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MANAGING YIELD AND YIELD ATTRIBUTES OF TRITICALE IN A DEFICIT IRRIGATION SYSTEM WITH METHANOL FOLIAR APPLICATION

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ABSTRACT. Triticale is mainly grown for feed grain and biomass production for thatching straw and general human use. A combined analysis with a factorial layout in the two years of 2016 and 2017 with five replications was used to evaluate the yield and yield components of triticale under different methanol concentrations and irrigation managements in Isfahan, Iran. Irrigation treatments consisted of irrigation on the basis of 70%, 80%, 90% and 100% crop water requirements, and methanol treatments as foliar application on the basis of 15% methanol concentration, 30% methanol concentration and control treatment (0%). Methanol application influence on one hundred grain weight was significant. The maximum plant height, number of tillers, Leaf area index (LAI), leaf area duration (LAD), one hundred grain weight, grain yield, biological yield, harvest index and protein content were achieved in irrigation on the basis of 100% crop water requirement. The maximum plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein were obtained in 2017. Foliar methanol application with 15% concentration obtained the maximum plant height, LAI, LAD, one hundred grain weight, biological yield, soil plant analytical development (SPAD) and protein percentage. The results of this experiment suggest that methanol can aid in alleviating the effects of drought stress on triticale in the climatic condition of Isfahan. It is concluded that triticale cultivars performed better in 2017, with 15% concentration of methanol application and irrigation on the basis of 100% crop water requirement.

Keywords: drought; agronomic traits; grain yield; LAI; LAD; SPAD.

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INTRODUCTION

Triticale is a man-made crop developed by crossing wheat (*Triticum turgidum* or *Triticum aestivum*) with rye (*Secale cereale*). Compared with wheat, triticale has superior characteristics, such as higher protein content (Kamyab *et al.,* 2009), less requirement for nitrogen fertilization and more tolerance to salinity and drought stresses (Moharrery *et al.,* 2015; Giunta *et al.,* 2017). Heidari *et al.* (2016) reported that triticale seems to be an alternative to other small grain cereals, particularly wheat and barley for cultivation under unfavourable conditions or in low-input agricultural systems. It has been reported that under drought stress conditions and problematic soil regions, triticale showed distinct yield superiority and had adaptive advantages over wheat (Lelley 2006; McKenzie *et al.,* 2014; Roques *et al.,* 2016). Agronomic traits such as grain yield and its components are the major selection criteria for evaluating drought tolerance under field conditions (Shahrajabian *et al.,* 2020). The closely linked yield components of LAI, leaf area duration (LAD) and SPAD (Chlorophyll index) with high grain yield have been reported for some crops, such as spring barley (Janušauskaitė and Auskalniene, 2014) and spring triticale (Janušauskaitė *et al.,* 2017). Many scholars have reported that SPAD measurements can be used as a single and rapid tool to detect and select stable and high yielding plants (Nakano *et al.,* 2010; Janušauskaitė *et al.,* 2017).

Methanol spray is a method that increases CO_2 fixation in plants and methanol may act as a carbon source for plants. Methanol is the simplest alcohol and can be produced through anaerobic metabolism by some bacteria. Furthermore, methanol is emitted from leaves of C_3 plants (Fall and Benson, 1996). In one study, plant biomass and SPAD chlorophyll content were increased by foliar spraying of soybean plant with 15% (v/v) methanol. The decline in intercellular CO_2 is a key factor limiting photosynthesis under drought stress conditions, and plant productivity may be promoted by increasing the availability of CO_2 in leaves through applying a carbon source. Consequently, foliar methanol application in arid and semi-arid regions may be useful in increasing productivity and plant growth. Foliar application of methanol under drought stress conditions at flowering stage may increase the growth and yield of safflower, whereas under fully watered conditions the application of lower doses of methanol may be more effective in yield improvement than use of higher dose. Passioura (1996) stated that foliar sprays of aqueous 1-50% methanol increased growth and development of C_3 crop plants in an arid environment. Most triticale cultivars have a high grain yield, but perform poorly with regard to biomass yield (Pronyk and Mazza, 2011). The application of water below the full crop water requirements is known as deficit irrigation, and it is one of the options for maintaining productivity (Farooq *et al.,* 2009; Shahrajabian *et* *al.,* 2020). Supplemental and managed irrigation, even in semi-arid and arid climates, is one of the crucial means, which guarantee stable and reliable yields. In the centre of Iran, because of limited rainfall, water shortage and stress, major loss in crop productivity occurs.

