Misr J.Ag. Eng., **19 (1): 123-135**

Irrigation effects on wheat yield under sprinkling in sandy soil.

A. Abou El Azem[1], A. Nassar[1], T. Hussien[2] and A. El Ghamry[3].

ABSTRACT

This experiment was conducted to study the effect of four irrigation water levels to reach the available soil moisture of 100%, 85%, 80% and 75% from available water, on wheat yield, during winter season of year 1999-2000, in sandy soil in Enshas Water Requirement, Research Station, El-Sharkia Governorate, Egypt.

Recorded data included amount of irrigation water, reference evapotranspiration, crop coefficient, soil moisture depletion by plant roots, grain yield, field water use efficiency and specific yield response factor. On the other hand, strong correlation coefficients of 0.9956, 0.9876 and 0.9801 clearly existed among grain yield, field water use efficiency and specific yield response factor.

A simple computer program was designed to calculate the wheat grain yield, field water use efficiency and specific yield response factor under water stress in sandy soil under Enshas conditions.

Data were fitted in the following general regression equations.

$$Y1 = -9.1334 + 0.2305\,X - 0.0012\,X^2$$
$$Y2 = -4.8805 + 0.1332\,X - 0.0008\,X^2$$
$$Y3 = 21.75 - 0.4452\,X + 0.0023\,X^2$$

Where:

- Y1 is grain yield (kg/feddan)
- Y2 is field water use efficiency (kg/m^3).
- Y3 is specific yield response factor (derived from the experimental field data)
- X is moisture content percentage from available soil moisture (%).

Results indicated that the amount of irrigation water is the critical factor controlling wheat grain yield in sandy soil, in spite of the highest field water use efficiency obtained from irrigation with 85% from available soil moisture.

[1,2,3] Researchers, Associate professor and engineer: Water Management Reseaarch Institute. National Water Research Center (NWRC). Egypt. Fax (+202) 2189561

INTRODUCTION

The rapid increase of country population, limited area, and scarcity of fresh water for agriculture requires. A new ways to increase agriculture productivity and the efficient use of irrigation water "more crop per drop" through an appropriate farm water management. This is the major issue that may be identified for the twenty-first century.

Wheat is the most important cereal crop in the world, since it ranks the first among major crops. However, approximately 32% of the wheat *(Triticum aestivum L.)* growing regions in development countries experience some types of drought stress during the growing seasons (Morris et. al., 1991). The national wheat production does not meet the current demand for the crop and yield. So, additional amounts have to be imported up to 50% of the total consumption.

The findings of various studies in sandy soil detected a great of variability in yield and its attributes of wheat as mentioned by Fisher wood (1979) on plant height, Wong and Baker (1986) on spike length, Acharya et al., (1991) as for own length, Acevedo and Naji (1990) as well as Azraf-Ul-Haq et al., (1997) respecting yield and yield components of wheat.

Scheduling wheat irrigation through its growing season by using the optimum limit from available soil moisture of irrigation treatments under sandy areas is very important.

In this connection, Raghu et al. (1974) found that dwarf wheat gave higher grain yields with five irrigations of 75 mm per irrigation than with three such irrigations. Reducing the amount to 50 mm per irrigation decreased yield by 14.6%. Gauman and Maurya (1986) reported that irrigation wheat plants with 60 mm at seven days interval produced greater yield than those irrigated with 30 mm only. Jensen et al. (1990) found that the maximum allowable depletion of soil water between irrigations is up to 55% for wheat. El-Kalla et al. (1994) mentioned that decreasing the available soil moisture content caused a significant decrease in plant height, spikes/m^3, spike length, grain yield/plant, 1000-grain weight as well as grain and straw yields/feddan. Azraf-Ul-Haq et al. (1997) recorded significant differences among the irrigation treatments for grain yield and harvest index.

