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# WHEAT IRRIGATION SCHEDULING USING INFRARED THERMOMETER

**M.M. Attia[(1)], A.A. Sallam[(1)] and E. Ghalab[(2)]**
[(1)] Soils, Water and Environment Res. Inst. A.R.C.
[(2)] Field Crops Res. Inst. A.R.C.

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**ABSTRACT:** *A field experiment was conducted at Nubaria Agricultural Research Station (calcareous sandy loam soil),30.900 E, 29.960 N, and 25 m above sea level, El-Behiera governorate, Egypt, in the two successive seasons of 2013-2014 and 2014-2015 to assess the suitability of using infrared thermometer in irrigation scheduling of wheat crop, and to determine the effect of irrigation treatments on wheat grain and straw yields, water consumptive use, amounts of applied water, stress index and water utilization efficiency. Three irrigation treatments, based on the temperature difference (dt) between air (Ta) and canopy (Tc), were adopted to accomplish the tested objectives. The irrigation treatments were, $I_1$ irrigating when the difference between the canopy temperature (Tc), and air temperature (Ta) =-1 °C, $I_2$ irrigating when Tc- Ta = 0 °C, and $I_3$, irrigating when Tc- Ta = +1°C. Results revealed that maximum grain and straw, wheat yields were produced when irrigating at dt= -1 °C, in two growing seasons.The total amounts of applied irrigation water for wheat crop were 42.1, 36.5 and 29.7 cm for $I_1$, $I_2$ and $I_3$ treatments, respectively, in first season, and were 41.7, 36.1 and 30.6 cm for the same respective treatments, in the second season. The seasonal water consumption were 32.4, 26.8 and 21.2 cm for $I_1$, $I_2$ and $I_3$ treatments, respectively in the first season, whilein the second season, the values were 30.3, 25.3 and 20.0 cm for the same treatments, respectively. The highest values of stress index were recorded with $I_3$and $I_2$ irrigation treatments, while, the lowest value was recorded with $I_1$tratment. The highest values of water utilization efficiency (1.68 and 1.93 Kg grain per $m^3$applied irrigation water) were obtained by $I_1$treatment (dt=-1 °C). in the first and second seasons, respectively. The obtained results allowed us to conclude that infrared thermometer can be used as an easy tool for scheduling irrigation of wheat crop based on the measurements of canopy and air temperatures.*

**Key words:** *Infrared thermometer -Stress Index - Irrigation scheduling - wheat*

## INTRODUCTION

The use of infrared thermometer to measure canopy temperature for irrigation scheduling purposes has been successfully applied in arid region, but it had complications in humid areas where the vapor pressure deficit is low. When plantsare under water stress, thiscauses stomatal closure, which interrupts energy dissipation and results in the rise of leaf temperature. The leaf or canopy temperature is used as an indicator of plant water stress (Jackson *et al.,* 1981) and Jackson (1982). Blum *et al.,* (1989) indicated the suitability of canopy temperature depression as an indicator of yield and stress tolerance prediction. However, it must be evaluated for every individual environment and inparticular for every plant species. Guofa *et al.,* (2004) reported a significant correlation between canopy temperature and wheat grain yield which may appear under severe water stress, and suggested further experiments ~~on~~to study root uptake. Orta *et al.,* (2004), conducted a study, in Turkey, to develop baseline equations which can be used to quantify and evaluate crop water stress index of three winter wheat genotypes, and to schedule irrigation and to predict yield. Jalali-Farahani *et al.,* (1993), showed that changes in crop water stress index (CWSI) depended on the applied irrigation volume. Bijanzadeh and Emam (2012), reported that maximum wheat grain yield was obtained in shiraz and Yavaroscultivars under well and excess watering and crop water stress index (CWSI) in these cultivars ranged from 0.31 to 0.36, whereas by decreasing water supply and increasing CWSI, grain yield in these cultivars decreased significantly. Reynolds *et al.,* (2007), indicated that canopy temperature is phenotypically and genetically associated with grain yield under drought stress. Inagaki and Nachit (2008), indicated that the canopy temperature difference of approximately 7°C, is large enough to visually detect transpiration changes in foliage and distantly monitor the soil water stress during plant growth. They concluded that, infrared thermography has great potential as a tool to instantly monitor water stress in fields. Ehsan and Yahya (2012) found that, maximum wheat grain yield was obtained, in Shiraz and Yavaros cultivars, under well and excess watering. They indicated also that, the canopy temperature reflects the interactions among plants, soil, and atmosphere. The application of canopy – air temperature difference was appropriate for crop water stress determination as it is non–contact, reliable;provide considerably precise estimation and represents actual crop water demand. Abdolreza *et al.,* (2014) indicated that, the index of difference between the temperature of air and leaf (ΔT= Tair – Tleaf) showed the leaf temperature which could indicate the amount of water absorbed by the root. Thus, leaf temperature can be widely used as an effective indicator of the estimated timing of irrigation. Kim *et al.,* (2015) found that the values of Tc- Ta was negatively related to vapor pressure deficit (VPD). Further, cucumber growth in the under and over irrigated field, showed water stress in contrast to that grown in the optimally irrigated field. They concluded that, thermal infrared measurements could be useful for evaluating crop water status and plays an important role in irrigation scheduling of agricultural crops.

