DOI: 10.1515/cerce-2016-0032
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

Cercetări Agronomice în Moldova
Vol. XLIX , No. 4 (168) / 2016: 15-26

THE EFFECT OF IRRIGATION INTERVALS SCHEDULING AND NITROGEN AND ZINC CONTENT ON WHEAT YIELD AND YIELD COMPONENTS IN DROUGHT STRESS

N. PARSAI[1], F. VAZIN[1,]*, M. HASSANZADEH[1]

*E-mail: farshidvazin@gmail.com

Received June 30, 2016. Revised: Sept. 27, 2016. Accepted: Nov. 29, 2016. Published online: Feb. 13, 2017

ABSTRACT. In order to evaluate the effect of irrigation interval on yield and quantitative-qualitative characteristics of bread wheat, splited plot experiment in randomized block with four replications in the 2010-11 crop years was conducted in the research field of Islamic Azad University of Gonabad. A number of 7, 9 and 10 days irrigation treatments formed the main factors of test, and spraying and non-spraying of nitrogen and zinc were considered as subfactor of test. The results showed that the effect of irrigation was significant for the number of grains per spike in the level of 5% and on 1000-grain weight and fat percent at the level of 1%, and had no significant effect on grain yield, biological yield, number of spikes/sq m stem height, stem diameter and protein content. Nitrogen treatment was significant at the level of 5% on biological yield and number of spikes/sq m, but had no significant effect on grain yield, number of grains per spike, 1000-grain weight, stem height, fat and protein percent, and stem diameter. Treatment with zinc was statistically significant in probability level of 1% only on percentage of fat and had no significant effect on grain yield, biological yield, grain numbers per spike, weight of 1000 seeds, spikes/sq m, stem height, protein percent and stem diameter. Seven days irrigation with of nitrogen allocated for highest seed yield (265.38 g/m²/sq m) and biological yield (659.33 g/m²/sq m). Means comparison showed the highest 1000-grain weight was obtained from 7 days irrigation (47.10 g) and the lowest from 13 days irrigation (40.44 g). According to the experiment results, 7 days irrigation was recognized as the best irrigation to achieve maximum economic performance and 13 days irrigation were determined as most appropriate irrigation for maximum performance for the region due to lack of water and weather conditions of Gonabad, spraying zinc and nitrogen to improve production was proposed depending on different irrigation and the purpose of production.

Keywords: nutrients; sprying; wheat; irrigation.

[1] Islamic Azad University,Gonabad Branch,Gonabad, Iran

INTRODUCTION

Wheat was the world's oldest and most widely used crop and most important source of human's food that grows in wide range of world's weather conditions and has largest distribution in the world (Asadi and Hammett, 1998). Generally, cereal production in large areas of the world is limited each year by lack of water, also in Iran, cultivated fields of wheat forms half of cultivated land of country, that this lands contains 36% of irrigated land and 64% of the drylands. A proper irrigation planning results in optimum use of limited water resources. The morphological, physiological and biochemical reactions of plants to water shortages depends upon a variety of factors, including stress, during periods of stress and growth stages of plants (Asadi and Hammett, 1998). According to surveys conducted by Hagan *et al.* (1967), heavy and excessive watering causing delays in the production and harvest time and, thereby, will be followed by reduced grains yield.

Kang *et al.* (2002) in their experiment showed that reactions of grain yield and water use efficiency of wheat varieties were different significantly with respect to irrigation regimes, that this is due to the amount of soil moisture and irrigation scheduling.

The results obtained by Ahmadi and Siose Marde (2004), moisture stress created in spike emergence step 20 days after flowering, decreased seed yield cultivars of Chamran, M-75-7, Alvand and Tajan 2, 8, 22 and 34%, respectively.

Between drought stress and protein content in grain during the early stages of grain filling a significant positive relationship was reported by various researchers (Johnson *et al.*, 1972). Drought stress could enhance the value of some economic performance components, such as amount of protein (Guttieri *et al.,* 2000). Gooding *et al.* (2003) stated that increased grain protein content in moisture stress, that applied before seed ripening, is due to the lower effect of stress on nitrogen harvest index, compared with dry matter harvest index.

