)	ESP, %
	Sand	Silt	Clay							
0–15	11.99	20.74	67.27	Clay	1.10	2.50	53	8.1	3.8	8.4
15-30	13.56	20.30	66.14	Clay	0.86	2.51	52	8.1	4.2	8.4
30-45	14.56	23.65	61.79	Clay	0.75	2.52	50	8.0	5.2	8.2
45-60	41.88	21.44	36.68	SCL	0.75	2.54	50	8.0	5.1	8.2

SCL= silty clay loam

Soil field capacity, wilting point, available water and bulk density at the experimental site are listed in Table (2).

Table 2: Soil field capacity, wilting point, available water and bulk density.

Soil Depth (cm)	Field Capacity (% mass)	Wilting Point (% mass)	Available water (% mass)	Bulk Density (g/cm^3)
0 – 15	49.49	26.89	22.60	1.21
15 – 30	46.72	25.39	21.33	1.28
30 – 45	43.79	23.79	20.00	1.35
45 – 60	41.36	22.48	18.88	1.49
Average	45.34	24.64	20.70	1.33

Wheat cultivar Sakha 69 at the rate of 65 kg/fed was sown on the 20th and 26th of November 1997 and 1998, respectively and was harvested on the 12th and 10th of May 1998 and 1999, repectively. All agronomic practices, except for irrigation and nitrogen fertilization, were applied according to the recommended practices for wheat production in the region. At harvest time, grain and straw yields from each plot were recorded for statistical analysis.

A split-plot statistical design with four replications was used in this experiment. Four irrigation treatments represented the main plots and three nitrogen fertilizer levels represented the sub-plot. Each treatment was replicated four times in 6 by 7 m^2 experimental units.

The irrigation treatments were:

I_1: Full irrigation.

I_2: Withholding irrigation at tillering stage of growth.

I_3: Withholding irrigation at late heading (booting) stage of growth.

I_4: Withholding irrigation at flowering stage of growth.

The nitrogen fertilizer levels were:

N_1: 30 kg N/fed.

N_2: 60 kg N/fed.

N_3: 90 kg N/fed.

Data were analyzed using the CoHort Software (1986) statistical package. Average grain and straw yields from the four replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Studen-Nuwman-Keuls Test (SNK) was used for comparisons between the different sources of variations.

Gravimetric soil samples at 0.15 m intervals to a depth of 0.60 m were collected after sowing, before and after each irrigation and at harvest time to determine the amount of applied water at each irrigation and the actual evapotranspiration (ET_a) values. The ET_a values for the soil profile were calculted according to the equation given by Israelson and Hansen (1962) .

$$\mathbf{ETa} = \sum_{\mathbf{i=1}}^{n=4} \frac{(\theta 2 - \theta 1)}{100} \mathbf{X} \rho_b \mathbf{X} \mathbf{D} \qquad \mathbf{(cm)}$$

Where:

ET_a = actual evapotranspiration (cm).
i = soil layer.
n = total number of soil layers.
Θ_2 = (%) soil moisture on mass basis after irrigation.
Θ_1 = (%) soil moisture on mass basis before irrigation.
ρ_b = soil bulk density (g/cm^3).
D = layer depth (cm).

Water use efficiency values (WUE) were calculated according to the relation given by Jensen (1983) as follows:

$$\mathbf{WUE} = \frac{\textbf{Grain yield (kg)}}{\textbf{Total Water Consume (cubic meter)}}$$

Wheat crop coefficient (Kc) values at El-Serw for the growing season were calculated using the following relation:

$$\mathbf{K_c} = \frac{\mathbf{ET_a}}{\mathbf{ET_o}}$$

where:

ETa: actual evapotranspiration (≈ water consumptive use),
ET_o: potential evapotranspiration. The values of ET_o was calculated using Penman (Zazueta *et al.*, 1988) and Penman-Montieth equations as reported in the CROPWAT model (Smith, 1991). Also, the measured ET_o values at the experimental site by the class A pan (Doorenbos and Kassam, 1979) was used.

RESULTS AND DISCUSSION

1. Wheat grain and straw yields:

The effect of irrigation and N-fertilizer treatments on average grain yield (t/fed) is presented in Table (3). Results indicated that grain yield increased significantly with each increase in N-fertilizer. Average grain yield for N_2 and N_3 levels was 31.7 and 66.7% higher than the average grain yield for N_1 fertilizer level. These results were in agreement with those reported by Abdel Monem *et al.* (1997). Results showed also that grain yield was significantly affected by deficit of irrigation treatments at all growth stages. The highest reduction in the yield was due to withholding irrigation during tillering stage of growth. There was no significant difference between grain yields due to deficit of irrigation during heading or flowering stages of growth. Averages of grain yield for I_2, I_3 and I_4 were 27.23, 13.8 and 15.9%, respectively which were less than the yield of I_1 (full irrigation) treatment.