Doorenbos et al. (1978) found that plants draw their needs according to the moisture status in different soil layers of the root zone. The standard extraction pattern gives 40, 30, 20, and 10% for the first, second, third and fourth quarters of the root depth. Water uptake and extraction patterns are related to root density. In general, for wheat, 50 to 60% of the total water uptake occurs from the first 0.3 m, 20 to 25% from the second 0.3 m, 10 to 15% from the third 0.3 m, and less than 10% from the fourth 0.3 m soil depth. Also they found that the crop coefficient is 0.30-0.40 during the initial stage, 0.70-0.80 during the development stage, 1.05-1.20 during the mid-season stage, 0.65-0.70 during the late-season stage and 0.20-0.25 at harvest.

Keller and Bliesner (1990) reported that the crops yield are directly proportional to crop evapotranspiration in desert areas, while in soils where overwatering is not a problem, the relative irrigation water applied gives the actual yield compared to potential yield. Moreover, they also found that the specific yield response factor for average water deficits during the total growing season for wheat equals 1.0. Allen et al. (1998) reported that the specific yield response factors is a factor that describes the reduction in relative yield according to the reduction in crop evapotranspiratior caused by soil water shortage. Doorenbos et al. (1978) found that the water use efficiency for wheat is about 0.8 to 1.0 kg/m^3.

MATERIALS AND METHODS

A field experiment was conducted during the winter season of year 1999-2000 at water requirement research station in sandy soil under Enshas area to study the effect of different irrigation levels i.e. 100%, 85%, 80%, and 75% from available soil moisture T1, T2, T3, and T4 respectively on grain yield and water use efficiency for wheat plants.

Physical and chemical analysis of experimental soil and chemical analysis of irrigation water were done (Table 1).

Four irrigation treatments were investigated in a complete randomized block design at three replicates. The net area of each experimental plot was 2304 m^2 .

All agricultural operations were practiced as usual in El-Sharkia Governorate area in each experimental plot, except for irrigation treatments. Twelve, medium pressure sprinkler irrigation systems were in experimental plots. Each system consisted of 3 laterals, 75 mm diameter, 96 m long, 12 m apart with sprinklers which had 1.7 m^3/h discharge at pressure 3.0 bar, placed at 12 m apart. They were equipped with a water meter and a pressure gauge, and laterals were paralleled to the wheat rows.

The aim of the irrigation was to provide the plants with sufficient water and to raise its soil moisture content and keep it within certain limits. These limits were referred to the available soil moisture and had different values.

The soil moisture limits were 100, 85, 80, and 75% from the available soil moisture. The irrigation was applied when the soil moisture had reached to 40% from available water. Soil moisture was determined before and after each irrigation.

The determination of irrigation requirements from meteorological data was carried out where the modified penman equation was used to determine reference crop evapotranspiration and consumptive use according to Allan et al.(1998) and Jenesn et al.(1990). Soil moisture was determined before and after each irrigation.

Where:

$$Q = \left(\frac{\theta_{fc} - \theta}{100}\right) * Bd * D * A \qquad CUa = \left(\frac{\theta_a - \theta_b}{100}\right) * Bd * D * A$$

Q	is amount of irrigation water (m^3)
θ_{fc}	is the moisture content at field capacity by weight (%)
θ	is the moisture content before irrigation by weight (%)
Bd	is bulk density (g/cm^3)
D	is the root depth (m)
A	is the area (m^2)
CUa	is actual consumptive use (m^3).
θ_a	is soil moisture content after irrigation by weight (%)
θ_b	is soil moisture content before irrigation by weight (%)

Table (1) : Soil physical and chemical characteristics.