In other researches it was found that in effect of moisture stress in grain filling stage, although moisture stress reduced dry matter yield and protein content per plant, but grain protein percent increased under severe drought conditions and no irrigation in grain filling stage (Tahmaseby and Jenner, 1991).

Nitrogen is a key factor in achieving optimum performance in cereals. Normally wheat in the course of its development has a great need to absorbable nitrogen. Increase in nitrogen use, increase the leaf area, tilering, leaf area index and leaf area durability, and this increase leads to production further dry matter and grain yield (Banziger *et al.,* 1944).

Increasing nitrogen causes expansion and voluminous of roots, and absorption more moisture from the soil. In addition, the increase of nitrogen promotes the chlorophylly growth, increasing the volume of aerial part of plant and increase the crop evapotranspiration (Read *et al.,* 1982). Also, there are significant correlation between available water and nitrogen, because increased nitrogen leads to further development of wheat roots and increased available water in the root zone, resulting in reduced moisture stress. But if there is not enough water, increased nitrogen fertilizer application increases the moisture stress of plant and therefore reduced crop yield and water use efficiency (Huang *et al.,* 2003). On the other hand use of high amounts of nitrogen reduces nitrogen uptake by plant and decreases nitrogen use efficiency (grain yield per unit of nitrogen fertilizer) (Limon-Ortega *et al.,* 2000; Sowers *et al.,* 1994).

Also, inappropriate and abundant use of nitrogen fertilizers increases crop cost and the risk of groundwater contamination, therefore, methods must be applied to increase plant yield while preventing environmental pollution (Ellis *et al.,* 2000; Sharpe *et al.,* 1988). Also, use of nitrogen usually has no effect on amount of water consumed by plants, unless added nitrogen to the soil has a significant effect on increasing leaf surface. Research (Sowers *et al*., 1994) showed that the evapotranspiration of winter wheat was not affected by N levels, but grain yield, plant aerial parts weight and water use efficiency increased by increasing the amount of nitrogen.

In order to achieve maximum yield per unit area, widespread use of common chemical fertilizers, such as nitrogen and phosphorus and lack of micronutrients lead to micronutrients, such as zinc (Zn) down dramatically in most wheat fields, while that plant has an extreme sensitivity to zinc deficiency (Brenna., 1992).

Bansal *et al.* (1990) reported that zinc deficiency in plants is widespread, which contains about 30% of lands under cultivation in worlds. Zinc deficiency directly leaves and indirectly an adverse effect on human and animal health, so that, according to Welch *et al. (*1999), about 40% of people worldwide suffer from micronutrient elements deficiency. And high consumption of cereals containing low zinc in the diet is main reason zinc deficiency in humans.

Tandon (1995) has reported an increase in wheat yield due to consumption of 540, 780 and 860 kg of zinc, iron and manganese per hectare, respectively, compared with no consumption of them. Cakmak *et al*. (1997) observed that wheat grain yield is increased significantly by consumption of 23 kg fertilizer contains zinc. Bansal *et al.* (1990) reported a significant correlation between the amounts of zinc in soil and grain. Marschner (1993) believes that taking zinc, in addition to increased performance, by rising protein and zinc concentration in the grain, can be effective in relieving zinc deficiency in humans.

Mohamad *et al.* (1990) also reported that the application of zinc in different ways can increase concentrations of this element in grain and enrich the wheat. In summary, the most important goals that followed by this research, in addition to evaluate the effect of irrigation intervals on yield and quality, is to determine the optimal irrigation intervals for province, more economic yield for farmers and increase production performance of province. So that every farmer will be able to use most desirable irrigation intervals, according to the available irrigation water in his possession.

MATERIAL AND METHODS

This study was carried out in crop year 2011 in the research field of Islamic Azad University, Gonabad (34°2' north, 58°40' east and 1056 m above sea level) by use of bright wheat cultivar. 30-year average meteorological statistics in Gonabad show that average annual rainfall was 142 mm, the average annual temperature equal to 19.5°C and the relative humidity 39.2% annually. Based on chemical analysis, soil has no salinity and alkalinity limit, carbon is low and soluble phosphorus and potash is in average level.

Surface soil texture is clay loam, average moisture of soil profile to a depth of 30 cm at field agronomic capacity (FC) and permanent wilting point (PWP) are 25 and 12 wt %, respectively, and mean bulk density (BD) is equal to 1.5 g/m^3.