The aim of this study was to see how methanol application and irrigation management affected triticale yield and yield components in Iran's semi-arid region.

MATERIALS AND METHODS

Two-year experiments were conducted at the agricultural research farm of the Faculty of Agriculture, Islamic Azad University, Isfahan (Khorasgan) Branch, Isfahan, Iran (Longitude 51°40' E, latitude 32°39' N, and elevation 1570 m) in order to investigate the influence of different methanol concentrations and irrigation, a combined analysis with a factorial layout in the two years of 2016 and 2017 with five replications was conducted. Irrigation treatments consisted of irrigation on the basis of 70%, 80%, 90% and 100% crop water requirements, and methanol foliar treatments were 15%, 30% methanol concentration (v/v) and control treatment (0%). On the basis of soil analysis, the organic carbon was 1.2% and 1.0% at depth of 0-30 cm and 30-60 cm, respectively; moreover, at both depths soil texture was clay (*Table 1*). Mean temperature changes from 22nd October to 23rd October at the Isfahan experimental field in 2016 is shown in *Table 2*. Moldboard ploughing was used to prepare the soil, which was then disked and smoothed with a land leveller. Autumn triticale (ET-84-8) was sown at a density of 400 viable seeds per m^2 by trained workers on Oct 23rd. On the basis of soil analysis, nitrogen fertilizer was used from urea source (80 kg N ha^{-1}). Half of the nitrogen was added to the soil during the pre-sowing cultivation process and the remaining nitrogen fertilizer was applied at the tillering stage of the triticale. Each plot (10 m^{-2}) had six rows with a 17.5 cm spacing between them. The crop was harvested at the stage of full maturity, and grain yield was measured and adjusted at 14% moisture. Weed control, diseases and pest management were carried out in accordance with the crop development as required. At the tillering stage, foliar therapies were applied. A foliar application was not applied to the control plots. Chlorophyll index (SPAD, soil plant analysis development) was measured by using a chlorophyll meter (Minolta SPAD 502). A portable meter was used to take measurements from the middle of the leaf blade just before harvesting. Before harvest, the primary shoot height was measured with a ruler. Plants were harvested at physiological maturity, oven-dried at 72°C, and after that yield and yield components including grain yield and one hundred grain weight (g) were determined. Leaf area was measured by leaf area meter (Delta T Device, UK). LAD was measured using the following formula (Janušauskaitė *et al.,* 2017):

$$LAD = \frac{L1+L2}{2(T1-T2)}$$

where, L1 and L2 are the first and second measurements of green leaf area, and T1 and T2 represent the time of the first and second measurements. The separated grain weight and harvest index (HI) (%) were calculated according to the following formula:

$$HI\ (\%) = \frac{\text{Grain yield}}{\text{Biological}} \times 100$$

Kjeldahl analysis was used to determine the amount of nitrogen in dry and ground samples (Bremner and Breitenbeck, 1984), and then nitrogen was multiplied by 6.26 to determine protein content. After collection of data related to the measured properties, variance analysis was done by SAS statistical software.

