Jordan Journal of Agricultural Sciences, Volume **13**, No.**3** 2017

Crop Water Stress Index and Canopy Temperature Changes of Triticale (X *Triticosecale* Wittmack) Cultivars Under Irrigation Scheduling

Tahereh Irandoust[1], Ehsan Bijanzadeh[1]✉

ABSTRACT

A field experiment was laid out to evaluate the crop water stress index (CWSI) and canopy temperature of triticale under drought stress in 2013 growing season. Three triticale cultivars including Sanabad, ET-83-3, and ET-84-5, were arranged in sub-plots and four levels of irrigation regimes including well watered, cutting off irrigation at flowering, milk development, and dough development stages as main plots of a split plot experiment with three replicates. Results showed that Sanabad and ET-83-3 cultivars with 6.31 and 6.89 °C had the higher canopy-air temperature differences, while in ET-84-5 this difference reached to 2.66 °C. In all cultivars and cutting off irrigation regimes, high amount of variation (0.18 to 0.91) was observed for monthly CWSI and increased by progressing drought from cutting off irrigation at flowering to milk development. Under cutting off irrigation at flowering, ET-83-3 with 0.67 had the highest mean seasonal CWSI, while in ET-84-5 reached to 0.50. Polynomial regression showed that with decreasing water applied, CWSI increased and the slope of regression from 353 to 429 mm water applied was more than that of well watered condition (R^2=0.85). The highest grain yield (476.2 g/m^2) was obtained in ET-84-5 under well watered and CWSI in these cultivars ranged from 0.18 to 0.33. By lowering water applied (from flowering to milk development) and increasing CWSI, grain yield decreased especially in Sanabad and ET-83-3. Overall, ET-84-5, with lower T*c*-T*a*, water applied, and mean CWSI had better performances when exposed to drought.

Keywords: Cutting Off Irrigation, Drought, Flowering, Grain Yield, Water Applied.

INTRODUCTION

In arid and semi-arid areas where the amount of water is a major limiting factor, the lower amount of irrigation water, without the decrease in crop yield is worthy for irrigation scheduling**.** When a plant closes its stomata following water stress, stomatal conductivity, heat flux, transpiration and the cooling effects of evaporation decrease and the canopy temperature increase (Panda *et al.*, 2003). This is the basis for the use of canopy temperature to determine plant water status (Emekli *et al.*, 2007). The canopy temperature (Tc) has provided an efficient method for rapid and non-destructive monitoring of whole plant response to drought stress (Idso *et al.*, 1981; Jackson *et al.*, 1981). It is also argued that variation in Tc, under stress and nonstress conditions, provides clues for crop water status and yield performance during drought seasons. The crop water stress index (CWSI), derived from canopy±air temperature differences (Tc-Ta) versus the air vapor pressure deficit (AVPD), was found to be a promising tool for quantifying crop water stress (Idso *et al.*, 1981; Alderfasi and Nielsen, 2001).

The crop water stress index (CWSI) calculation is

[*]Department of Agroecology, Agriculture College and Natural Resources of Darab, Shiraz University, Iran.
Received on 31/1/2016 and Accepted for Publication on 17/10/2016.

based on three main environmental variables: plant canopy temperature (T*c*), air temperature (T*a*) and atmospheric vapor pressure deficiency (VPD). These three variables have much influence on water used by plants (Braunworth, 1989). An infrared thermo meter measures the surface temperature of a crop canopy without making direct physical contact (Howell *et al.*, 1986). Idso *et al.*, (1981) defined CWSI based on the empirical linear relationship between midday T*c*-T*a* and VPD under high net radiation and well watered conditions. The CWSI has been used to quantify water status in the field based on canopy temperature (Yuan *et al.* 2004; Emekli *et al.*, 2007) and irrigation scheduling of wheat in many places (Alves and Pereira, 2000; Alderfarsi and Nielsen, 2001; Orta *et al.*, 2004; Bijanzadeh and Emam, 2012).

Many studies have been done to evaluate the application of CWSI in irrigation scheduling for different plants such as tall fescue [(*Festuca arundinacea* Schreb.); Al-faraj *et al.*, (2001)], and turfgrass [(*Cynodon dactylon* L.); Bijanzadeh *et al.*, 2013]. Furthermore, Jalali-Farahani *et al.*, (1993) concluded that the changes in CWSI values depended on the applied irrigation level. Al-Faraj *et al.*, (2001) reported that T*c*-T*a* was increased with a decrease in soil water content for tall fescue (*Festuca arundinacea* Schreb.). They suggested that CWSI could be used for irrigation timing in turfgrass. Feng *et al.*, (2001) declared that wheat cultivars with low canopy temperature could maintain superiority to cultivars with high canopy temperature and low canopy temperature in wheat could be used as an index to evaluate physiological capacities of wheat under drought stress and also as a useful marker in wheat breeding for drought tolerance.