Test was conducted in a split-factorial randomized block design with three replications. Treatments consisted of three levels of increasing irrigation intervals (7, 10 and 13 days), foliar of nitrogen in two levels (no foliar, foliar of nitrogen) and foliar of zinc in two levels (non-foliar, zinc foliar).

Land preparation was done a week before the planting by plow, disc, leveler and implementation the map of project. Each plot consists of six planting lines with 4 m length and row spacing from each other by 25 cm. Based on the physico-chemical analysis of the soil before conducting the experiment, the amount of required nitrogen 100 kg/ha was recommended and zinc was 1.4 mg in the soil.

Cluster planting (three seeds in each pit at a depth of 3 to 5 cm of soil surface) with a distance of 15 cm between plants on the row in early October was done by hand. In this experiment, the foliar of zinc from zinc sulfate source with ratio of 3 per 1000 and foliar nitrogen from urea source at a ratio 5 per 1000 in two phases (stem elongation stage and spike appearance), respectively on 2010/2/24 and 2011/4/14 were performed. After measuring the yield and yield components (number of grains per spike, spikes per unit area, 1000-grain weight, biological yield, grain yield), also plant height, stem diameter, measuring percentage of fat by Soxhlet method and protein content by Kjeldahl set was performed .

RESULTS AND DISCUSSION

The number of grains per spike

Analysis of the data showed that changing irrigation interval had a significant effect on the number of grains per spike in the level of 5% (*Table 1*). Means comparison showed that the highest number of grains per spike is related to irrigation intervals treatment of 10 days, with 32.15 grains per spike and the lowest number of grains per spike grain is 27.8 by belated irrigation, means irrigation 13 days (*Table 1*).

Research has shown that stress during flowering and pollination induces infertility pollen (Guttieri *et al.,* 2000) and the disruption of current photosynthesis and assimilates translocation and store in grains, which can be a reason of reduced grains. Drought stress also reduces the transfer of nutrients from leaves to grains and due to weather conditions accelerate the ripening seeds in dry area.

In irrigation 7, days since the plants have more water and produce more carbohydrates, the grains have been larger and 1000-grain weight has increased, but the number of grains per spike was reduced, also plants have fewer spikes. In 13 days irrigation, due to low production of carbohydrate, the 1000-grain weight and number of grains per spike was reduced but the number of spike in plants was high. In 10 days, irrigation plants produce more grains per spike and 1000-grain weight and spike per plant was lower. Ziaeian and Malakoti (1998) also found that the highest number of grains per spike was in spike treatment without stress.

Table 1 - Means effects on irrigation intervals, nitrogen and zinc on yield components of wheat

Treatment	GY	BY (g m^{-2})	GN (g)	1000 GW	SN	FP (%)
Irrigation						
I_{7d}	210.84a	519.3a	29.01b	47.10a	199.33a	2.00b
I_{10d}	220.86a	530.5a	32.15a	43.82b	212.42a	166.b
I_{13d}	210.90a	553.2a	27.80b	40.44c	247.25a	3.25a
N rate						
N_0	198.76a	487.17b	29.34a	43.26a	198.44b	2.11a
N_1	229.64a	581.50a	29.96a	44.31a	240.89a	2.50a
Zn rate						
Zn_0	211.73a	549.50a	29.04a	43.36a	225.39a	1.44b
Zn_1	216.67a	519.17a	30.26a	44.21a	213.94a	3.16a
Irrigation	ns	ns	*	**	ns	**
N	ns	*	ns	ns	*	ns
Zn	ns	ns	ns	ns	ns	**
IxN	*	**	ns	ns	ns	*
IxZn	ns	ns	ns	ns	ns	**
NxZn	ns	ns	ns	ns	ns	ns
IxNxZn	ns	ns	ns	ns	ns	**

[1]Significant effects are denoted as: ns, *, **, non significant or significant at P ≤ 0.05, 0.01, respectively.