Texture	Coars Sand (%)	Fine Sand. (%)	Silt. (%)	Clay (%)	Bulk Density (gr/cm)^3	Total Porosity (%)	Saturation Capacity. (%)	*FC (%)	*PWP (%)	AW (%)	K (cm/min)
Sandy	48.80	43.30	5.80	2.10	1.59	40.00	24.60	8.38	3.70	4.68	0.385

Irrigation water chemical characteristics

EC Ds/m (m/cm)	Anions. (meq/L)				Cations. (meq/L)				SAR	Adj. SAR
	$CO_3^{=}$	HCO_3^{-}	CL-	$SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}		
0.49	-	3.38	0.60	0.84	1.60	1.63	1.44	0.15	1.13	2.49

*FC: Field capacity PWP: permanent wilting point AW: Avaliable water as % by weight
K:Hydraulic conductivity.

Table (2): Amount of irrigation added, grain yield and field water use efficiency for wheat crop.

Treatments	Amount of water (m^3/feddan)	Grain yield (kg/feddan)	Field water use efficiency (kg/m^3)
T1	1908.16	1738.5	0.91
T2	1657.94	1672.5	1.01
T3	1574.53	1495.5	0.95
T4	1491.12	1311.0	0.88

Table (3): Actual consumptive use, reference evapotranspiration and crop coefficient during the wheat season.

Months	Actual consumptive use (mm/day)	Reference evapotranspiration (mm/day)	Crop coefficient (Kc)
December	1.30	2.03	0.64
January	1.90	2.43	0.78
February	2.85	3.00	0.95
March	3.17	3.77	0.84
April	3.56	5.94	0.60
Average	2.56	3.43	0.76

Table (4): Average extraction pattern of the soil moisture at the depths under investigation.

Depth (cm)	0-15	15-30	30-45	45-60	60-75
Extraction (%)	35.0	26.8	16.3	12.5	9.4

The efficient use of irrigation water is an obligation to use it carefully. Therefore, irrigation efficiency is a broad general term, which can be applied to irrigation practices in a qualitative manner.

The field water use efficiency was calculated using following equation:

WUE_{field} (kg/m^3)= Yield (kg/feddan)/ water application (m^3/feddan)

The specific yield response factor is derived from the experimental field data. Its values for most crops are based on assumptions that the relationship between relative yield and relative evapotranspiration or relative water applied is linear, this relation is valid for water deficits of up to about 50%.

The specific yield response factor was calculated using the following equation:

$$\left(1-\frac{Y_a}{Y_m}\right)=K_y\left(1-\frac{d_a}{d_m}\right)$$

Where:

- Y_a is actual yield (kg/feddan)
- Y_m is maximum yield (kg/feddan)
- K_y is specific yield response factor
- d_a is actual seasonal depth of irrigation water applied and available for crop use (mm/season)
- d_m is maximum seasonal depth of irrigation water applied and required for crop use (mm/season)

Soil samples were taken from 12 spots, evenly distributed amerig test plots. Five successive samples were taken to represent the depths of (0-15), (15-30), (30-45), (45-60), and (60-75) cm, and analyzed with respect to their particle composition, field capacity, permanent wilting point, and bulk density. The average values for this analysis can be seen in (Table 1).

Twelve soil samples were collected from experimental replicate plots before and after irrigation, to determine the soil moisture content, in order to calculate the amount of irrigation water. Another soil samples were taken to represent the depths of (0-15), (15-30), (30-45), (45-60), and (60-75) cm to calculate the average extraction pattern.

At the end of growing season, a random sample of 1 m^2 was taken from each experimental plot to determine the wheat yield. Grain yield was determined in (kg/feddan).

RESULTS AND DISCUSSION

Amount of applied water:

The amounts of added water for the different irrigation treatments are listed in table (2) and figure (1). The average amounts were 1908.16, 1657.94, 1574.53 and 1491.12 m^3/feddan for treatments T1,T2,T3, and T4 respectively. These results show that the last three irrigation treatments, under investigation saved water comparing with the first treatment as follows: 250.22, 333.63, and 417.04 m^3/feddan for treatments T2,T3, and T4 respectively.