The main objectives of this study are to assess the suitability of using the infrared thermometer in irrigation scheduling of wheat crop, and to determine the effect of irrigation treatments on wheat grain and straw yields, water consumptive use, amounts of applied water, stress index and water utilization efficiency.

## MATERIALS AND METHODS

A field experiment was conducted at Nubaria Agricultural Research Station (calcareous sandy loam soil) (30.900 E, 29.960 N, and 25 m above sea level), El-Behiera governorate, Egypt, in the two successive winter seasons of 2013-2014 and 2014-2015. Soil samples were collected before sowing to determine main soil physical and chemical characters (Page *et al.,* 1982) and some soil hydro-physical parameters. The values of the measured parameters are presented in Tables 1 and 2.

**Table 1: Field capacity, wilting point, available soil moisture and bulk density of the soil at the experimental site.**

| Soil depth (cm) | Field Capacity (%) | Wilting Point (%) | Available water (%) | Bulk density($gcm^{-3}$) |
|---|---|---|---|---|
| 0-15 | 27.1 | 15.0 | 12.1 | 1.08 |
| 15-30 | 25.8 | 13.4 | 12.4 | 1.15 |
| 30-45 | 23.0 | 12.8 | 10.2 | 1.17 |
| 45-60 | 21.3 | 11.8 | 9.5 | 1.27 |
| Average | 24.3 | 13.3 | 11.0 | 1.16 |

**Table 2: Chemical analysis of the soil at the experimental site.**

| Soil depth (cm) | Total N% | Available Mg/g | | Soluble cations (meq/l) | | | | Soluble anions (meq/l) | | | pH | EC (dS/m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | K | P | $K^+$ | $Na^+$ | $Mg^{++}$ | $Ca^{++}$ | $Cl^-$ | $SO_4^{--}$ | $HCO_3^-$ | | |
| 0 - 30 | 0.07 | 105 | 3.2 | 0.70 | 6.39 | 1.80 | 8.30 | 9.30 | 2.82 | 5.00 | 8.30 | 1.73 |
| 30 – 60 | 0.09 | 80 | 2.3 | 0.72 | 6.25 | 1.30 | 7.20 | 9.20 | 2.50 | 4.10 | 8.50 | 1.56 |

A randomized completely blocks design (RCBD) with four replicates was used. Three irrigation treatments were applied, the irrigation treatments were, $I_1$: irrigating when the difference (dt) between the canopy temperature (Tc) and air temperature (Ta)=-1°C. $I_2$: irrigating when Tc- Ta = 0 °C, and $I_3$: irrigating when Tc- Ta = +1 °C. All irrigation treatments were applied after the 1$^{st}$ irrigation.

The total number of the experimental plots were 12 plot. The area of the plot was 42m$^2$.(7m long X 6m width).