The effect of tested variables on average straw yield is presented in Table (4). Results indicated that there was a significant effect of nitrogen fertilizer levels on straw yield. Average straw yields as affected by N-rates were 3.08, 4.78 and 6.76 t/fed for N_1, N_2 and N_3 fertilizer treatments, respectively. Also, there were significant differences between straw yields for each irrigation treatment. Results revealed that deficit of irrigation at tillering growth stage resulted in the higher reduction in straw yield as compared to the other treatments.

Table 3. Average grain yield (t/fed) as affected by irrigation and N-fertilization treatments.

Irrigation treatments	N-fertilizer treatments (kg N/fed)			Mean Irrigation $LSD_{.05}$ = .071
	N_1 = 30	N_2 = 60	N_3 = 90	
I_1	1.459	2.008	2.617	2.028 a
I_2	1.229	1.669	1.884	1.594 c
I_3	1.378	1.712	2.256	1.782 b
I_4	1.322	1.707	2.221	1.750 b
Mean N-level $LSD_{.05}$ = .045	1.347 c	1.774 b	2.245 a	

Values followed by the same letters are not significant at the 5% propability level.

Table 4. Average straw yield (t/fed) as affected by irrigation and N-fertilization treatments.

Irrigation treatments	N-fertilizer treatments (kg N/fed)			Mean Irrigation $LSD_{.05}$ = .071
	N_1 = 30	N_2 = 60	N_3 = 90	
I_1	3.696	6.089	8.416	6.067 a
I_2	2.337	3.785	5.309	3.810 d
I_3	3.029	4.218	6.243	4.497 c
I_4	3.260	5.020	7.086	5.122 b
Mean N-level $LSD_{.05}$ = .045	3.081 c	4.778 b	6.764 a	

Values followed by the same letter are not significant at the 5% propability level.

2. Water relations

2.1. Water consumptive use (CU):

Average water consumptive use (ET_a) values as affected by N-fertilizer levels and deficit of irrigation treatments are presented in Table (5). Results showed that water consumptive use values increase with increasing nitrogen rates and without exposing wheat plants to water deficit at any stage of growth. Average water consumptive use value for N_3 treatment (90 kg N/fed) was 16.4% more than the average CU value for N_1 treatment (30 kg N/fed). Also, the average CU value for I_1 irrigation treatment (full irrigation) was higher than all other treatments. These results are in agreement with those reported by Serry *et al.* (1980). They reported that the average CU values for wheat crop at the North Delta region is about 35.0 cm. For the I_2N_3 treatment (no irrigation at tillering and 90 kg N/fed), results indicated that a decrease of 21% of the CU value resulted in a reduction in grain yield of 28% as compared to the I_1N_3 treatment (full irrigation and 90 kg N/fed).

To relate wheat grain yield (t/fed) with nitrogen fertilizer levels (kg N/fed) and water consumptive use values (cm), a multiple regression analysis was done. The equation expressing this relation is:

$$\textbf{Grain Yield(t/fed)} = -0.732 + 0.01\,\textbf{N (kg N/fed)} + 0.057\,\textbf{CU (cm)},\ r2 = 0.957$$

The equation can be used to predict wheat grain yield at North Delta region under similar conditions.

Table 5. Average water consumptive use (cm) as affected by N-levels and irrigation treatments.

Irrigation treatments	N-fertilizer treatments (kg N/fed)			Mean Irrigation
	$N_1 = 30$	$N_2 = 60$	$N_3 = 90$	
I_1	33.65	37.32	39.66	36.88
I_2	27.30	29.48	31.46	29.41
I_3	31.40	34.33	35.81	33.85
I_4	29.95	33.57	35.36	32.96
Mean N-level	30.57	33.67	35.57	

2.2. Water use efficiency (WUE):

Effect of tested variables on water use efficiency values (kg grain/m^3 water consumed) is presented in Table (6). Results indicated that water use efficiency values increase with increasing N-rates and without water deficit at wheat growth stages. Average WUE values increased by 50% with increasing N-levels from 30 to 90 kg N/fed. While, the effect of irrigation treatments on average WUE values was less than 5%. Since there is a significant reduction in wheat grain yield due to the tested N-rates and irrigation treatments. It is recommended to use the I_1N_3 treatment to obtain the highest water use efficiency value at North Delta area.

Table 6. Water use efficiency values as affected by N-levels and irrigation treatments.