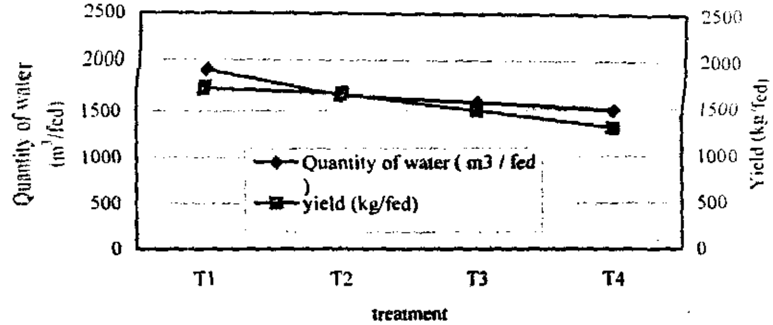

Fig (1) Relationship between quantity of applied water and yield with various treatments.

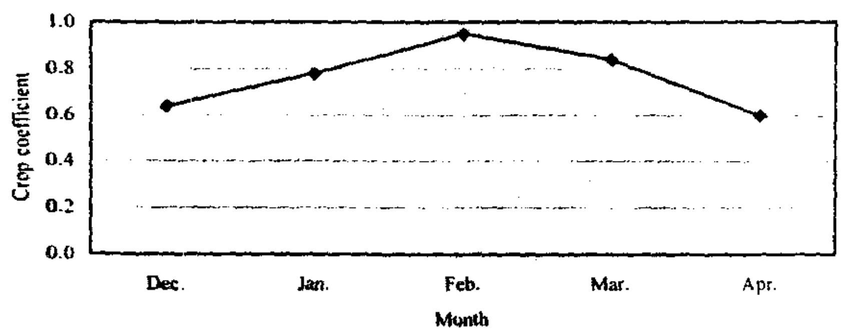

Fig (2) Crop coefficient for wheat during crop season

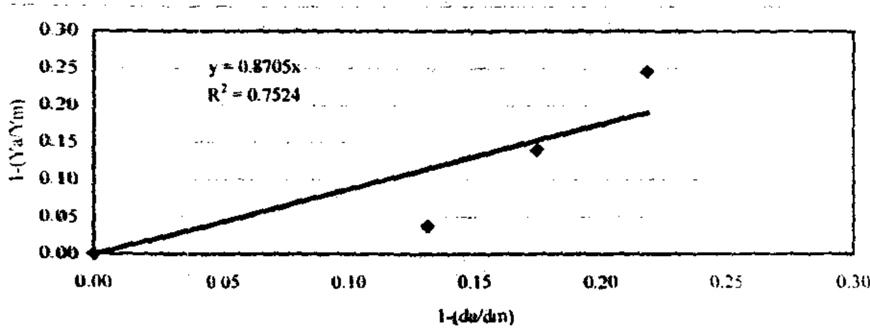

Fig (3) Relationship between reduction in relative yield and depth of applied water

From the previous discussion, it can be concluded that, the changes in the crop production under each studied treatment are mainly due to the effect of how much water to apply, where the amounts should be sufficient to replace moisture depleted from the root zone before plants suffer lack of moisture.

Reference evapotranspiration and crop coefficients

The crop evapotranspiration of wheat plants responded positively to the meteorological data, which were combined together as in the modified Penman equation, which was used to calculate it.

Table (3) reveals that the obtained values for December, January, February, March, and April were 2.03, 2.43, 3.00, 3.77, and 5.94 mm/day respectively. Comparing these values with the actual consumptive use of water values, it can be concluded that, the reference evapotranspiration surpassed the actual consumptive use values at each month. Moreover, both values were affected in general by the soil moisture content, which affected by the meteorological data and the stage of the plant growth.

The same table shows that the crop coefficient increased with the age of the plant and reached its maximum in February as shown in fig. (2), where it decreased at the end of grain filling.

Water uptake

Wheat has a primary system and later it develops a fibrous root system. The latter roots are formed from the nodes which are at or near the ground surface. Depth and density of rooting are affected by water, nutrients, and oxygen in the soil.