Canopy and air temperatures and stress index reading were measured during midday every two days using the scheduler plant stress monitor (Standard Oil Engineered Materials Company, 1987). In the field, the monitor compares plant temperature to its total environment, measuring and analyzing: relative humidity, air temperature, plant temperature, and sunlight intensity. The interpretation of the Stress Index readings are given as follows:

| | | |
|---|---|---|
| Stress Index Reading | ≤ 0 | Plant is extremely well irrigated |
| | 0-2 | Plant is operating at top efficiency |
| | > 2 | Cause plant performance to suffer |

Wheat grains (Giza 168 Varity) were sown on the 20$^{th}$ and 25$^{th}$of November and were harvested on the 19$^{th}$ and 14$^{th}$of Mayin the first and second seasons, respectively. Yield data were obtained from central area of each plot (30 m$^2$, 6m long X 5m width) to avoid any border effects. Fertilization practices included the application of 30 Kg $P_2O_5$/fed (as calcium super phosphate, 15%), 24 Kg $K_2O$/fed (as potassium sulphate, 48%), and 100 Kg N/fed (as ammonium nitrate, 33.5%).

Soil moisture contents were determined gravimetrically as average of four samples per plot taken at 0-15, 15-30, 30-45, and 45-60 cm depth just before and two days after each irrigation to determine water consumption. Irrigation water was applied to raise the soil moisture irrigation to field capacity. An extra amount of 20% of applied water was added to each plot to insure distribution uniformity of water and for leaching requirements. The irrigation water delivered to field plots was measured by using a water flow meter connected to an irrigation pump placed very close to the experimental plots to ensure high water application efficiency. The total depths of the rainfall precipitated at the experimental site were 78.2 and 108.9 mm in the first and second season, respectively (Table 3).

Water consumption (CU) and depth of irrigation water (DIW) were calculated according to equations of Hansen *et al.* (1974).

$$\mathrm{CU} = \sum_{i=1}^{i-4} \frac{\theta 1 - \theta 2}{100} \times Db \times d \quad cm$$

$$\mathrm{DIW} = \sum_{i=1}^{i-4} \frac{F.c - \theta 2}{100} \times Db \times d \quad cm$$

The applied of irrigation water (AIW) were calculated as follows:

$$AIW = \frac{DIW}{Ea\,(1 - LR)} \qquad cm$$

**Table 3. Precipitation(mm) during the 2013/2014 and 2014/2015 growing seasons.**

| Season | 2013/2014 | 2014/2015 |
|---|---|---|
| Month | Precipitation (mm) | Precipitation (mm) |
| Nov. | 7.8 | 10.3 |
| Dec. | 19.5 | 27.6 |
| Jan. | 19.8 | 29.9 |
| Feb. | 13.2 | 21.1 |
| Mar. | 11.1 | 17.1 |
| Apr. | 6.8 | 2.9 |
| Total | 78.2 | 108.9 |

where:
FC = % of field capacity
$\Theta_1$ = % of soil moisture content after irrigation.
$\Theta_2$ = % of soil moisture content before irrigation.
d = Soil depth in (cm).
$D_b$= Soil bulk density (gm cm $^{-3}$).
i = number of soil layer.
LR = Leaching requirement (addition of 20% of AIW in the calcareous soil).
Ea = Application efficiency ≈ 70% for the control surface irrigation system.

Water utilization efficiency (WUTE) was calculated according to Jensen (1983).

$$WU_tE = \frac{wheat\ grain\ \ yield\ (kg/fed)}{water\ applied\ \ \ (m^3/fed)}$$

The obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the simple design as described by Steel and Torrie (1980). Means were separated using the least significant different (L.S.D) method.

## RESULTS AND DISCUSSION

### 1- Wheat grain and straw yields:

Grain and straw yields of wheat crop for the two growing seasons are presented in Table 4. The results indicated that all tested traits were significantly affected by irrigation treatments.

The highest values of grain and straw yields obtained when irrigated under the $I_1$ treatment, in the first and second seasons, while the lowest values were recorded for $I_3$ treatment, in the two growing seasons. Results showed also that, the grain and straw wheat yields for $I_1$ irrigation treatment were 49.1, and 17.2%, and were 47.0 and 13.9%, higher than those obtained from the $I_3$ treatment in the 1$^{st}$ and 2$^{nd}$ growing seasons respectively. These results are agreement with the results of Guofa *et al.,* (2004), Reynolds *et al.,* (2007) and Ehsan and Yahya (2012).