Irrigation treatments	N-fertilizer treatments (kg N/fed)			Mean Irrigation
	$N_1 = 30$	$N_2 = 60$	$N_3 = 90$	
I_1	1.03	1.28	1.57	1.31
I_2	1.07	1.35	1.42	1.29
I_3	1.04	1.19	1.50	1.25
I_4	1.05	1.21	1.49	1.26
Mean N-level	1.05	1.25	1.50	

2.3. Crop coefficient (K_c):

The actual monthly evapotranspiration (ET_a) values (mm/day) calculated for the I_1 treatment (full irrigation) potential evapotranspiration (ET_o) values calcultated according to Penman, Penman-Montieth and Class A Pan methods, and the calculated crop coefficient values are presented in Table (7). Results indicated that the calcultaed ET_o values according to Penman method were higher than those of the other two methods. According to the three methods, the K_c values reached its maximum value during March. Average K_c values for the three methods are 0.44, 0.80, 0.86, 0.86, 0.96, 0.80 and 0.23 for wheat growing season starting from November until May, respectively. These values can be used to calculate the actual amount of irrigation water needed for wheat crop grown at the north Delta region.

Table 7 . Wheat crop coefficient values.

Month	ET_a (mm/day)	ET_o (mm/day)			K_c		
		Penman	Penman-Montieth	Class A pan	Penman	Penman-Montieth	Class A pan
Nov.	1.00	3.12	2.5	1.7	0.32	0.40	0.59
Dec.	1.57	2.37	1.8	1.8	0.66	0.87	0.87
Jan.	1.72	2.56	1.8	1.8	0.67	0.95	0.95
Feb.	2.10	3.24	2.3	2.2	0.65	0.91	0.95
Mar.	3.16	4.45	3.2	2.7	0.71	0.99	1.17
Apr.	3.50	5.52	4.1	3.8	0.63	0.85	0.92
May	1.20	6.54	5.0	4.6	0.18	0.24	0.26

CONCLUSIONS

Due to the results of this study it could be said that:

1- Deficit of irrigation at any stage of wheat growth will significantly decrease the yield.
2- Wheat production at El-Serw area requires 90 kg N/fed.
3- Tillering stage is the most sensitive stage for deficit of irrigation.
4- The calculated seasonal average of wheat crop coefficient at North Delta area is 0.78.

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تـأثير مستويات السماد النيتروجينى ونقص المياه خلال بعض مراحل النمو على محصول القمح فى شمال الدلتا بمصر

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[١]قسم بحوث المقننات المائية والرى الحقلى بمحطة البحوث الزراعية بالسرو.
[٢]قسم بحوث المقننات المائية والرى الحقلى بمحطة البحوث الزراعية بالنوبارية.
[٣]قسم بحوث خصوبة الأراضى وتغذية النبات بمحطة البحوث الزراعية بالسرو.

نفذت تجربة حقلية بمحطة البحوث الزراعية بالسرو (شمال الدلتا) خلال موسمى الزراعة الشتوية ١٩٩٧/٩٨ و ١٩٩٨/٩٩ بهدف دراسة أثر المستويات المختلفة للسماد النيتروجينى ومنع الرى خلال بعض مراحل النمو على انتاج القمح ، الإستهلاك المائى ، كفاءة إستخدام المياه وتقدير قيم معامل محصول القمح لمنطقة شمال الدلتا.

استخدم صنف سخا ٦٩ فى هذه الدراسة. التصميم الإحصائى المستخدم لتنفيذ هذه التجربة هو القطع المنشقة واستخدمت أربعة تكرارات. شغلت معاملات الرى (أ١ = رى كامل ، أ٢ = منع الرى فى طور التفريع ، أ٣ = منع الرى فى طور الحمل ، أ٤ = منع الرى فى طور التزهير) القطع التجريبية الرئيسية. وشغلت معاملات التسميد الآزوتى (ن١ = ٣٠ ، ن٢ = ٦٠ ، ن٣ = ٩٠ كجم نيتروجين/فدان) القطع الشقية.

وقد أوضحت النتائج أن هناك تأثيرا معنويا للمعاملات المدروسة على محصول القمح من الحبوب والقش. وأدى منع الرى فى أى مرحلة من مراحل النمو تحت الدراسة الى نقص المحصول معنويا بالمقارنة بالرى الكامل. وكانت أكثر مراحل النمو تأثيرا على نقص محصولى الحبوب والقش هى مرحلة منع الرى أثناء طور التفريع. وبلغت إنتاجية القمح من الحبوب ٢,٠٣، ١,٥٩، ١,٧٨، ١,٧٥ طن/فدان وذلك لمعاملات الرى أ١، أ٢، أ٣، أ٤ على الترتيب. وتراوحت قيم الإستهلاك المائى من ٢٧,٣ سم للمعاملة أ٢ن١ الى ٣٩,٦٦ سم للمعاملة أ١ن٣. وبلغت كفاءة إستخدام وحدة المياه ١,٥٧ كجم حبوب/متر مكعب للماء المستهلك للمعاملة أ١ن٣. والمتوسط السنوى لمعامل محصول القمح والمحسوب لمنطقة شمال الدلتا هو ٠,٧٨.