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Grain N, P, K Concentrations in Wheat as Affected By Potassium and Zinc Sulfate Fertilization to Cope with Drought Conditions

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Abstract

This study has been performed to determine Grain N, P, K concentrations in wheat as affected by potassium and zinc sulfate fertilization to cope with drought conditions in Zahak agricultural research station, at weather condition of Sistan's area. Experimental design was for two years (2005-2007) with three replications. The water stress included: three irrigation treatments (I1, I2 and I3 are irrigation after 50, 70 and 90% soil water depletion (SWD), respectively), three level of potassium sulfate intake fertilizer (K0, K1 and K2 are Control, 150 and 250 Kg/ha, respectively) and three level of zinc sulfate intake (Z0, Z1 and Z2 are Control, 50 and 80 Kg/ha, respectively). The results showed that the grain N concentrations are not affected by water stress, but, decreased with an increase in potassium consumption. Also, zinc consumption increased the grain N concentration. Increasing zinc consumption caused an increase in N consumption in case of moisture availability (irrigation after 50% soil water depletion). Moreover, the grain phosphorus concentration declined with an increase in zinc consumption, but enhanced by potassium increase of the soil around the roots and hard stress conditions (irrigation after 50% soil water depletion). In this study, continued soil available water depletion up to 90% soil water depletion associated with increased potassium consumption resulted in improved potassium concentration of the grain.

Keywords: Grain wheat; water stress; potassium sulfate; zinc; N concentration.

1. Introduction

Wheat is the most widely used staple food grain of the world. Wheat is also a very important internationally traded commodity [69]. Mineral concentrations in wheat grain are dependent on the interaction of a number of factors including weather conditions, soil type, fertilizer management, and genotype [50, 62]. Crop fertilizer response is strongly associated with water availability in semi-arid conditions [14]. Many tropical and temperate soils are not able to provide enough potassium for crops [17]. K play important role in improvement of the growthindices. Increasing K amount in wheat grain increased dry matter, 1000-grain weigh and proteincontents and grain yield [16]. Potassium fertilizers also increasedcrop quality, plant nutrition, and increased protein content [70]. Potassiumapplication also significantly helped uptake of N andP in straw as well as wheat grain [59]. The interaction between N and K had positive significanteffects on grain yield and quality [65].Potassium is a macronutrient element which is required for higherconcentration for the growth of plants. It playsan important role in the activation of enzyme,stomata opening and closing, tropisms, photosynthesis [21]. It helps tomaintain the osmotic adjustment more than Na+ and Cl- in the plants under salineconditions [4, 32]. Alsoapplication of potassium showed a positive effect on Zinc (Zn) is an important micronutrient in biological systemsand is receiving growing attention worldwide because of increasingreports about Zn deficiencies in human populations and crop plants[2, 14, 30]. Zinc deficiencyis considered one of the top five micronutrient deficiencies inhumans and is conservatively estimated to negatively affect nearly1/3 of the world's populations [30, 63].

Water scarcity increases potassium concentration in wheat grain rather than full irrigation. There is a positive correlation between lack of water and grain nitrogen content in a way that its rate inclines due to

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dryness [45]. In addition, increase wheat protein has been reported by Malakouti and Saghebi (1999) to increase up to 14.33% with the application of zinc and potassium sulfate fertilizers [39]. Nitrogen is a major component of protein, with approximately 17% of protein being composed of N. [49]. During grain filling, starch synthesis is initiated prior to protein deposition. Therefore application of N after a thesis may have a greater influence on protein accumulation than starch accumulation [62, 72].Application of potassium showed a positive effect on thousand kernel weight (TKW) and enhanced the assimilation and remobilization of other elements like nitrogen and phosphorus [15]. Researchers have found a positive effect of zinc on the increase of protein percentage in grains[7, 49]. Hussein and Faiyad (1996) were found with zinc application of 60 Kg/ha, grain nitrogen concentration increased from 1.2 in the control treatment to 2%. Reports indicate that irrigation management has different effects on wheat flour nitrogen through tillering to pollination stages [29]. However, along with increasing irrigation, wheat grain protein content inclines [25]. In other study, zinc application (10 Kg/ha) reduced phosphorus in a way that the grain phosphorus concentration declined from 0.44 to 0.38% in the control treatment [58], indicating plant phosphorus and zinc interactions [41]. In another experiment, phosphorus/zinc ratio decreased from 150.41 in the control group to 70 in the 10 Kg/ha treatment [57]. Also wheat balanced phosphorus/zinc ratio has been reported to be 50 [44].