I_{7d}: irrigation per 7 day, I_{10d}: irrigation per 10 day, I_{13d}: irrigation per 13 day. Zn_0: Without Zn, Zn_1: With Zn, N_0: Without N, N_1: With N, GY: Grain yield, BY: Biological yield, GN: Number of grain in spike, 1000 GW: 1000 grain-weight, SN: Number of spike in m^2, FP: Fat percent

1000-grain weight

Analysis of variance showed a significant effect of irrigation changing on 1000-grain weight in 1% probability level (*Table 1*). Just as means comparison showed the highest grains weight was from early on treatment, 7 days irrigation with 47.10 g, and the lowest 1000-grain weight related to irrigation intervals treatments 13 days (delay in carrying out irrigation) with 40.44 g (*Table 1*). This implies that drought stress by reducing the grain filling period decreased 1000- grain weight.

It seems that with increasing irrigation intervals and reducing soil moisture in the reproductive stages the grain filling period has been decreased and, therefore, reduced grain weight. According to the results of research it can be concluded that delay of irrigation has more of influence on 1000-grain weight than nitrogen and zinc application. As it seems, 7 days irrigation produced more 1000-grain weight. The results of this study corresponded to other researchers (Ozturk and Aydin, 2004).

Fat percentage

Analysis of variance showed that changing irrigation interval has significant effect on fat percent of grains in 1% probability level (*Table 1*). Means comparison showed that the highest fat percent of grains obtained from delayed irrigation treatment (13 days irrigation interval) equal to 3.25% and lowest fat percentage was from in 10 days irrigation treatments with 1.66% (*Table 1*). It seems that the fat percentage is more under the influence of delay phase in irrigation that soil moisture has been less. Because as was mentioned, the lowest number of grains obtained from 13 days irrigation interval treatments (stress treatment). In addition, although the number of grains per spike was low, the lowest 1000-grain weight refers to the 13 days irrigation intervals. Therefore, in weather conditions of Gonabad that associate with warm and dry air. In addition to increasing irrigation intervals tensions that exacerbated conditions for transfer of stored materials, food shortages also increased fat percent.

The results revealed a significant effect of zinc application in 1% surface on fat percent (*Table 1*). Means comparison showed that the use of zinc produced 3.16 fat percent grains, that are more than non-application of zinc with 1.44% fat percent (*Table 1*). It seems that by improving the process of nutrition in plant increased grain quality can be expected. Emam *et al.* (2007) showed that the grain yield and fat percentage finds a significant increase by taking 5 mg of zinc in 1 kg of soil for each plant. Also, other studies have confirmed this finding.

Biological yield

Analysis of data showed that nitrogen application has significant effects on biological yield in 5% probability level (*Table 1*). Averages showed that nitrogen application with 581.5 g/sq m had biological yield more than treatment non-nitrogen application with 487.17 g/sq m. With nitrogen foliar application, biological yield increased at a rate of 19.4% (*Table 1*).

It seems that nitrogen increases photosynthesis efficiency and enhance biological yield by impact on the rate of photosynthesis. Other studies have also reported significant positive effect of nitrogen on biological yield (Sanjari and Yazdansepas, 2008). Since that application of nitrogen fertilizer is effective on biochemical reactions, photosynthesis, increased period of growth and more dry matter accumulation in aerial parts and grain yield components, its impact on biological function seems obvious.

The number of spikes per square meter

Application of nitrogen at 5% level had a significant effect on the number of spikes per square meter. Means comparison showed that the highest number of spikes per square meter related to nitrogen application treatment with 240.89 spikes/sq m and the lowest amount obtained by non-use nitrogen treatment with 198.44 spikes/sq m. It seems that due to sufficient moisture and nitrogen application in usual amount as well as the climatic conditions of the region in terms of appropriate light intensity and temperature, all these factors increases the number of tillers and the number of spikes per/sq m. The results were consistent with the findings of other researchers (Bulman and Smith, 1993).

Hashemi Dezfouli (1998) and Marschner (1993) stated that nitrogen application in crops is responsible for increases in density of tillers and there is a positive correlation between the number of tillers and grain yield. And by increasing nitrogen the number of spikes per unit area was increased and there is significant differences between grain yield at different levels of nitrogen fertilizer. Also, with increasing plant density, number of spikes per unit area was increased.