### 2- Applied irrigation water (AIW):

Monthly and total of applied irrigation water for wheat in the first and second seasons are given in Table 5. The results showed that, for each irrigation treatment the data for both seasons were almost the same. The seasonal of applied irrigation water were 42.1 and 41.7 cm for $I_1$ treatment while they were 29.7 and 30.6 cm for $I_3$ treatments in the two growing seasons, respectively. The applied irrigation water for wheat crop were close agreement with that reported by Attia (1989) who found that the water requirement was 38.4 cm, for the best irrigation treatment (irrigation at 75% depletion of available water). Also, these results are agreement with the results of Abdolreza *et al.,* (2014).

**Table 4: Means of wheat grain and straw yields (ton/ha) as affected by irrigation treatments during the 2013/2014 and 2014/2015 winter growing seasons.**

| Treatments | Grain yield | | Straw yield | |
|---|---|---|---|---|
| | 2013/2014 season | 2014/2015 season | 2013/2014 season | 2014/2015 season |
| $I_1$ | 7.08 | 8.08 | 14.75 | 14.33 |
| $I_2$ | 6.08 | 6.50 | 13.58 | 12.83 |
| $I_3$ | 4.75 | 5.50 | 12.58 | 12.58 |
| L.S.D at 5% | 0.45 | 0.72 | 0.82 | 2.22 |

**Table 5. Monthly and total applied irrigation water (cm) for wheat crop as affected by irrigation treatments during the 2013/2014 and 2014/2015 growing seasons.**

| Season | 2013/2014 | | | | | | 2014/2015 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation treatments | Irrigation date | | | | | | Irrigation date | | | | | |
| | Sowing 20/11/2013 | 1st 8/1/2014 | 2nd 9/3/2014 | 3rd 26/3/2014 | 4th 15/4/2014 | Total | Sowing 25/11/2014 | 1st 6/1/2015 | 2nd 12/3/2015 | 3rd 30/3/2015 | 4th 19/4/2015 | Total |
| $I_1$ | 12.30 | 6.50 | 10.40 | 6.20 | 6.70 | 42.10 | 11.50 | 6.80 | 11.10 | 5.50 | 6.80 | 41.70 |
| $I_2$ | 12.30 | 6.50 | - | 10.00 | 7.70 | 36.50 | 11.50 | 6.80 | - | 10.30 | 7.50 | 36.10 |
| $I_3$ | 12.30 | 6.50 | - | -- | 10.90 | 29.70 | 11.50 | 6.80 | - | - | 12.30 | 30.60 |

## 3- Stress index (SI)

Canopy and air temperatures and Stress Index for the two growing seasons are given in Figures 1 and 2. Results indicated that the highest Stress Index values of 6.5 and 6.9 were recorded for irrigation treatment $I_3$in the 1st and 2nd growing seasons, respectively. While, the lowest values (less than 2.9) were recorded with irrigation treatment $I_1$ in the two growing seasons. The results indicated that, wheat plants under $I_3$ irrigation treatment were under severe stress (6.5-6.9) which resulted in significant yield reduction. Results showed also that the Stress Index values were higher than 3(3.2-3.5) with |$I_2$ irrigation treatment in the two seasons, indicating moderate stress on wheat plants. The obtained results were in agreement with Jalali-Farahani *et al.,* |(1993) and Bijanzadeh and Emam (2012).

## 4- Water consumption (CU):

Water consumption as determined by soil moisture depletion during the two growing seasons are given in Table 6. The water consumption were 32.4, 26.8 and 21.2 cm for the irrigation treatments $I_1$, $I_2$ and $I_3$, respectively, in the first season, while in the second season the values were 30.3, 25.3 and 20.0cm for the previous treatments, respectively. These results are in agreement with the results of Abdolreza *et al.,* (2014).

## 5- Water Utilization Efficiency (WUTE):

Results in Table 7 represent the effect of irrigation treatments on water utilization efficiency (WUTE) expressed as Kg of wheat grain yield per cubic meter ($m^3$) of applied irrigation water. The highest values of WUTE were scored by $I_1$ treatment in the two growing seasons, while the lowest values were obtained by $I_3$ treatment in the two growing seasons. These results varied from 1.59 to 1.68 and 1.79 to 1.93 Kg wheat grain yield per $m^3$ applied irrigation water for first and second seasons, respectively.