Karimian (1995) found that by increasing zinc concentration of wheat grain, its potassium concentration decreases, but its nitrogen and phosphorus concentrations increase [31]. The study further revealed that zinc application has no effects on total phosphorus concentration and absorption in corn. A close relationship between P and N concentrations in theshoot biomass has been reported inmaize [75], timothy[8], and spring wheat [74]. In a report a critical grain N concentration of 12.6 mg N g−1 DM was determinedin maize by using the relationship between grain yield andgrain N concentration [35].Also in cereal crops, criticalgrain P concentrations ranging from 1.3 to 3.9 mg P g−1 DM wasdetermined by using the relationship between relative grain yieldand grain P concentration [7, 9, 28, 53]. Also reported thegrain P concentration tended to decrease with increasing N concentration [1].

This investigation aimed to assess the Grain N, P, K concentrations in wheat arid area using zinc and potassium sulfate fertilizers to cope with drought conditions during two cropping seasons.

2. Material and Methods

This study was conducted to effects of potassium and zinc in conditions of the water stress on quantitative characteristics of Hamoun wheat cultivars in the Zahak Research Station located 25 kilometers southeast of the city of Zabol (30° 53' 38" N, 61° 40' 49" E) with an altitude of483 meters above sea level. The average annual rainfall of the area is 55 mm, and the annual evaporation rate is 4000 to 5000 mm. Average annual rainfall in the area is 55 mm, the mean annual temperature is 22.6 C° and the average relative humidity is 38%. According to the classification Domarten and Ambrgeh with indices of 1.68 and 12.9, respectively, the area is classified as extra dry and hot desert. Soil andwater characteristics arepresented in Tables 1 and 2.

Table 1. Characteristics of top 30 Cm of soil at experimental sites

Depth (Cm)	Ec (ds/m)	pH	OC (%)	P(A.V)	K (A.V)	Fe	Cu	Zn	Mn
			(ppm)						
0-30	2.1	8.1	0.54	3.2	140	6.8	0.92	0.5	16.2

Table 2. Water chemical characteristics at experimental sites

Ec (ds/m)	pH	HCO3	CO3	Mg+Ca	Cl	Na
		(meq/lit)				
0.9	8.2	4.4	0	5.6	3	3.2

Experimental design was a split plot arrangement based on a randomized complete block design with three replications with three irrigation treatments (I1, I2 and I3 are irrigation after 50, 70 and

90% soil water depletion (SWD), respectively), three level of potassium sulfate intake fertilizer (K0, K1 and K2 are Control, 150 and 250 Kg/ha, respectively) and three level of zinc sulfate intake (Z0, Z1 and Z2 are Control, 50 and 80 Kg/ha, respectively). Application of chemical fertilizer was performed based on soil analysis. The size of the main plots were 12 m2 (5×2.4 m), including 12 planting lines with 20 cm distance for each sort, and 2.5 m length in each main treatment, and also there was 3.5 m distance between replications in which the areas of sideway plots. All fertilizers were applied to the soil before planting. Irrigation was provided from river water around the station, and measurement of needed water in each test plot was done by a volumetric flow. To determine the depth of the required water for irrigation, before each irrigation procedure, soil samples were extracted from 0-50 Cm depth of every test plots, and in this way the amount of the humidity weight was evaluated. Then, based on the humidity percentage before irrigation, the maximum development of plant's root and the soil physical parameters, the amount of irrigation water was measured by the following formula (1), and this formula was used untilreaching the desired depth to the field capacity (FC).

(1)

$$d = \frac{(FC - W) \times (\rho b \times D)}{100}$$

Where, FC and W are the moisture contents (based on weights) corresponding to the field capacity and Soil moisture before watering (gr/gr), respectively, ρb is the soil bulk density (gr/Cm3) and D is the soil-root depth (mm). The performed calculation during two years (2006-2007) of the experiment consisted of height of the plant, grain yield, water use efficiency (WUE) and the biologic yield.

Total nitrogen concentration was determined using modified Kjeldahl method [14], phosphorus measured, after dry ashing, through the Vanadad-molybdate method [48] and potassium concentration was determined using flame photometer method [5].

3. Results and Discussion

3.1. Grain K concentration

The effect of year on Grain potassium concentration was not significant and the effect of irrigation treatments was significant (P < 0.01) (Table 3).