RESULTS

The influence of year was not significant on any experimental characteristics except for LAD. Irrigation treatment has significant effects on plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein, but SPAD was not significantly affected by irrigation treatment. Among all experimental characteristics, just one hundred grain weight was influenced by methanol concentration, while no significant influence of methanol concentrations on other experimental characteristics was found. The analysis of variance showed that the effect of interactions between irrigation × year, and also irrigation × methanol on LAD and grain yield was statistically significant. Aside from LAD and one hundred grain weight, no experimental characteristics were influenced by interaction between methanol and year (*Table 3*). The maximum value for plant height, number of tillers and LAI related to 2017, followed by 2016. Moreover, no significant differences were found between treatments. The maximum and minimum LAD were achieved in 2017 and 2016, respectively; a significant difference was found between 2016 and 2017. In 2017, the highest grain yield (517.36 g/m^{-2}), biological yield (1813.39 g/m^{-2}) and harvest index (0.29) were obtained. No meaningful differences were found between 2016 and 2017. On the one side, the highest value for SPAD was obtained for 2016 (46.03), and for protein in 2017 (13.53%); on the other side, no significant differences were found between treatments (*Table 4*). The maximum plant height, number of tillers and LAI were obtained for irrigation on the basis of 100% of crop water requirement, followed by irrigation on the basis of 90% of crop water requirement. Irrigation on the basis of 100% of crop water requirement had no significant differences from irrigation on the basis of 90% of crop water requirement.

The maximum number of LAD, one hundred grain weight (6.03 g), grain yield, biological yield and harvest index (0.31%) were related to irrigation on the basis of 100% of crop water requirement. Although, the highest number of harvest index was achieved in irrigation on the basis of 100% of crop water requirement, followed by 90%, 80% and 70%, but no significant differences were found between treatments. The maximum value for SPAD was related to irrigation on the basis of 90% of crop water requirement (46.58). Moreover, it only had a significant difference with irrigation on the basis of 70% of crop water requirement. The protein percentage of triticale differed between various irrigation treatments.

Table 1 - Soil analysis of the agriculture research field in Isfahan (0-30 cm)

Depth (cm)	EC (dS/m)	pH	$CaCO_3$	Organic carbon (%)	Nitrogen (ppm)	Available P (ppm)	Available K (ppm)	Sand %	Silt %	Clay %	Soil texture
0-30	2.5	7.8	35	1.2	0.12	15.6	400	11	41	48	Clay
30-60	2.43	7.9	38	1.0	0.10	10.2	380	11	37	52	Clay

Table 2 - Mean temperature changes from 22nd October to 23rd October at the Isfahan experimental field in 2016

Month	Mean maximum temperature (°C)	Mean minimum temperature (°C)	Mean monthly temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Monthly rainfall (mm)
23rd Oct-23rd Nov	16.15	5.31	10.73	24.00	-3.18	11.70
23rd Nov-23rd Dec	10.62	-2.01	4.30	18.12	-8.23	5.80
23rd Jan-23rd Feb	9.76	-3.93	2.92	15.26	-8.67	1.00
23rd Feb-23rd Mar	9.72	0.97	5.35	16.64	-6.99	18.00
23rd Mar-23rd Apr	17.54	2.80	10.17	23.30	-3.42	35.50
23rdh Apr-23rd May	17.86	5.26	11.56	23.00	-0.43	26.72
23rd May-23rd June	23.46	10.12	16.79	29.94	2.90	26.70
23rd June-23rd July	31.64	15.18	23.41	35.00	12.05	0.21
23rd July-23rdAug	35.62	16.65	26.14	36.40	15.00	0