After a decade of genetic manipulation and breeding, triticale (*X Triticosecale* Wittmack) stand out as a crop of high grain yield potential which generally surpass that of wheat under stress conditions. Its high productivity is most likely derived from high rates of carbon assimilation linked to stomatal physiology and probably low respiration rate. Being a derivative of rye, triticale has always been assumed to be relatively resistant to abiotic stresses such as drought (Blum, 2014). Little research has been done to quantify the CWSI of triticale cultivars especially in middle east, where water stress in cereals is pervasive and frequent during grain filling period. The aim of the present study were develop a baseline equation which can be used to calculate CWSI for monitoring water status of triticale genotypes and evaluate the relationship of CWSI with water applied and grain yield of triticale cultivars under different cutting off irrigation scheduling.

Materials and Methods

Field experiment was laid out during November 2013-June 2014 at the Research Station of College of Agriculture and Natural Resources of Darab, Shiraz University, Iran (28°29´ N, 54°55´ E and 1180 m above mean sea level), for determination of the crop water stress index of triticale cultivars. Ten-day averages of some meteorological data measured daily in the study area during April to June 2014 are shown in Table 1. Three triticale cultivars including Sanabad, ET-83-3, and ET-84-5, were arranged in sub-plots and four levels of irrigation regimes including well watered, cutting off irrigation at flowering, cutting off irrigation at milk development, and cutting off irrigation at dough development were as main plots of a split plot experimental arrangement with three replications.

Table 1. Ten-day means of climatic data measured daily at experimental site.

	Mean			
Month	**Temperature(°C)**	**evaporation (mm)**	**Relative humidity (%)**	**Wind speed (m/s)**
April				
1-10	19.3	11.8	27.8	2.1
11-20	19.8	12.6	28.3	2.0
21-30	20.5	13.2	29.3	2.2
May				
1-10	24.6	14.2	30.2	2.5
11-20	25.9	14.7	31.3	1.5
21-31	27.3	14.9	32.4	1.6
June				
1-10	30.2	15.7	33.4	1.1
11-20	32.1	16.3	34.3	1.6
21-30	34.5	17.6	36.8	1.3

On November 23th 2013, triticale genotypes were sown in rows 30 cm apart with 250 plants/m^2 in plots of 2×4 m. According to soil test, before planting, 60 kg P/ha, as super phosphate, and 60 kg N/ha, as urea, were applied. Another 60 kg N/ha was added at the end of tillering stage. The soil water status was monitored in each plot by gravimetric method at 30 cm intervals down to 120 cm. The amount of water applied was measured by time-volume technique according to Grimes *et al.,* (1987) and is presented in Figure 1 for each cultivar under different irrigation regimes.

To measure CWSI of triticale cultivars, an infrared thermometer (LT Lutron, Model TM-958, Taiwan) was used and the canopy temperature was measured (3, 6 and 9 days after each irrigation) from 4 April to 21 June 2010 (151- 233 days after planting). To ensure collection of accurate data, the infrared thermometer was held with a horizontal angle of 45° during measurements. Temperature measurement was done when there was no cloud. According to Idso *et al.,* (1981), midday canopy temperature is the best indicator to detect the crop water stress. The measurements were carried out from four directions (east, west, north and south) in each experimental plot.

Simultaneously, air temperature and relative humidity were recorded using thermo hygrograph (Lambrecht, Model 252, Germany) and psychrometer (Lambrecht, Model 1030, Germany) as basis for calculating vapour pressure deficit (VPD) (Monteith and Unsworth 1990). VPD was computed from standard psychrometer equation (Allen *et al.,* 1998). Then, CWSI values were calculated using the empirical method of Idso et al., (1981). The relationship between canopy-air temperature differences (T_c-T_a) and VPD were plotted under stressed and non-stressed conditions (Fig. 1). In this graph, the non-stressed baseline for each triticale cultivar was determined from the data collected three days after irrigation in excess watered treatment between 08:00 and 17:00 h with 30-min intervals.