Data in table (4) show that, in general 61.8% of the total water uptake occurs from both the first (0-15) cm and the second (15-30) cm soil layers. 26.8% from both the third (30-45) cm and the fourth (45-60) cm soil layers, and 9.4% from the fifth (60-75) cm soil layer.

From the previous discussion, it can be concluded that the 100% of the water uptake occurs over the first 75 cm soil depth under the experimental conditions.

Wheat grain yield

From Table (2) and figure (1) show wheat grain yield for all studied treatments. Analysis of variance reveals that there was a highly significant difference among treatments due to the effect of irrigation treatments.

The highest grain yield value was obtained from T1 which was given irrigation with limit of 100% from available soil moisture. The total grain yields 1738.5, 1672.5, 1495.5, and 1311.0 kg/feddan for treatment were T1, T2, T3,and T4 respectively.

It is obvious that the decreasing of irrigation limit by 15, 20 and 25 % from the available soil moisture for treatments T2, T3,and T4 yielded 3.8, 13.98, and 24.59% decrease respectively, than treatment T1.

The wheat grain yield responded to moisture content percentage from available soil moisture percentage, where the results show this trend clearly. It increased with increasing soil moisture content from 75 to 100 percent from available soil moisture..

The grain yield is correlated significantly to moisture content percentage from available soil moisture and the quadratic relationship is fitted in the following equation, as shown in figure (3), which had 0.9956 regression coefficient:

$$Y_1 = -9.1334 + 0.2305\,x - 0.0012\,x^2$$

Where

$Y1$ is grain yield (kg/feddan)

x is moisture content percentage from available soil moisture (%).

The previous result leads to conclusion that, the more the soil moisture stresses the more is the grain yield reduction.

Field water use efficiency

The field water use efficiency expressed as water requirement in m^3/kg of wheat grain .Yield was used to evaluate the efficiency of irrigation water level for maximum utilization of water applied under field conditions. The field water use efficiency was calculated ,in table (2). For all the treatments under investigation the results showed that using irrigation water with limit of 85% from available soil moisture during the growing season recorded the highest field water use efficiency (1.01 kg/m^3).

On the other hand, using irrigation water without stress i.e. T1, recorded the highest grain yield, but it did not record the highest field water use efficiency (0.91 kg/m^3).

It can be also noted that water stress at treatments which received irrigation water with limits of 80, and 75% from available soil moisture were (0.95 and 0.88 g/m^3 respectively) comparing with received irrigation water with limit of 85% from available soil moisture.

The field water use efficiency has special relationship with moisture content percentage from available soil moisture, where this relationship indicates that sensitivity to increase and / or decrease water is somewhat higher in wheat plants.

The correlation was used to show that changes in field water use efficiency as affected by moisture content percentage from available soil moisture.

Results of analysis are fitted in the following equation, which had 0.9876 regression coefficient figure (4):

$$Y2 = -4.8805 + 0.1332x - 0.0008x^2$$

Where:

$Y2$ is field water use efficiency (kg/m^3)

x is moisture content ratio from available soil moisture (%)

Finally it can be concluded that more irrigation water during the growing season is giving the highest grain yield although it is not giving the highest value of field water use efficiency, while the sufficient amount of irrigation water with slight stress gave its highest value.

Specific yield response factor:

Grain yield is related to the duration and intensity of water stress and this relation is depends on the growth period under stress. There is, however, some variation in wheat plants resistance to the percentage of soil moisture content from available soil moisture reduction as to the magnitude of the resulting grain yield decrease.

The relationships between relative grain yield decrease (1-Ya/Ym) and relative evapotranspiration deficit (1-ETa/ETm) for wheat are calculated for all the irrigation treatment levels.