Table 3 - Analysis of variance for the experimental characteristics

S.O.V.	df.	Plant height	No. tillers	LAI	LAD	100 grain	Grain yield	Biological yield	HI	SPAD	Protein
Year	1	3.125^{ns}	0.429^{ns}	0.0001^{ns}	0.046*	2.219^{ns}	10829.013^{ns}	92306.722^{ns}	0.0005^{ns}	170.786^{ns}	26.257^{ns}
Block*Year	4	387.541	0.783	0.501	0.004	0.620	17943.930	80801.611	0.007	107.450	25.995
a	3	2943.717*	16.129**	6.674**	0.216**	16.452**	297893.532**	1877382.167**	0.0118^{ns}	199.061^{ns}	57.082*
a* Year	3	116.236^{ns}	1.404^{ns}	0.742^{ns}	0.010*	0.777^{ns}	48642.088*	111051.426^{ns}	0.005^{ns}	108.967^{ns}	12.982^{ns}
block*a(Year)	12	917.449	0.772	0.552	0.002	4.037	9168.560	80196.852	0.005	53.606	5.829
b	2	1148.791^{ns}	0.211^{ns}	0.729^{ns}	0.001^{ns}	21.079**	14355.680^{ns}	198968.167^{ns}	0.006^{ns}	26.523^{ns}	24.344^{ns}
a*b	6	1303.606^{ns}	1.327^{ns}	0.376^{ns}	0.009*	0.434^{ns}	21913.421*	163750.500^{ns}	0.009^{ns}	48.530^{ns}	16.290^{ns}
b* Year	2	688.041^{ns}	0.334^{ns}	0.577^{ns}	0.020*	6.028*	4817.180^{ns}	318124.389^{ns}	0.004^{ns}	105.575^{ns}	0.482^{ns}
a*b* Year	6	513.930^{ns}	0.275^{ns}	0.843*	0.005^{ns}	1.470^{ns}	11428.810^{ns}	208549.537^{ns}	0.003^{ns}	98.210^{ns}	22.047^{ns}
Error	32	640.951	1.214	0.344	0.003	1.433	9007.153	132085.56	0.007	170.786	10.242

* significant at 0.05 significance in F-tests, ** significant at 0.001 in F-tests, ^{ns} non-significant.
A= Irrigation on the basis of Crop Water Requirement; B = Methanol

Table 4 - Mean comparison for experimental characteristics in different years

Year	Plant height (cm)	Number of tillers	LAI	LAD	100 grain weight (g)	Grain yield (g/m^{-2})	Biological yield (g/m^{-2})	HI	SPAD	Protein (%)
2016	100.33a	4.41a	3.24a	0.45b	4.71a	492.83a	1741.78a	0.28a	46.03a	12.32a
2017	100.75a	4.57a	3.25a	0.50a	5.06a	517.36a	1813.39a	0.29a	42.95a	13.53a

Common letters within each column do not differ significantly.

Table 5 - Mean comparison for experimental characteristics on the basis of crop water requirements

Irrigation treatment	Plant height (cm)	Number of tillers	LAI	LAD	100 grain weight (g)	Grain yield (g/m^{-2})	Biological yield (g/m^{-2})	HI	SPAD	Protein (%)
%70	84.77b	3.10b	2.37c	0.31b	3.93b	327.61c	1346.1c	0.25a	39.55b	10.63b
%80	95.66ab	4.69a	3.29b	0.52a	4.28b	500.94b	1713.8b	0.30a	45.54ab	12.43a
%90	109.77a	5.07a	3.58ab	0.53a	5.29a	567.33a	2023.3a	0.28a	46.58a	14.04a
%100	112.00a	5.09a	3.72a	0.55a	6.03a	624.50a	2027.2a	0.31a	46.30ab	14.59a

Common letters within each column do not differ significantly.

Table 6 - Mean comparison for experimental characteristics on the basis of different methanol concentrations

Methanol concentrations (%)	Plant height (cm)	Number of tillers	LAI	LAD	100 grain weight (g)	Grain yield (g/m^{-2})	Biological yield (g/m^{-2})	HI	SPAD	Protein (%)
0	94.33a	4.58a	3.05a	0.47a	4.72b	531.25a	1782.3a	0.30a	43.79a	11.81a
15	108.00a	4.50a	3.39a	0.49a	5.89a	501.25a	1866.2a	0.27a	43.99a	13.78a
30	99.29a	4.39a	3.29a	0.47a	4.04b	482.79a	1684.3a	0.28a	45.70a	13.18a

Common letters within each column do not differ significantly

The maximum and minimum protein percentages were related to irrigation on the basis of 100% of crop water requirement (14.59%) and irrigation on the basis of 70% of crop water requirement (10.63%), which had no significant differences with each other (*Table 5*).