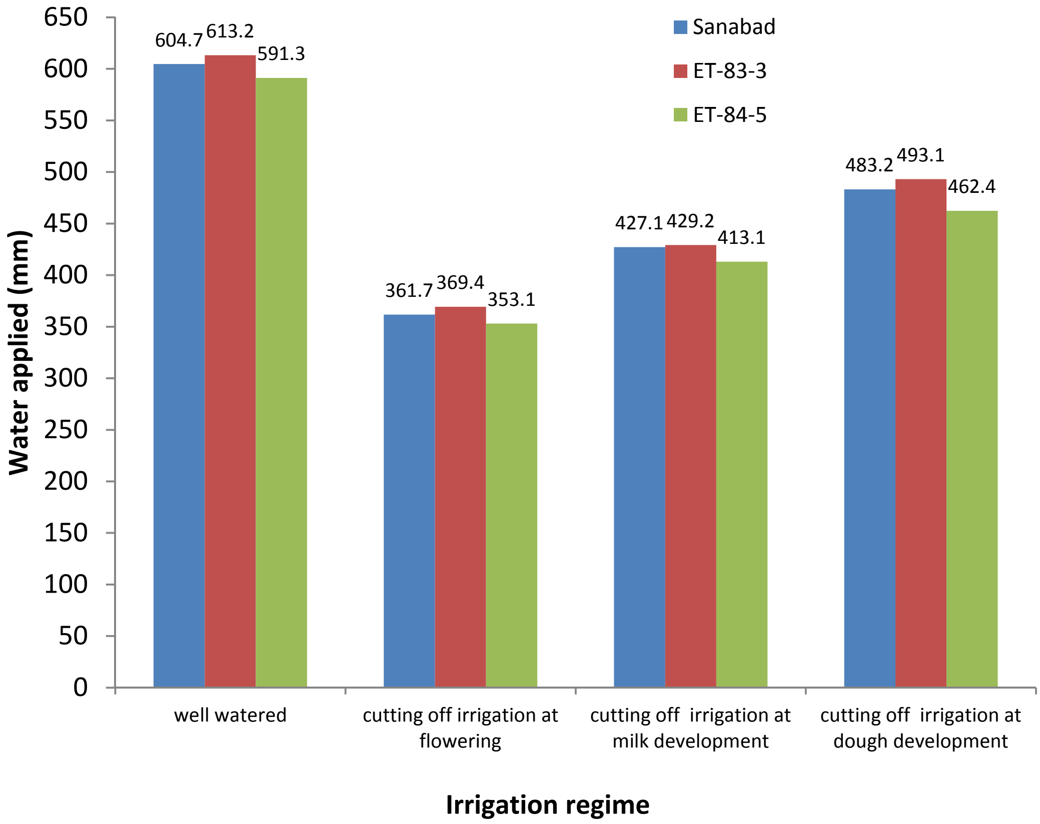

Figure 1. Total water applied (mm) in each irrigation regime and triticale cultivars.

The Idso's empirical non-stressed baseline can be expressed as Equation (1):

$$Tc - Ta = aVPD + b \quad (1)$$

where T*c*–T*a* is the measured canopy and air temperature differences for non- stressed treatment (ºC) and VPD is vapor pressure deficit (kPa) and *a* (slope) and *b* (intercept) are the linear regression coefficients of *Tc–Ta* on *VPD*. The upper baseline was determined using the average T*c*–T*a* values measured at 13:00, 14:00 and 15:00 h before each irrigation. Using the upper and lower limit estimates, a CWSI can be defined by the following Equation (2) (Idso *et al.*, 1981):

$$CWSI=[(Tc\text{-}Ta)m\text{-}(Tc\text{-}Ta)ll]/[(Tc\text{-}Ta)ul\text{-}(Tc\text{-}Ta)ll] \quad (2)$$

where (T*c*–T*a*)*m*, (T*c*–T*a*)*ll* and (T*c*–T*a*)*ul* are the measured canopy and air temperature differences at the moment and the lower and upper limit values (ºC), respectively. Grain yield measured from center of 1 m^2 final harvest area in each plot. The data were analyzed using SAS (2003) software and means were compared by Duncan's multiple range test at 0.05 probability level.

Results and Discussion

Canopy temperature changes of triticale cultivars

Changes in canopy-air temperature differences (T*c*-T*a*) observed among triticale cultivars, was significant at 5% probability level so that, Sanabad and ET-83-3 cultivars with 6.31 and 6.89 °C had the higher canopy- air temperature differences, while in ET-84-5 this difference reached only 2.66 °C (Table 2 and Fig. 2). Feng *et al.,* (2009) concluded that canopy temperature could be considered as a consistent character for each wheat genotype. They declared the difference in canopy temperature between low temperature wheat cultivars and high temperature cultivars could be observed mainly during the grain filling period, a key period for wheat to form grain and Xiaoyan 6 genotype could be considered as a low canopy temperature wheat genotype (LTW), whereas Yanshi 9, NR 9405, and 9430 as high canopy temperature wheat genotypes (HTW). Results of the present study are in agreement with the finding of Bijanzadeh and Emam (2012) where they found a significant variations in T*c*-T*a* of wheat so that, Shiraz and Yavaros cultivars (sensitive to drought) with 7.36 and 6.81 °C had the higher T*c*-T*a* difference, respectively while in Bahar cultivar this difference reached to 3.9 °C.