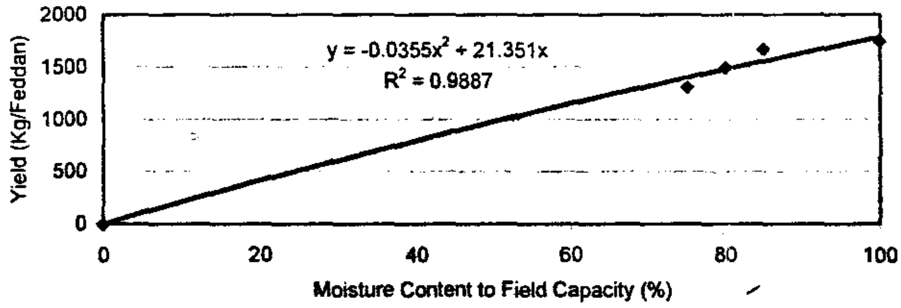

Fig.(4) Relationship between wheat yield and moisture content to field capacity

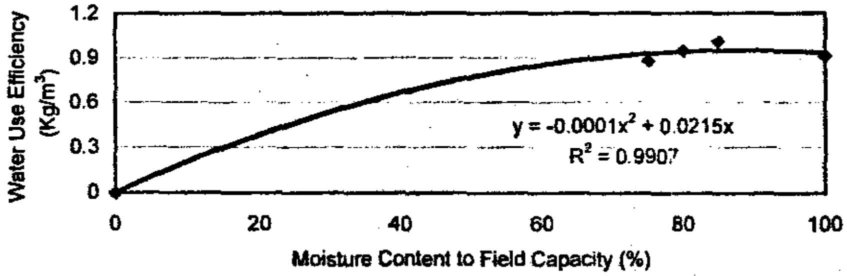

Fig.(5) Relationship between water use efficiency and moisture content to field capacity

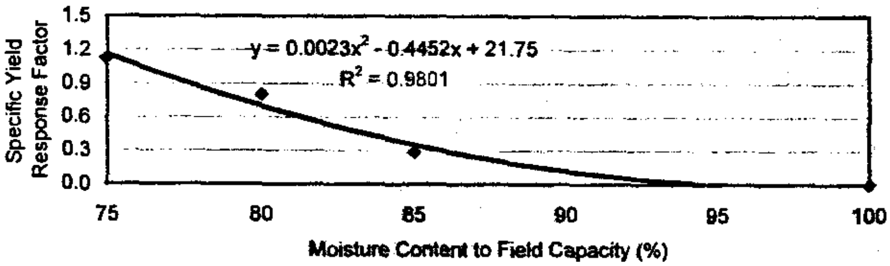

Fig.(6) Relationship between specific yield response factor and moisture content to field capacity