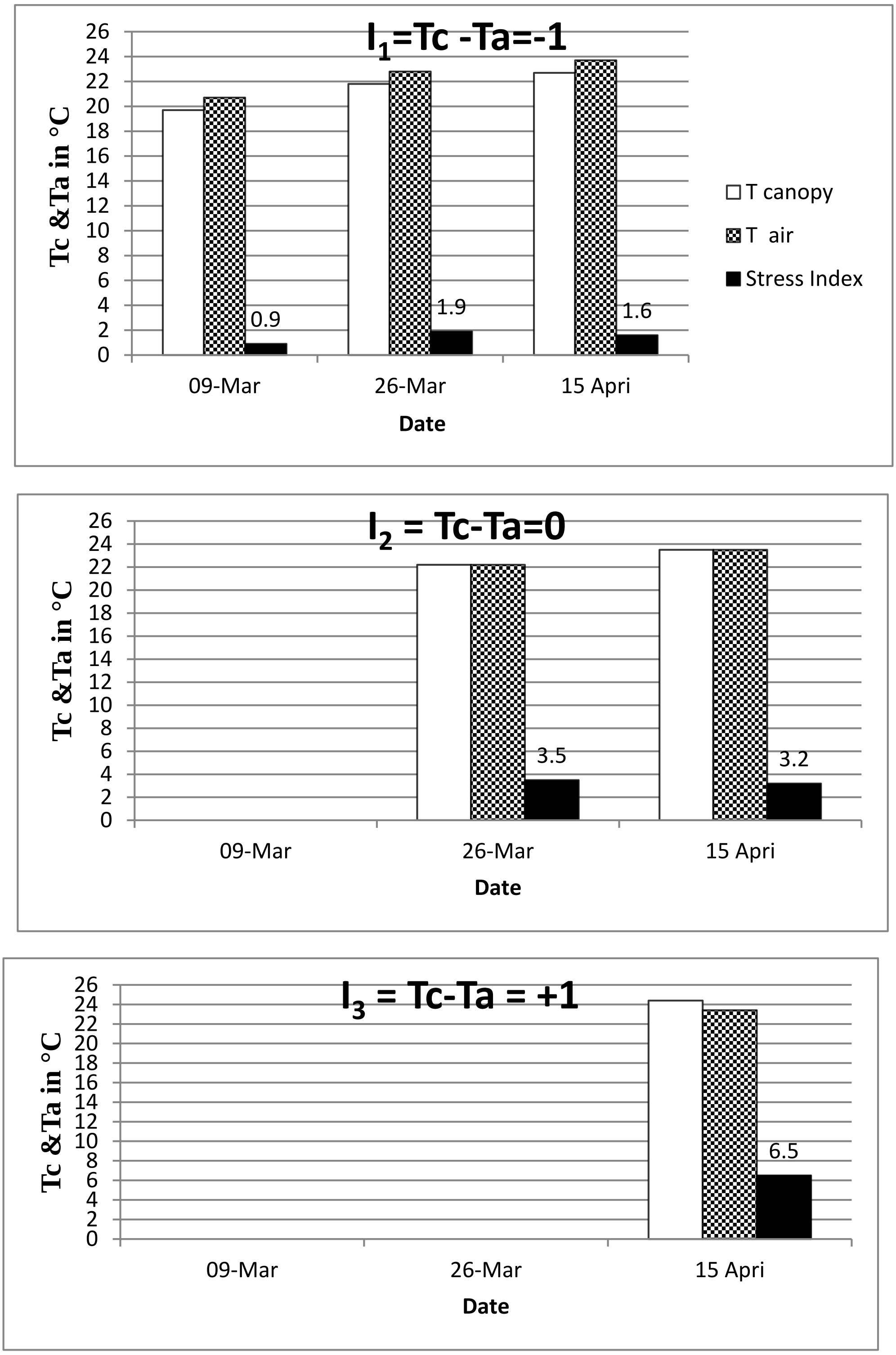


**Fig. 1. Irrigation treatments and Stress Index during 2013-2014 growing season.**

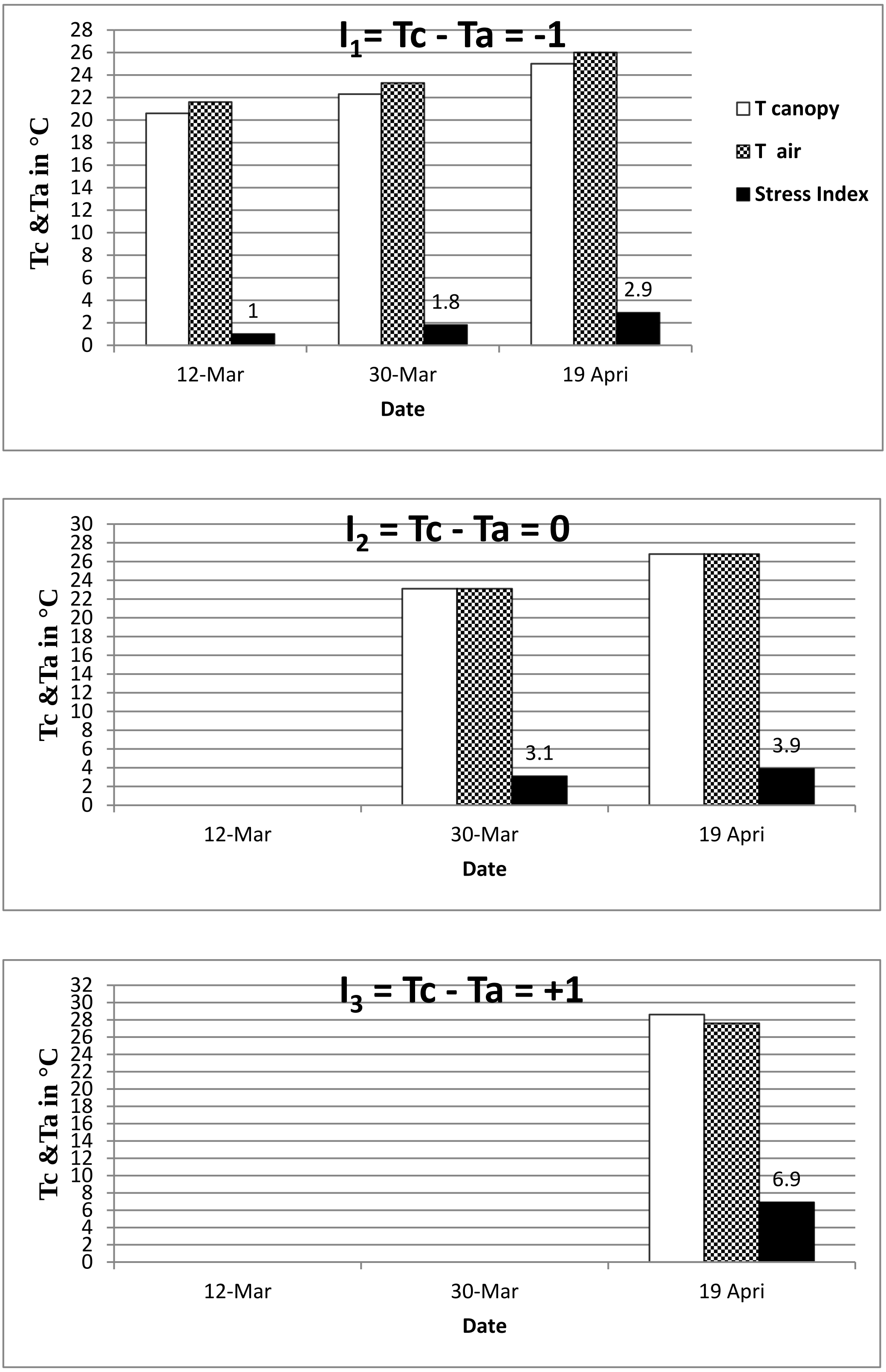


**Fig. 2: Irrigation treatments and Stress Index during 2014-2015 growing season.**

**Table 6. Water consumption (cm)by wheat crop as affected by irrigation treatments during 2013/2014 and 2014/2015 growing seasons.**