Table 3. Results of ANOVA on the effects of year (Y), treatment irrigation (A), potassium fertilizer (B) and zinc fertilizer (C) on K, N and P Concentration in grain wheat

S.O.V	df	MS		
		Concentration (%)		
		K	N	P
Year	1	0.00ns	0.004ns	0.00ns
A	2	0.023**	0.007ns	0.001ns
Year×A	2	0.001ns	0.001ns	0.001ns
B	2	0.007*	0.24*	0.002ns
Year×B	2	0.00ns	0.001ns	0.00ns
A×B	4	0.01**	0.27**	0.008**
Year×A×B	4	0.001ns	0.00ns	0.00ns
C	2	0.01**	0.19**	0.007**
Year×C	2	0.00ns	0.002ns	0.001ns
A×C	4	0.003ns	0.19**	0.002ns
B×C	4	0.012**	0.28**	0.003ns
A×B×C	8	0.005ns	018**	0.002ns

*- F values and significance levels (**P < 0.01, *P < 0.05 and nsP ≥ 0.05).

Furthermore, a biennial average potassium concentration of the grain demonstrated that potassium concentration enhances by increasing stress and prolonged irrigation in such a way that the grain potassium concentration inclined to 7.32% in the irrigation after 90% soil water depletion treatment (I3) compared to non-stressed conditions (irrigation after 50% soil water depletion (I1)) (Figure 1A). The reasons for increased potassium concentration with increasing stress [45] were related to dilution effects and the grain yield reduced in these treatments [51, 52].

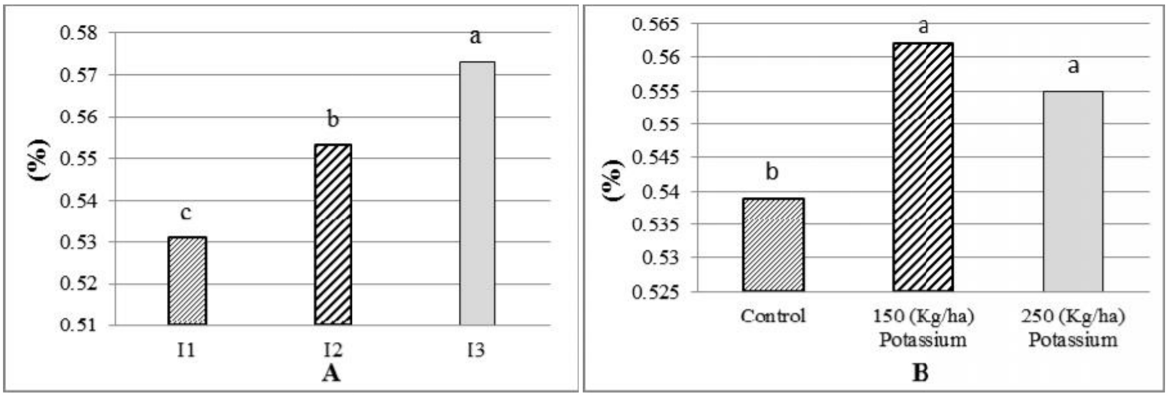
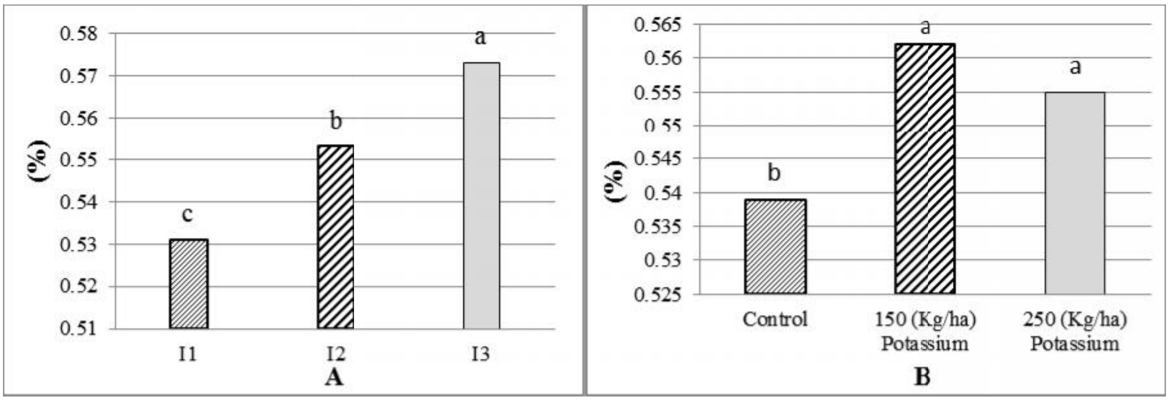


Figure 1. The effect of irrigation treatments (A) and levels of potassium sulfate intake fertilizer (B) on grain K concentration.