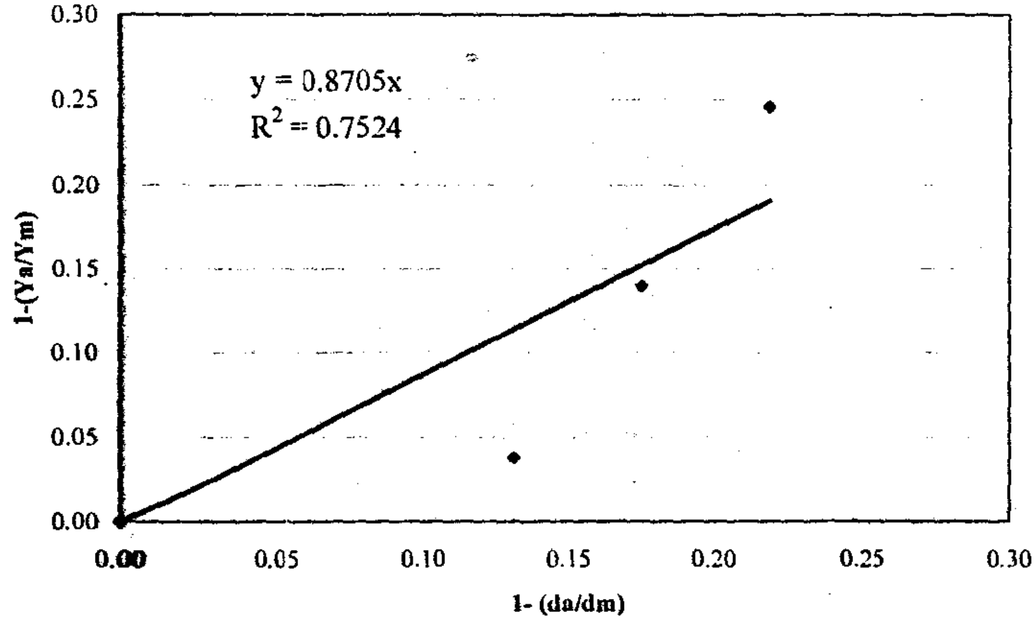

Fig (7) Relationship between reduction in relative yield and depth of applied water

A quadratic relationship related the specific yield response factor and moisture content is shown in figure (5).

Results of analysis are in the following equation, which had 0.9801 regression coefficient:

$$Y3= 21.75-0.4452x+0.0023x^2$$

Where:

Y3 is specific yield response factor.

x is moisture content from available soil moisture (%)

The specific yield response factor for wheat responded to the soil moisture, where the range of the average response factor was (0.87-1.0) as shown in figures (6 and 7) and this value is close to this obtained from Keller and Bliesner, (1990).

Computer program

A simple computer program is designed when soil moisture content as a percentage from available soil moisture is known to obtain the grain yield; water use efficiency and specific yield response factor.

CONCLUSION

A field experiment on wheat crop was carried out in sandy soil under sprinkler irrigation. The effect of irrigation requirement on growth and grain yield of wheat was studied. The quantitative relationship between the grain yield and irrigation water added was calculated.

The results indicated that: the reduction of moisture content from the available soil moisture induced a significant reduction in wheat grain yield.

Irrigation with limit of 75% from available soil moisture caused the severest reduction to grain yield (24.59%). The lowest yield reduction was caused by irrigation with limit of 85% from available soil moisture. Therefore, scheduling irrigation as practiced is based on the highest field water use efficiency (1.01 kg/m3), but not the highest grain yield. Data of actual consumptive use showed that it was much lower than the reference evapotranspiration, where the crop coefficient value ranged from 0.64 in December and 0.95 in February with an average of 0.76 during the growing season. A model was developed for predicted grain yield; water use efficiency and specific yield response factor based on moisture content percentage from available soil moisture. Correlation coefficients of 0.9956, 0.9876 and 0.9801 were obtained for the relationships respectively.

Reference

1. Acevado, E. and I. Naji, (1990). " Genotype characterization of durum wheat" Cereal improvement program, Annual report, ICARDA, Aleppo, Syria: 105-115.
2. Acharya S., R.B. Srivastova and S. K. Sethi, (1991). "Impact of awn on grain yield and its components in spring wheat under rain-fed conditions". Rachis (Barely and wheat Newsletter). 10 (1 and 2): 5-6.
3. Allen, R.G., L. S. Pereira, D. Raes, and M. Smith (1998). "Crop evapotranspiration". FAO Irrigation and Drainage paper NO. 56: P 90-102.