| Season | 2013/2014 | | | | | | 2014/2015 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation treatments | Irrigation period | | | | | | Irrigation period | | | | | |
| | from20/11/2013 to 8/1/2014 | from8/1/2014 to 9/3/2014 | 9/3/2014 To25/3/2014 | 25/3/2014 To 15/4/2015 | 15/4/2014 To 19/5/2014 | Total | From 5/11/2014 To 6/1/2015 | 6/1/2015 To 12/3/2015 | 12 /3/2014 To 30/3/2015 | 30 /3/2015 To 19/4/2015 | 19 /4/2015 To 14/5/2015 | Total |
| $I_1$ | 5.80 | 6.10 | 6.80 | 6.80 | 6.90 | 32.40 | 5.60 | 5.60 | 6.50 | 6.60 | 6.00 | 30.30 |
| $I_2$ | 6.00 | - | 6.90 | 6.90 | 7.00 | 26.80 | 5.90 | - | 6.80 | 5.80 | 6.80 | 25.30 |
| $I_3$ | 6.10 | - | - | 7.60 | 7.50 | 21.20 | 5.80 | - | - | 6.90 | 7.30 | 20.00 |

**Table 7: Water Utilization Efficiency (WUTE) in Kg wheat grain yield per $m^3$ applied irrigation water as affected by irrigation treatments during 2013/2014 and 2014/2015 growing seasons.**

| Treatments | Water Utilization Efficiency (WUtE) | |
|---|---|---|
| | Season 2013/2014 | Season 2014/2015 |
| $I_1$ | 1.68 | 1.93 |
| $I_2$ | 1.66 | 1.80 |
| $I_3$ | 1.59 | 1.79 |

## CONCLUSIONS

From the obtained results it could be concluded that:

1- Wheat grain yield is better if the watering is scheduled to keep the dt = -1 °C.
2- The soil moisture is higher when dt = -1 °C
3- The water utilization efficiency (WUTE) is higher when dt = -1 °C
4- The highest values of stress index were recorded when dt = 0 and dt = +1 , while the lowest value was recorded when dt = -1.
5- Infrared thermometer can be used for determination irrigation scheduling.

## REFERENCES

Abdolreza, E. N., E.M. Esfahani, M. B., Harchegani, M. Jafarpour and M. Golabadi (2014). Leaf temperature as an index to determine the irrigation interval.Research on Crop Ecophysiology. 91 (2): 89-95.

Attia, M. M. (1989). Effect of water stress, nitrogen fertilization and soil conditioners on water requirements ofcorn, wheat, soybean and lentil in North Delta Region- Ph.D Thesis Fac. Agric. Alex. Univ. Egypt.

Bijanzadeh, E. and Y. Emam, (2012). Evaluation of crop stress index canopy temperature and grain yield of five Iranian wheat cultivars under late season drought stress. Journal of plant physiology and breeding, 2(1): 23:33.

Blum, A., L. Shpiter, G. Golan and J. Mayer (1989). Yield stability and canopy temperature of wheat genotypes under drought stress. Field Crop Res., 22:289-296.

Ehsan, B. and Y. Yahya (2012). Evaluation of crop water stress index, Canopy temperature and grain yield of five Iranian wheat cultivars under late season drought stress. Journal of plant physiology and Breeding 2(1): 23-33.

Guofu, Y., Yiluo, X. Sun and D. Tang (2004). Evaluation of crop water stress index for detecting water stress in winter wheat in the Notth China Plain, Agricultural Water Management 64: 29-40.

Hansen, V.E., O.W. Israelsen and G.E. Stringham (1974). "Irrigation Princiles" 4th Ed. John Wiley Sons. New York.

Inagaki, M.N. and M. M. Nachit (2008). Visual monitoring of water deficit stress using infrared hermography in wheat.The 11th International wheat Genetics Symposium Proceedings Edited by Rudi Apples Russell Eastwood Evans Lagudah Peter Langridge Michael Mackay Lynne.

Jackson, R. D., S. B. Idso, R. J. Reginato and J. P. Pinter (1981). Canopy temperature as a crop water stress indicator. Water Resources Research 17 (4), 1133-1138.

Jackson, R. D. (1982). Canopy temperature and crop water stress. Advances in Irrigation, Vol. 1. Academic Press, New York.