Determination of lower base line

Comparison of the upper limits values of canopy and air temperature difference (Tc -Ta)*ul* and slopes(*a*) and intercepts(*b*) for lower limit [(T*c* -T*a*)*ll* = a VPD + b] of three triticale cultivars was given in Table 2. In all cultivars, *a* and *b* of lower base line equation between T*c*-T*a* and VPD were significantly increased due to more limitation in water and increasing VPD (Fig. 2). Our result was in agreement with Orta *et al.,* (2004) who declared that T*c*-T*a* measured above a crop was negatively related to the atmospheric VPD. The value of *a* varied from -1.35 in Sanabad to -1.00 in ET-84-5 (Table 2). It appeared that Sanabad and ET-83-3 cultivars with higher *a* value were more sensitive to increasing VPD (Table 2 and Figure 2). On the other hand, in Sanabad and ET-83-3 difference between upper base line (under stress) and lower base line (non-stress) was more than in ET-84-5 genotype (Fig. 2). The value of *b* ranged from 3.00 to 0.72 and was significantly different among triticale cultivars (Table 2) Bijanzadeh and Emam (2012) showed that the lower baseline equation obtained for wheat crop was (T*c*-T*a*)*ll*= - 1.0001(VPD)+1.8934 during flowering to maturity and *a* and *b* parameters in the following equation were close to parameter of ET-84-5 (Fig. 2). On the other hand, in ET-83-3 and Sanabad cultivars the value of *a* was very close to that reported by Alderfarsi and Nielsen (2001) for winter wheat in Colorado [(T*c*-T*a*)*ll*= -1.35VPD+0.41], however, *b* in this equation was smaller than that for ET-83-3 and Sanabad cultivars of our study. This might be attributed to higher temperature in our experimental site, i.e. ET-83-3, from April to June (Fig. 1), compared to Colorado. Overall, many researchers pointed out that cultivar type and environmental conditions could influence the baseline equation causing differences in slopes(*a*) and intercepts(*b*) (Panda *et al.,* 2003; Yuan *et al.,* 2004; Bijanzadeh *et al.,* 2013).

Table 2. Comparison of the upper limits values of canopy and air temperature difference (Tc -Ta)*ul* and slope (a) and intercept (b) for lower limit [(T*c* -T*a*)*ll* = a VPD + b] of three triticale cultivars.

		Triticale cultivars	
	Sanabad	**ET-83-3**	**ET-84-5**
T*c*-T*a*	6.31a	6.89a	2.66b
Slope (*a*)	-1.35a	-1.31a	-1.00b
Intercept (*b*)	3.00a	1.88b	0.72c

Means in each row by the same letters are not significantly different at 5% probability level using Duncan’s multiple range test.