Grain yield

The results of data analysis showed that the grain yield on the level of 5% being influenced by interaction between irrigation interval and nitrogen stress (*Table 1*). So, that nitrogen application treatment in early irrigation (watering every 7 days) with 265.38 g/sq m gain the highest grain yield, and by taking same statistical level the non-nitrogen application treatment in early irrigation (watering every 7 days) with 156.29 g/sq m assign lowest grain yield to their self (*Table 1*).

Data analysis showed that despite the fact that irrigation treatment had no significant effect on grain yield, but the number of spikes per plant, the number of grains per spike and 1000-grain weight was significantly affected by irrigation treatment. It seems that in irrigation every 7 days (watering early) 1000-grain weight get further from irrigation every 10 days (irrigation without stress) and watering every 13 days (irrigation with a delay). As a result of this interpretation, each of yield components (1000-grain weight, number of spikes per plant, number of grains per spike) in changing irrigation interval treatments (every 7 days-every 10 days-every 13 days) by neutralizing each other cause grain yield get not significant.

In 7 days irrigation, treatment once increase in nitrogen amount inhances the grain yield while in other two treatments nitrogen have no positive impact due to drought stress. In this way that nitrogen application in optimum irrigation treatment increases yield and biological yield by 41% and 42%, respectively. But nitrogen application did not affect in other two levels of irrigation treatment. In 7 day irrigation and nitrogen application, since plant growth is high and produced photosynthetic material consumed the accumulation of photosynthesis material in plants is low and plant does not consume a lot of energy, therefore highest yield was related to this treatment. But in 7 days irrigation that photosynthetic material accumulation was high and due to lack of nitrogen plant growth was under normal conditions, ultimately reduces grain yield due to the deceleration of assimilate translocation from the source (photosynthetic parts of plants) into the tank (grain).

Biological yield

Biological yield in 1% probability level affected by interaction between irrigation intervals and nitrogen (*Table 1*). Means comparison showed that most biological yield achived by nitrogen application under early irrigation treatment conditions (irrigation intervals 7 days) with 659.33 g/sq m. And the lowest one was observed non- nitrogen application treatment in early irrigation conditions (irrigation intervals 7 days) with 379.33 g/sq m (*Table 1*). It seems that under prematurely irrigation conditions due to increasing the efficiency of photosynthesis, dry matter production is more and also existence of sufficient food contributed to this trend and increase the biomass yield (Chart 2). In 7 days irrigation, since we have lowest number of spikes per plant and the number of tillers is low, as a result fewer straw produced and biological yield is lower. But, in this 7 days irrigation, that in comparison with other treatments more water is available for plants when we applied nitrogen increased stem diameter and more resistance to lodging was observed, as a result straw weight was increased and plant had greater biological yield. Fowler (2003) reported that under suitable irrigation the use of nitrogen increases the resistance to lodging.

Fat percentage

Analysis of variance showed that change irrigation intervals and nitrogen interactions have significant effect on fat percent of grains in 5% probability level (*Table 1*). So, that treatment of non-use of nitrogen under 13 days irrigation conditions (delay in irrigation), and nitrogen application under 13 days irrigation conditions treatments (delay in irrigation) with 3.5 and 3 fat percent, respectively, by situating in the same statistical level produced the highest percentage of fat. The treatment of lack of nitrogen application in conditions of early irrigation (watering 7 days) produces lowest grain fat, 1.33% (*Table 1*). This implies that the fat content was more affected by irrigation intervals, and this treatment with increased irrigation intervals greater affected the efficiency of photosynthesis and fat content than nitrogen and zinc treatments.

In lack of nitrogen application, the prolonging watering interval increases grain fat percentage, but at the time of nitrogen application availability of water had no significant effect on this trait. Comparison of means indicated that the largest percentage of fat grain (5%) is related to zinc application with 13 days irrigation intervals treatments (delay in irrigation) and the second value (2.83%) was in zinc application under 7 days irrigation conditions (early watering) and the lowest value (1.16%) obtained from lack of zinc application under 7 days irrigation conditions treatment (watering early).

The highest grain fat content (5%) occurred in application zinc treatment and irrigation with longest intervals. In other treatment, combination fat content were varied between 1 and 2.8%.

It is clear that although reduction of grain filling period will reduce the amount of fat, but in this case the plant poor nutrition is also important in terms of zinc application, so that zinc application under longer intervals irrigation can increase potential of grain fat production.