4. Azraf-Ul-Haq-A, Naeem, A. and Bul-Akhtar (1997). "Effect of different depths of irrigation on the grain yield of promising late sown wheat cultivars". Rachis, 16 (1/2): 77-80.
5. Doorenbos J., A. H. Kassam, C. Bentvelder, and G. Uittenboogoard. (1988). "Yield response to water". FAO Bulletin, 33.
6. EL-Kalla S. E., A. A. Leilah, A. H. Basiouny and Samira M. Hussein (1994). "Effect of irrigation and foliar nutrition treatments on growth and yield of some wheat cultivars under El-Arish area conditions". Broc. Six. Technology of Agron., Al-Azhar, University, Cairo, Egypt, 4:365-378.
7. Fisher R. A. and I. T. Wood (1979). "Drought resistance in spring wheat cultivars". Yield association with morpho-phyiological traits. Aust. J. Agric. Res., 30: 1001-1020.
8. Ghuman B. S. and P. R. Maurya (1986). "Response of wheat to irrigation in tropical soil". Agron. J., 78: 791-795.
9. Jensen M. E., R. D. Barman, and R. G. Allen (1990). "Evapotranspiration and irrigation water requirements" ASCE Manuals and Reports on Engineering Practice NO. 70: P 164 – 170.
10. Keller J. and R. D. Bliesner (1990). "Sprinkler and Trickle irrigation". Pub. by Van Nostrand Reinhold, N.Y.
11. Morris M. L., A. Belaid and D. Byerlee (1991). "Wheat and Barely production in rain-fed". Marginal environments of the developing world, CIMMYT, Mexico, D.F: 15 pp.
12. Raghu J. S., S. R. Sharma and S. O. Chaudhry (1974). "Effect of frequency and data of irrigation on wheat". Res. J., 8 (3 and 4): 267-269 (Field Crop Abst., 29 (6): 4345: 1974).
13. Wong L. S. L. and J. Baker (1986). "Select for time to maturity in spring wheat". Crop Sci., 26: 1171-1175.

الملخص العربي

تأثير استخدام الري بالرش علي إنتاجية القمح في الأراضي الرملية

د. عبد الله أبو العزم *د. عاطف عبد الغفار محمد *د. طه مصطفي حسين **م. أحمد الغمرى***

أجريت هذه الدراسة بمحطة تجارب المقننات المائية فى تربة رملية بمنطقة أنشاص. محافظة الشرقية. وقد تمت زراعة القمح تحت نظام الرى بالرش الثابت ؛ واستخدم تصميم القطاعات الكاملة العشوائية في ثلاث مكررات ، و أربعة معاملات ري لإعادة المخزون المائي بالتربه كالأتي: ١٠٠%، ٨٥%، ٨٠%، ٧٥% من الماء الميسر.

أوضحت النتائج وجود فروق معنوية في إنتاجية معاملات محصول القمح حيث سجلت المعاملة الأولى أعلى إنتاجية ١٧٣٨,٥ كج/فدان بينما سجلت المعاملة الرابعة أقل إنتاجية ١٣١١ كج/فدان، وكانت المعاملة الثانية أفضل المعاملات بعد الأولى حيث سجلت ١٦٧٢,٥ كج/فدان الثانية وأعطت أعلى قيمة بالنسبة لكفاءة استخدام المياه على مستوى الحقل حيث كانت ١,٠١ كج/م^{3}. وأوضحت النتائج أيضا أنه يمكن استخدام معامل النبات ٠,٧٦ للتنبؤ بالاستهلاك المائي لمحصول القمح بمنطقة الشرقية .

وأوضحت النتائج تناقصا في كمية ماء الري الكلية المضافة للمعاملات، حيث كانت أعلى كمية ماء ري للمعاملة الأولى وهى ١٩٠٨,١٦ م^{3}/فدان، بينما كانت للمعاملة الرابعة والتي أعطت أقل إنتاجية هى ١٤٩١,١٢ م^{3}/فدان.

وقد تم استنتاج نموذج رياضي يمكن باستخدامه حساب الإنتاجية وكفاءة استخدام الميله ونسبة تأثر الإنتاجية فى محصول القمح، عن طريق الرطوبة الأرضية كنسبة من الرطوبة المتاحة.

- * باحث بمعهد بحوث إدارة المياه-المركز القومي البحوث المياه
- ** أستاذ باحث مساعد بمعهد بحوث إدارة المياه-المركز القومي البحوث المياه
- ***مهندس بمعهد بحوث إدارة المياه-المركز القومي البحوث المياه