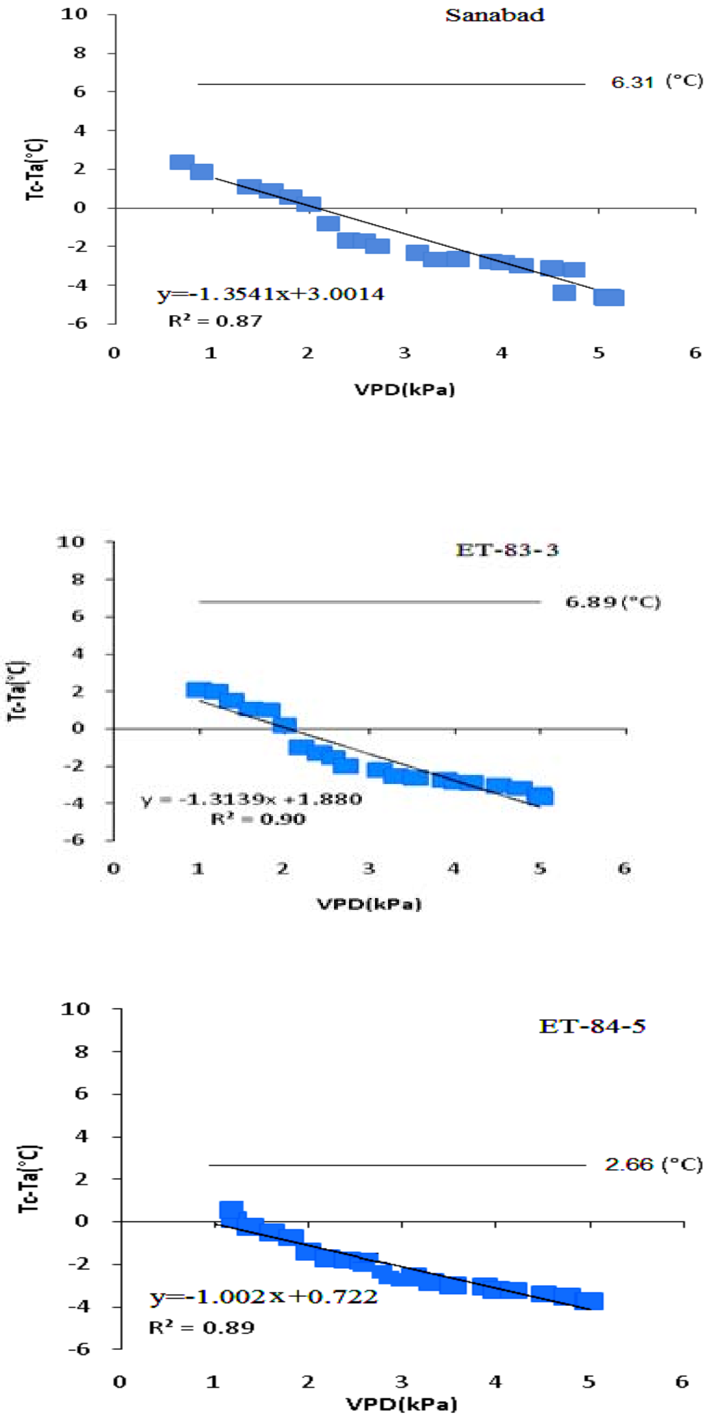

Figure 2. Stressed and non-stressed baselines for calculation of CWSI in three triticale cultivars.
VPD = vapor pressure deficit.

Crop water stress (CWSI) changes of triticale cultivars

In all cultivars and cutting off irrigation regimes, high amount of variation (0.18 to 0.91) was observed from April to June for monthly CWSI and increased by progressing drought stress from cutting off irrigation at flowering to milk development (Table 3). When plant exposed to cutting off irrigation at flowering, ET-83-3 and Sanabad cultivars with 0.67 and 0.63 had the highest mean seasonal CWSI, respectively, while in ET-84-5 reached to 0.50 and CWSI variation of these cultivars was less than ET-83-3 and Sanabad (Table 3). Garrot *et al.*, (1994) reported that in durum wheat (CV. Aldura) mean CWSI varied from 0.11 under well watered to 0.82 under severe drought stress. Gontia and Tiwari (2008) reported that the maximum CWSI of 0.52, 0.58, 0.68 and 0.89 were found under irrigation according to 100, 60, 40 and 20% of field capacity, respectively.

CWSI and water applied relationship

Crop water stress index (CWSI) values were negatively correlated with water applied (Figure 3a). Polynomial regression showed that with decreasing water applied in cutting of irrigation regimes, CWSI increased and the slope of regression from 353 to 429 mm water applied was more than that of well watered conditions (R^2=0.85). Stokcle and Dugas (1992) reported that as plants closed their stomata due to water shortage, and hence stomatal conductivity, heat flux, transpiration and the cooling effects of evaporation were decreased, the canopy temperature and CWSI were increased, compared with well watered conditions. In a similar study, Bijanzadeh and Emam (2012) declared that CWSI values were negatively correlated with water applied in wheat cultivars (R^2=0.80). In the present study, ET-83-3 and Sanabad cultivars consumed more water (Fig. 1) and had more CWSI when subjected to late season drought stress (Table 3).

Table 3. Effect of cutting off irrigation regimes on monthly and mean seasonal CWSI values and grain yield of triticale cultivars.