Based on the analysis of data grain fat significantly affected by trilateral interaction of irrigation intervals variation, nitrogen and zinc application in 1% statistical level (*Table 1*). So, that the highest percentage of grain fat were related to lack of nitrogen application in presence of zinc application treatment with 13 day irrigation (watering delayed) and treatments without nitrogen application in the presence of zinc application under 10 days irrigation (the common irrigation interval in region) as well as treatments without nitrogen application and non-application of zinc with 7 days irrigation conditions (early watering) and 13 days irrigation (delay in irrigation) with 1% fat content had the lowest percentage of fat in the treatments of this scheme. On this basis we can say that the delay in irrigation and soil moisture reduction with zinc application increase percentage of fat and reduce quality.

As a result, adequate nutrition in situations that grain filling period is short can increases grain protein content and enhances the quality of wheat grain. The highest fat content obtained from zinc application in longest interval irrigation treatment and without nitrogen application. But, in general, simultaneously zinc and nitrogen application treatments at all three levels of irrigation had high fat content.

CONCLUSIONS

The results show that irrigation scheduling is one of most important tools for optimizing water consumption. Increasing irrigation intervals reduced 1000-grain weight and number of grains per spike about 18 and 15%, respectively, compared to control treatment. The use of nitrogen foliar application, compared with control treatment increased grain yield from 198.76 to 229.64 g/ sq m and biological yield from 487.17 to 581.50 g/ sq m. It also increases the number of spikes/sq m from 198.44 to 240.89.

Use of foliar application, compared with control treatment, increased fat percentage from 1.44 to 3.16 and number of spikes from 213.94 to 225.39 spikes/sq m. The foliar application of zinc increased grain yield and 1000-grain weight. Use of nitrogen foliar application in 7 days irrigation in grain filling stage increased grain yield by as much as 65%, compared to non-nitrogen foliar application in the same irrigation treatment. And the use of both elements at the same time had the highest grain yield. Drought stress in two phase of plant growth reduces grain yield. Fertilizers and micronutrients have a crucial role in increasing agronomic crop yields, so that by adding these elements in condition of increasing irrigation intervals, that in fact we are faced with reduced yield and under a proper management and planning decline in yield can be compensated.

REFERENCES

Asadi, A., & Hammett, A. (1998). Effects of different tillage methods on irrigated wheat crop and comparison their performance parameters. Final research report of Agricultural Engineering Research Institute, No. 106.

Ahmadi, A., & Siose Marde, A. (2004). Effects of drought stress on soluble carbohydrates, chlorophyll and proline in four wheat cultivars Compatible with different climatic condition in Iran. *Iranian Journal of Agricultural Science*, 35(3), 753-763.

Bansal, R.L., Takkar, P.N., Bhandari, A.I., & Rana, D.S. (1990). Critical levels of DTPA extractable Zn for wheat in alkaline soils of semiarid region of Punjab, India. *Fertil. Res.* 21(3): 163-166.

Banziger, M., Feil B., & Stamp P. (1994). Competition between nitrogen accumulative and grain growth for carbohydrates during grain filling of wheat. *Crop Sci.*, 34: 440-446.

Brenna, R.F. (1992). The effect of zinc fertilizer on take-all and the grain yield of wheat grown on zinc-deficient soil of the Esperance region, Westem Australia. *Fertil. Res*., 31(2): 215-219.

Bulman, P., & Smith, D.L.. (1993). Yield and yield component response of spring barley to fertilizer nitrogen. *Agron. J.,* 85:226-231.

Çakmak, I., Ekis, H., Yilmaz, A., Torun, B., Köleli, N., Gültekin, I., Alkan, A., & Eker, S. (1997). Differential response of rye, triticale, bread and durum wheats to zinc deficiency in calcareous soils. *Plant Soil,* 188(1): 1-10.

Emam, Y., Ranjbar, A.M., & Bahrani, M.J. (2007). Evaluation of yield and yield components in wheat genotypes under post-anthesis drought stress. *J. Sci. Techn. Agric. Natur. Resour.,* 11, 1(B): 221-232.