DISCUSSION

Water stress is the major limiting factor in crop production in the world. Yield is the principle selection index used under drought stress conditions. Like the results of this experiment, the influence of the weather conditions in different years on grain yield has been confirmed by studies on other cereals (Gonzalez *et al.,* 2010). The maximum values of plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein content were achieved in irrigation on the basis of 100% crop water requirement. The result of this research is in agreement with Nakano *et al.* (2010). Reduction in plant height under drought stress was reported by Guttieri *et al.* (2001) and Denčić *et al.* (2000). Leaf extension can be limited under water stress conditions in order to get a balance between the water status of plant tissues and the water absorbed by plant roots (Passioura, 1996). Reduced plant height as the result of water deficit is a general response of plants to reduced water availability. Gonzales *et al.* (2010) also reported that water deficit and drought stress may delay development of plants, leading to plant height reduction.

Guttieri *et al.* (2001) also observed that moisture deficit induced reduction in 100-grain yield of wheat due to reduction in the number of grains per spike. Plant growth occurs by cell elongation and cell division, which are very sensitive to drought stress. Cell elongation is inhibited by a reduction in turgor pressure resulting from water deficiency. Water deficit also impairs cell division. Thereby, disruption of cell elongation and division can explain the observed reduction in plant height and growth. Ahmadi and Joudi (2007) and Krcek *et al.* (2008) also reported that grain yield is reduced depending on the degree of water deficit. The improvement of HI leads to more efficient redistribution of dry matter into grain and in turn increases grain yield. HI can be used as an indirect selection criterion for improving grain yield in cereals under moisture stress conditions (Fayaz and Arzani 2011; Shahrajabian *et al.*, 2011).

In agreement with the results of this experiment, Ahmed (2011) observed that the SPAD chlorophyll index was lower in their experiments under water deficit stress. The highest plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein was obtained in 2017. Foliar methanol application with 15% concentration had obtained the highest plant height, LAI, LAD, one hundred grain weight, biological yield, SPAD and protein percentage. Leaf area index (LAI) is a good indicator of crop state and is closely linked to other crop and soil variables, such as biomass, grain yield, nutrition status and crop nitrogen uptake (Janušauskaitė *et al.*, 2017). Significant reaction of safflower to methanol concentration in limited irrigation management indicated that the deleterious effects of drought stress can be alleviated by methanol application, to increase CO_2 concentration.

Nakano *et al.* (2010) ascertained that grain yield of wheat was significantly and positively correlated with the LAI and SPAD. In this experiment, triticale positively responded to methanol concentration in limited irrigation management. As a consequence, treating triticale with methanol can promote net photosynthesis leading to improved yield. Ling *et al.* (2011) mentioned that leaf chlorophyll content is an important indicator of physiological status in plants, and the variation in leaf chlorophyll content is considered to be a plant response to environmental stress. Furthermore, Rowe *et al.* (1994) reported that foliar spraying of methanol increased growth and yield of various C_3 plants. The yield increase caused by the applied measures can be explained by a better management of the irrigation of the plants, which found an important result in enhanced tillering, grain yield and one hundred grain weight. Gowda *et al.* (2011) also have recently reported that grain yield, plant height, spikes per square metre and thousand-kernel weight are key variables that allowed the prediction of early biomass yield. The results of this experiment suggest that methanol can aid in alleviating the effects of drought stress on triticale in the climatic condition of Isfahan. It is concluded that triticale cultivars performed better in 2017, with 15% concentration of methanol application and irrigation on the basis of 100% crop water requirement.

CONCLUSION

Water stress is the major limiting factor in crop production in the world. Yield is the principle selection index used under drought stress conditions. The highest values of plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein content were achieved in irrigation on the basis of 100% crop water requirement. Plant growth occurs by cell elongation and cell division, which are very sensitive to drought stress. Cell elongation is inhibited by a reduction in turgor pressure resulting from water deficiency. Water deficit also impairs cell division. Thereby, disruption of cell elongation and division can explain the observed reduction in plant height and growth. The highest plant height, number of tillers, LAI, LAD, one hundred grain weight, grain yield, biological yield, harvest index and protein was obtained in 2017. Foliar methanol application with 15% concentration obtained the highest plant height, LAI, LAD, one hundred grain weight, biological yield, SPAD and protein percentage. Significant reaction of triticale to methanol concentration in limited irrigation management indicated that the deleterious effects of drought stress can be alleviated by methanol application, to increase CO_2 concentration. The yield increase caused by the applied measures can be explained by a better management of irrigation of the plants, which found an important result in enhanced tillering, grain yield and one hundred grain weight.