Irrigation regime	Triticale cultivars	Monthly CWSI			Mean seasonal CWSI	Grain yield (g/m^2)
		April	May	June		
well watered	Sanabad	0.21	0.32	0.45	0.32d	355.1b
	ET-83-3	0.23	0.34	0.48	0.35d	344.6b
	ET-84-5	0.19	0.25	0.33	0.25e	476.2a
cutting off irrigation at flowering						
	Sanabad	0.45	0.65	0.79	0.63a	243.2c
	ET-83-3	0.45	0.66	0.91	0.67a	237.8c
	ET-84-5	0.41	0.48	0.63	0.50b	354.3b
cutting off irrigation at milk development						
	Sanabad	0.41	0.57	0.61	0.53b	289.2c
	ET-83-3	0.44	0.58	0.63	0.55b	279.1c
	ET-84-5	0.35	0.43	0.56	0.44c	434.1b

Irrigation regime	Triticale cultivars	Monthly CWSI			Mean seasonal CWSI	Grain yield (g/m^2)
		April	May	June		
cutting off irrigation at dough development						
	Sanabad	0.23	0.35	0.49	0.35d	357.2b
	ET-83-3	0.25	0.37	0.51	0.37d	344.1b
	ET-84-5	0.20	0.29	0.37	0.28e	453.6a

Means in each column by the same letters are not significantly different at 5% probability level using Duncan's multiple range test.

CWSI and grain yield relationship

The highest grain yield (476 g/m^2) was obtained in ET-84-5 under well watered and CWSI in these cultivars ranged from 0.18 to 0.33 (Table 3). In all cultivars, by lowering water applied (from flowering to milk development stages) and increasing CWSI, grain yield in these cultivars decreased sharply (Fig.3). Garrot *et al.*, (1994) found that the highest grain yield (606 g/m^2) was achieved at CWSI levels between 0.3 and 0.37. These results illustrate the value of using CWSI as an indicator of crop water status and many researchers suggested that CWSI could be used to evaluate crop water status, improve irrigation scheduling and obtain optimum grain yield especially under water shortage conditions (Gardner *et al.*, 1992; Alderfarsi and Nielsen 2001; Emekli *et al.*, 2007; Bijanzadeh and Emam, 2012).

The grain yield was correlated with mean seasonal CWSI values (Figure 3b) by the following polynomial Equation (3):

$$Y= 107.61 (CWSI)^2-580.22(CWSI)+580.39 \qquad (3)$$

where Y is grain yield (g/m^2). As was shown in Figure 3b, the seasonal mean CWSI was negatively correlated to grain yield, (R^2=0.79). This equation could be used for yield prediction under different CWSI value in triticale. Predicting the grain yield to crop water stress had a key role in developing strategies and decision-making by researchers and farmers for irrigation scheduling under water shortage conditions (Yuan *et al.*, 2004; Orta *et al.*, 2004; Bijanzadeh and Emam, 2012; Bijanzadeh *et al.*, 2013).

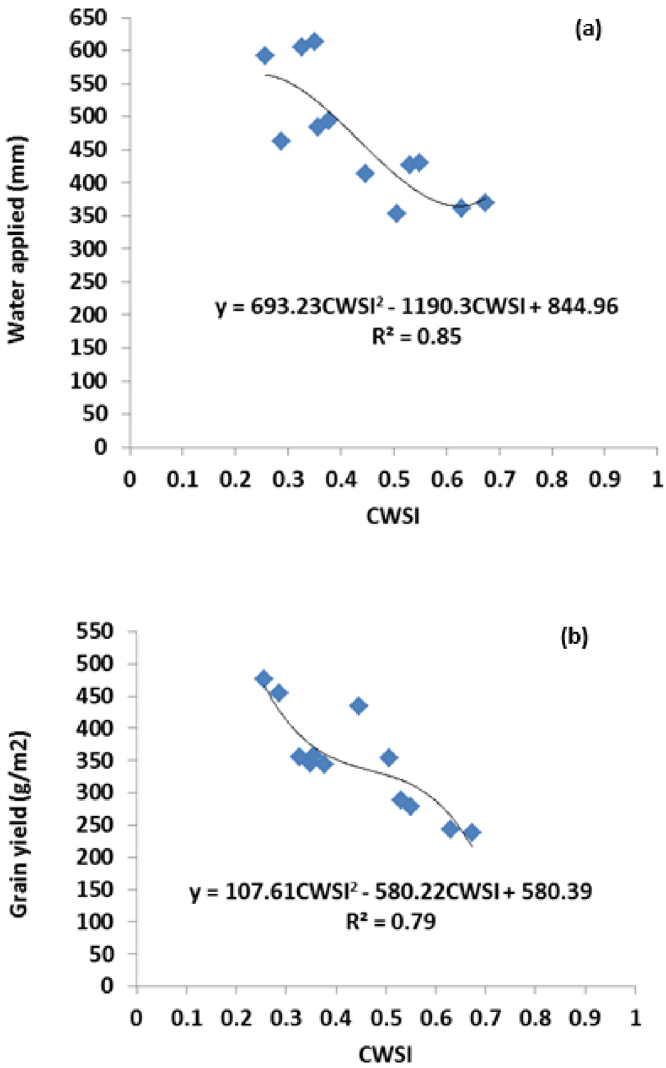

Figure 3. Relationships between CWSI with water applied (a), and grain yield (b) of triticale.