Ellis, E.C., Li, R.G., Yang, L.Z., & Cheng, X. (2000). Changes in village-scale nitrogen storage in China's Tai lake region. *Ecol. Appl.,* 10(4): 1074-1089.

Fowler, D.B. (2003). Crop nitrogen demand and grain protein concentration of spring and winter wheat. *Agron. J.,* 95:260-265.

Gooding, M.J., Ellis, R.H., Shewry, P.R. & Schofield, J.D. (2003). Effects of restricted water availability and increased temperature on grain filling, drying and quality of winter wheat. *J. Cereal Sci.,* 37: 295-309.

Guttieri, M.J., Ahmad, R., Stark, J.C. & Souza, E. (2000). End-use quality of six hard red spring wheat cultivars at different irrigation levels. *Crop Sci.,* 40: 631-635.

Hagan, R.M., Howard, R.H., & Talcoh, W.E. (1967). Irrigation lands. *Am. Soc. Agron.* U.S.A., 680-681.

Hashemi-Dezfouli, A., Kochaki, A., & Vytayan, D. (1998). Increase crop yield. Mashhad University Press (translation).

Huang, M., Dang, T., Gallichand, J., & Goulet, M. (2003). Effect of increased fertilizer applications to wheat crop on soil-water depletion in the Loess Plateau, China. *Agr. Water Manage*., 58: 267-278.

Johnson, J.A., Khan, M.N.A. & Sanchez, C.R.S. (1972). Wheat cultivars, environment and bread-baking quality. *Cereal Sci. Today,* 17: 323-326.

Kang, S.Z., Zhang, L., Liang, Y.L., Hu, X.T., Cai, H., & Gu, B.J. (2002). Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess Plateau of China, *Agr. Water Manage.,* 55: 203-216.

Limon-Ortega, A., Sayer, K.D., & Francis, C.A. (2000). Wheat nitrogen use efficiency in a bed planting system in northwest Mexico. *Agron. J.*, 92: 303-308.

Marschner, H. (1993). *Mineral nutrition of higher plants.* 2nd ed., Academic Press, London, UK.

Mohamad, W., Igbal, M., & Shal, S.M. (1990). Effect of mode of application to zinc and iron on yield of wheat. *Sarhad J. Agric.,* 6:6, 615-618.

Ozturk, A., & F. Aydin, F. (2004) Effects of water stress at various growth stages on some quality characteristics of winter wheat. *J. Agron. Crop Sci.,* 190:93-98.

Read, D.W.L., Wander, F.G., & Cameron, D.R. (1982). Factors affecting fertilizer nitrogen response of wheat in southwestern Saskatchewan. *Can. J. Soil Sci.,* 62: 577-588.

Sanjari, P.A., & Yazdansepas, A.(2008). Mobilization of dry matter and its relation with drought stress in wheat genotypes. *J. Agric. Sci. Technol.,* 11(2): 121-129.

Sharpe, R.R, Harper, L.A., Giddens, J.E., & Langdale, G.W. (1988). Nitrogen use efficiency and nitrogen budget for conservation tilled wheat. *Soil Sci. Soc. Am. J.*, 52: 1394-1398.

Sowers, K.E., Pan, W.L., Miller, B.C., & Smith, J.L. (1994). Nitrogen use efficiency of split nitrogen applications in soft white winter wheat. *Agron. J.*, 86: 942-948.

Tahmasebi, Z., & Jenner, S.A. (1991). Drought stress (moisture) and transfer of nitrogen and dry matter of aerial parts of wheat in grain filling stage, Abstracts of articles in *Fourth Agronomy and Plants Breeding Science Congress of Iran*, 264-265.

Tandon, H.L.S. (1995). Micronutrients in soils, crop and fertilizers: a source book cum directory, 1-138. *Fertilizer Development and Consultation Organization*, New Delhi, India.

Welch, R.M., Allaway, W.H., House, W.A., & Kubota, J. (1999). Geographic distribution of trace element problems. *In:* J.J. Mortvedt *et al.* (Eds.) *Micronutrients in Agriculture*, 2nd ed., *Soil Sci. Soc. Am.,* Madison. WI.

Ziaeian, A., & Malakoti, M.J. (1998). Effect of micronutrient application and application time on increasing yield. *Soil and Water*, 2(1): 56-62 (in Farsi).