The results of this experiment suggest that methanol can aid in alleviating the effects of drought stress on triticale in the climatic condition of Isfahan. It is concluded that triticale cultivars performed better in 2017, with 15% concentration of methanol application and irrigation on the basis of 100% crop water requirement.

REFERENCES

Ahmadi A. & Joudi M.J. (2007). Effects of timing and defoliation intensity on growth, yield and gas exchange rate of wheat grown under well-watered and drought conditions. *Pak.J.Biol. Sci.,* 10(21): 3794-3800, DOI: 10.39 23/pjbs.2007.3794.3800

Ahmed, S.U. (1970). Effects of soil water deficit on leaf nitrogen, chlorophylls and spad chlorphyll meter reading on growth stages of soybean. *Bangladesh J.Bot.,* 40(2): 171-175, DOI: 10.3329/bjb.v40i2.9773

Bremner, J.M. & Breitenbeck, G.A. (1983). A simple method for determination of ammonium in semimicro-Kjeldahl analysis of soils and plant materials using a block digester. *Comm. Soil Sci. Plant Anal.,* 14(10): 905-913. DOI: 10.10 80/00103628309367418

Denčić, S., Kastori, R., Kobiljski, B. & Duggan, B. (2000). Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. *Euphytica*, 113(1): 43-52. DOI: 10.1023/a:1003997700865

Fall, R. & Benson, A.A. (1996). Leaf methanol - the simplest natural product from plants. *Trends Plant Sci.,* 1(9): 296-301, DOI: 10.1016/s1360-1385(96)88175-0

Farooq, M., Wahid, A., Kobayashi, N., Fujita, D. & Basra, S.M.A. (2009). Plant drought stress: effects, mechanisms and management. *Agron.Sustain.Dev.,* 29(1): 185-212, DOI: 10.1051/agro:2008021

Giunta, F., Motzo, R., Virdis, A. & Cabigliera, A. (2017). The effects of forage removal on biomass and grain yield of intermediate and spring triticales. *Field Crops Res.,* 200: 47-57, DOI: 10.1016/j.fcr.2016. 10.002

González, A., Bermejo, V. & Gimeno, B.S. (2010). Effect of different physiological traits on grain yield in barley grown under irrigated and terminal water deficit conditions. *J.Agric.Sci.,* 148(3): 319-328, DOI: 10.1017/s0021859610000031

Gowda, M., Hahn, V., Reif, J.C., Longin, C.F.H., Alheit, K. & Maurer, H.P. (2011). Potential for simultaneous improvement of grain and biomass yield in Central European winter triticale germplasm. *Field Crops Res.,* 121(1): 153-157, DOI: 10.101 6/j.fcr.2010.12.003

Guttieri, M.J., Stark, J.C., O'Brien, K. & Souza, E. (2001). Relative sensitivity of spring wheat grain yield and quality parameters to moisture deficit. *Crop Sci.,* 41(2) : 327-335, DOI: 10.2135/cropsci2001.412327x

Heidari, B., Latifi, M., Dadkhodaie, A. & Shariatipour, N. (2016). Selection of salt-tolerant triticale (X triticosecale Wittmack) and genetic variation assay for agronomic and physiological traits. *International Journal of Plant & Soil Science,* 12(1): 1-13, DOI: 10.9734/ijpss/20 16/27098

Janušauskaitė, D. & Auškalnienė, O. (2014). Photosynthetic traits of spring barley throughout development stages under field conditions. *Comm. Soil Sci. Plant Anal.*, 45(3): 284-296, DOI: 10.1080/ 00103624.2013.861910