Conclusion

Application of canopy–air temperature difference was appropriate for crop water stress determination as it is non-destructive, noncontact, and reliable, provides considerably precise estimation and represents actual crop water demand. Crop canopy temperature reflects the interactions among plants, soil and atmosphere. The CWSI can be estimated using semiempirical approach with observations of T*c*-T*a* and VPD. A negative relationship was observed between CWSI and water applied under different irrigation regimes. The seasonal mean CWSI was related to triticale grain yield, negatively and a polynomial equation (Equation 3) can be used to predict the yield potential. Indeed high CWSI values could lead to less grain yield due to more water limitation. ET-84-5, with lower T*c*-T*a*, water applied, and mean CWSI had better performances than ET-83-3 and Sanabad, especially when subjected to cutting of irrigation. Evaluation of CWSI in the field should be further investigated as potential indirect selection criteria for grain yield sustainability of triticale cultivars under late season drought stress.

REFERENCES

Alderfasi, A.A., Nielsen, D.C. 2001. Use of crop water stress index for monitoring water status and scheduling irrigation in wheat. ***Agricultural Water Management***, 47: 69–75.

Al-Faraj, A., Meyer, G.E., Horst, G.L. 2001. A crop water stress index for tall fescue (*Fetusca arundinacea* Schreb.) irrigation decision-making: a traditional method. ***Commercial Agriculture***, 31: 107–124.

Allen, R.G., Pereira, L.S., Raes, D. Smith, M. 1998. Crop evapotranspiration. FAO Irrigation and Drainage Paper 56. FAO, Rome.

Alves, I., Pereira, L.S. 2000. Non-water-stressed baselines for irrigation scheduling with infrared thermometers: a new approach. ***Irrigation Science***, 19: 101–106.

Bijanzadeh, E., Emam, Y. 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: 23-33.

Blum, A. 2014. The abiotic stress response and adaptation of triticale–A review. ***Cereal Research Commonication,*** 42: 359-375.

Bijanzadeh, E., Naderi, R., Emam, Y. 2013. Determination of crop water stress index for irrigation scheduling of Turfgrass (*Cynodon dactylon* L. Pers.) under drought conditions. ***Journal of Plant Physiology and Breeding***, 3: 13-22

Braunworth W.S. 1989. The possible use of the crop water stress index as an indicator of evapotranspiration deficits and yield reductions in sweet corn. ***Journal of American Society of Horticulture Science***, 114: 542–546.

Emekli, Y., Bastug, R., Buyuktas, D. Emekli, N.Y. 2007. Evaluation of a crop water stress index for irrigation scheduling of bermudagrass. ***Agricultural Water Management***, 90: 205–212.

Feng, B.L. Wang, C.F. Miao, F. 2001. Leaf gas exchange character of low canopy temperature wheat in drought conditions. ***Journal of Triticale Crop***, 21: 48–51.

Feng, B.L., Yu, H., Hu, Y., Gao, X., Gao, J., Gao, D., Zhang, S. 2009. The physiological characteristics of the low canopy temperature wheat (*Triticum aestivum* L.) genotypes under simulated drought condition. ***Acta Physiology Plantarum***, 31: 1229–1235.

Gardner, B.R., Nielsen, D.C., Shock C.C. 1992. Infrared thermometry and the crop water stress index. II. Sampling procedures and interpretation. ***Journal of Production Agriculture***, 5: 466–475.

Garrot, D.J., Ottman, D.D., Fangmeier, D.D., Hunman, S.H. 1994. Quantifying wheat water stress with the crop water stress index to schedule irrigations. ***Agronomy Journal,*** 86: 195-199.

Gontia, N.K., Tiwari, K.N. 2008. Development of crop water stress index of wheat crop for scheduling irrigation using infrared thermometry. ***Agricultural Water Management***, 95: 1144–1152.

Grimes, D.W., Yamada, H., Hughes, S.W. 1987. Climate-normalized cotton leaf water potentials for irrigation scheduling. ***Agricultural Water Management***, 12: 293-304.

Howell, T.A., Musick, J.T., Tolk, J.A. 1986. Canopy temperature of irrigated winter wheat. ***Transition ASAE***, 29: 1692–1699.