Jalali-Farahani, H.R., D.C. Slack, D.M. Kopec and A.D. Matthias (1993). Crop water stress index models for bremudagrass. Agronomy Journal 85:1210-1217.

Jensen, M. E. (1983). "Design and Operation of Farm Irrigation Systems". Am. Soc. Ag. Eng. Mitchigan U.S.A, PP.827.

Kim, M., K. Seounghee, K. Yougjin, C. Yonghun and S. Myungchul (2015). Infrared estimation of canopy temperature as crop water stress indicator. Korean Journal of soil science and fertilizer, 48 (5): 499-504.

Orta, A.H., I. Baser, S. Sehirali, T. Erdem and Y. Erdem (2004). Use of infrared thermometry for developing baseline equations and scheduling irrigation in wheat. Cereal Research Communications 32(3), 363-370.

Page, A.L. R.H miller and D. R. Keeny (1982). Methods of soilanalysis. Am Soc. Agr.Inc., Madison, WI, USA.

Reynolds, M.P., C. S. Pierre, S.I Saad, M. Vargas and A.G. Condon (2007). Evaluating Potential Genetic Gains in Wheat Associated with Stress – Adaptive Trait Expression in Elite Genetic Resources under Drought and Heat Stress, Crop Sci. 47: 172-189.

Stel, R.G. and J.H. Torrie (1980). Principals and Procedures of Statistics.2nd Edi Now York, Mc. Grow Hill Book company.196p.

# جدولة رى محصول القمح باستخدام جهاز الحرارة بالأشعة تحت الحمراء

**محمود محمد عطية[1] ، أحمد عبدالهادى سلام[1] ، الحسينى غلاب جلال[2]**

[1] قسم المقننات المائية والرى الحقلى – معهد بحوث الأراضى والمياه والبيئة – مركز البحوث الزراعية

(2) قسم بحوث القمح – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية

**الملخص العربى**

نفذت تجربة حقلية فى موسمى 2013- 2014 , 2014 – 2015 بالأراضى الجيرية بمحطة بحوث النوبارية لدراسة جدولة رى محصول القمح باستخدام جهاز الحرارة بالأشعة تحت الحمراء. وكانت معاملات الرى هى أ$_1$- الرى عندما يكون الفرق بين درجة حرارة النبات و درجة حرارة الجو تساوى -1 م ° , أ$_2$- الرى عندما يكون الفرق بين درجة حرارة النبات ودرجة حرارة الجو تساوى صفر م ه , أ$_3$- الرى عندما يكون الفرق بين درجة حرارة النبات و درجة حرارة الجو تساوى +1 م °
تم تنفيذ التجربة باستخدام التصميم الأحصائي القطاعات كاملة العشوائيه.(RCBD) فى اربع مكررات و يمكن تلخيص اهم النتائج المتحصل عليها للأتى:-

1- هناك تأثير معنوى لمعاملات الرى أ$_1$, أ$_2$ , أ$_3$ على انتاجية محصول حبوب القمح والقش خلال موسمى النمو.
2- أعلى متوسط إنتاجية لمحصول حبوب القمح كانت 7.083 , 8.083 طن/هكتار لمعاملة الرى أ$_1$ خلال موسمى النمو على التوالى.
3- أنسب كمية مياه مضافة كانت 42.1 , 41.7 سم لمعاملة الرى أ$_1$ خلال موسمى النمو على التوالى.
4- أنسب كمية استهلاك مائى كانت 32.4 , 30.3 سم لمعاملة الرى أ$_1$ خلال موسمى النمو على التوالى.
5- أنسب كفاءة إستعمالية لمياه الرى كانت 1.68 , 1.93 كجم قمح لكل متر مكعب مياه مضافة لمعاملة الرى أ$_1$ خلال موسمى النمو.
6- أعلى قيم لدليل الاجهاد (Stress Index) كانت لمعاملات الرى أ$_3$, أ$_2$ وأقل قيمة كانت لمعاملة الرى أ$_1$.
7- من الممكن استخدام جهاز الحرارة بالأشعة تحت الحمراء Infrared thermometer فى تحديد ميعاد الرى وهو عندما يكون الفرق بين درجة حرارة النبات وحرارة الجو تساوى -1 م °.