Janušauskaitė, D., Feiziene, D. & Feiza, V. (2017). Relationship between spring triticale physiological traits and productivity changes as affected by different N rates. *Acta Agric. Scand. B Soil Plant Sci.*, 67(6): 534-541, DOI: 10.1080/09064710.201 7.1308545

Krček, M., Slamka, P., Olšovská, K., Brestič, M. & Benčíková, M. (2008). Reduction of drought stress effect in spring barley (*Hordeum vulgare* L.) by nitrogen fertilization. *Plant Soil Environ.,* 54(1): 7-13, DOI: 10.17221/2781-pse

Lelley, T. (2006). Triticale. *Genetic Resources Chromosome Engineering & Crop Improvement*, 395-430, DOI: 10.1201/978020348 9260.ch13

Ling, Q., Huang, W. & Jarvis, P. (2010). Use of a SPAD-502 meter to measure leaf chlorophyll concentration in *Arabidopsis thaliana*. *Photosynth.Res.,* 107(2): 209-214, DOI: 10.1007/s11120-010-9606-0

McKenzie, R.H., Bremer, E., Middleton, A.B., Beres, B., Yoder, C., Hietamaa, C., …& Henriquez, B. (2014). Agronomic practices for bioethanol production from spring triticale in Alberta. *Can.J. Plant Sci.*, 94(1): 15-22, DOI: 10.4141/cjps20 13-112

Nakano, H., Morita, S., Kusuda, O. & Sasaki, Y. (2010). Leaf blade dry weight and leaf area index × SPAD value at anthesis can be used to estimate nitrogen application rate at anthesis required to obtain target protein content of grain in bread wheat. *Plant Prod.Sci.,* 13(3): 297-306, DOI: 10.1626/pps.13.297

Passioura, J.B. (1996). Drought and drought tolerance. *Drought Tolerance in Higher Plants: Genetical, Physiological and Molecular Biological Analysis*, 1-5, DOI: 10.100 7/978-94-017-1299-6_1

Pronyk, C. & Mazza, G. (2011). Optimization of processing conditions for the fractionation of triticale straw using pressurized low polarity water. *Bioresour.Technol.,* 102(2): 2016-2025, DOI: 10.1016/ j.biortech.2010.09.064

Roques, S.E., Kindred, D.R. & Clarke, S. (2016). Triticale out-performs wheat on range of UK soils with a similar nitrogen requirement. *J.Agric.Sci.,* 155(2): 261-281, DOI: 10.1017/s0 021859616000356

Rowe, R.N., Farr, D.J. & Richards, B.A.J. (1994). Effects of foliar and root applications of methanol or ethanol on the growth of tomato plants (*Lycopersicon esculentum* Mill). *New Zeal. J. Crop Hort.,* 22(3): 335-337. DOI: 10.1080/01140671.19 94.9513842

Saadpanah, A., Rokhzadi, A. & Mohammadi, K. (2013). Growth response of soybean to the application of *Bradyrhizobium japonicum* and foliar methanol spraying in field conditions. *Int.J.Biosci.,* 3(4): 128-134. DOI: 10.12692/ijb/3.4.128-134

Shahrajabian, M.H., Soleymani, A. & Naranjani, L. (2011). Grain yield and forage characteristics of forage sorghum under different plant densities and nitrogen levels in second cropping after barley in Isfahan, Iran. *Res.Crop.,* 12(1): 68-78.

Shahrajabian, M.H., Sun, W. & Cheng, Q. (2020). Traditional herbal medicine for the prevention and treatment of cold and Ffu in the autumn of 2020, overlapped with COVID-19. *Nat. Prod.Commun.,* 15(8): 1934578X20 95143. DOI: 10.1177/1934578x2095 1431

Shahrajabian, M.H., Sun, W. & Cheng, Q. (2020). Chinese star anise (*Illicium verum*) and pyrethrum (*Chrysanthemum cinerariifolium*) as natural alternatives for organic farming and health care - a review. *Aust. J. Crop Sci.,* 14(03): 517-523, DOI: 10.21475/ajcs.20.14.03.p2209