Idso, S.B., Jackson, R.D., Pinter, J.R., Reginato, R.J. Hatfield, J.L. 1981. Normalizing the stress-degree-day parameter for environmental variability. ***Agriculture Meteorology,*** 24: 45–55.

Jackson, R.D., Idso, R.B., Reginato, R.J. Pinter, P.J., 1981. Canopy temperature as a crop water stress indicator. ***Water Resource,*** 17: 1133–1138.

Jalali-Farahani, H.R., Slack, D.C., Kopec, D.M. Matthias, A.D. 1993. Crop water-stress index models for bermudagrass. ***Agronomy Journal***, 85: 1210–1217.

Monteith, J.L. Unsworth, M.H. 1990. Principles of Environmental Physics. Edward Arnold, London, pp. 243.

Orta, A.H., Baser, I., Sehirali, S., Erdem, T., Erdem, Y. 2004. Use of infrared thermometry for developing baseline equations and scheduling irrigation in wheat. ***Cereal Research***, 32: 363–370.

Panda, R.K., Behera, S.K. Kashyap, P.S. 2003. Effective management of irrigation water for wheat under stressed conditions. ***Agricultural Water Management***, 63: 37–56.

SAS, 2003. SAS for windows. V. 9.1. SAS Inst, Cary, USA.

Stokcle, C.O., Dugas, W.A. 1992. Evaluating canopy temperature-based indices for irrigation scheduling. ***Irrigation Science***, 13: 31–37.

Yuan, G., Luo, Y., Sun, X., Tang, D. 2004. Evaluation of a crop water stress index for detecting water stress in winter wheat in the North China Plain. ***Agricultural Water Management,*** 64: 29–40.

أثر إجهاد الجفاف على مؤشر الإجهاد المائي للمحاصيل ودرجة حرارة المحصول

طاهرة أراندوست* وإحسان بيجانزادة*

ملخص

اجريت تجربة حقلية لتقييم اثر إجهاد الجفاف على مؤشر الإجهاد المائى للمحاصيل (CWSI) ودرجة حرارة محصول فول الصويا فى عام 2013.تم تعريض ثلاثة أصناف مختلفة من فول الصويا وهى سناباد، وات–83–3، و إت–84–5 لأربع مستويات مختلفة من كميات الرى وهى كميات رى كافية خلال الموسم الزراعى كامل، كميات رى كافية من بداية الموسم الزراعى الى مرحلة الازهار، او مرحلة تطوير الحليب، اومرحلة تطوير العجين ثم قطع الري عن المحصول الى نهاية الموسم الزراعى. أظهرت النتائج أن حرارة المحصول لسنباد و إت–83–3 ارتفعت 6.31 و 6.89 درجة مئوية ، بينما فى إت–84–5 بلغ هذا الا رتفاع إلى 2.66 درجة مئوية فقط. لوحظ وجود قدر كبير من التباين فى مؤشر الإجهاد المائى للمحاصيل الشهري (0.18 إلى 0.91) لجميع الأصناف و جميع معاملات الري، وازداد ذلك عندما قطع الري فى مرحلة الازهارالى مرحلة تطوير الحليب. عند قطع الري فى مرحلة الازهار، فان إت–83–3 وصل مؤشر الإجهاد المائى للمحاصيل له لاعلى قيمة وهى 0.67 ، بينما فى إت–84–5 وصل إلى 0.50. أظهر الانحدار متعدد الحدود أنه مع انخفاض المياه المزودة، زاد مؤشر الإجهاد المائى للمحاصيل وزاد منحدر الانحدار من 353 لمعاملات نقص الري إلى 429 لمعاملات الري الكامل ($R2 = 0.85$). تم الحصول على أعلى محصول من الحبوب (476.2 جم / م 2) فى إت–84–5 لمعاملات الري الكامل مع مؤشر إجهاد مائى للمحاصيل لهذا الصنف تراوحت بين 0.18 إلى 0.33. من خلال خفض المياه المزودة (من الازهار إلى تطوير الحليب) وزيادة مؤشر الإجهاد المائى للمحاصيل، انخفض انتاج الحبوب وخاصة في سناباد و إت–83–3. عموما، إت–84–5 كان أفضل أداء عندما تتعرض للجفاف.

الكلمات الدالة: قطع الري، الإزهار، الجفاف.

* كلية الزراعة والموارد الطبيعية، جامعة شيراز، ايران.

تاريخ استلام البحث 2016/1/31 وتاريخ قبوله 2016/10/17.