The effect of potassium sulfate intake was significant (P < 0.05) on grain K concentration (Table 3). Maximum amount of the grain potassium concentration (0.562%) was found with the application of 150 kg/ha potassium (K1) (Figure 1B), which did not create a significant difference from the rate of K2 treatment. Enhancement of the grain potassium concentration has been reported to be caused by increasing potassium chloride consumption [57]. Regarding area texture which is often clay minerals of type (ILLITE), potassium ions are stabilized in crystal textures of clay and prevent releasing of potassium and its absorption by plant roots that continued use of potassium fertilizer leads to saturation of the colloids and the remaining is absorbed by plant root [52]. However, excessive consumption of this element led to its stability and subsequent decline of adsorption in K2 treatment [47].

Lack of proper placement of potassium fertilizers has been reported to be the reason for lack of or low plant response to their applications [10, 67, 68]. According to the results obtained by the researchers, surface distribution of potassium fertilizers can lower their efficiency. Interactive effects of irrigation treatments in levels of potassium were significant (P < 0.01) (Table 3). The highest potassium concentration was obtained in irrigation stress conditions (I3) and K2 treatment (Figure 2A).



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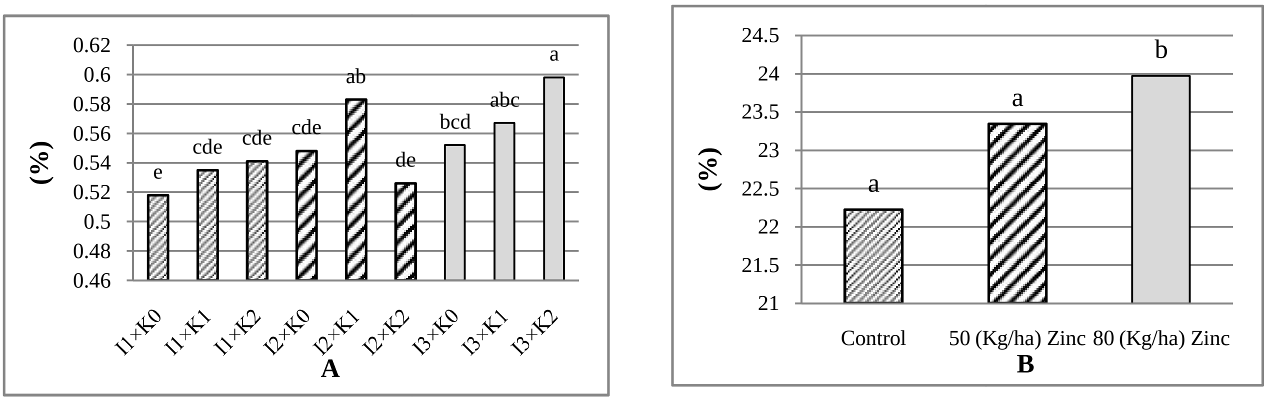

Figure 2. Interactive effects of irrigation treatments in levels of potassium (A) and levels of Zinc sulfate intake fertilizer (B) on grain K concentration.

Potassium can have a direct relationship with significant soil water stress and reduction under the influence of its concentration gradient even with the presence of high levels of soil potassium since plant release mechanism is important in its adsorption [41]. It is by this mechanism potassium movesfrom the area of higher concentration to that of the lower concentration under the influence of concentration gradient [64]. Also the effect of zinc sulfate intake was significant ($P < 0.05$) (Table 3). Zinc sulfate increases grain potassium concentration (Figure 2B). Zinc (Zn) is an essential nutrient element for plants and plays role in photosynthesis,[71] and photosynthesis enhances absorption of these elements from soil [31, 58].

The highest (0.584%) and lowest (0.524%) values of the grain potassium concentrations were obtained by Zn0 and K1 treatments and Zn1 treatment without potassium consumption, respectively (Figure 3A). The results [3, 58] were indicative of insignificant interactive effects of zinc and potassium on potassium concentration of wheat grain.

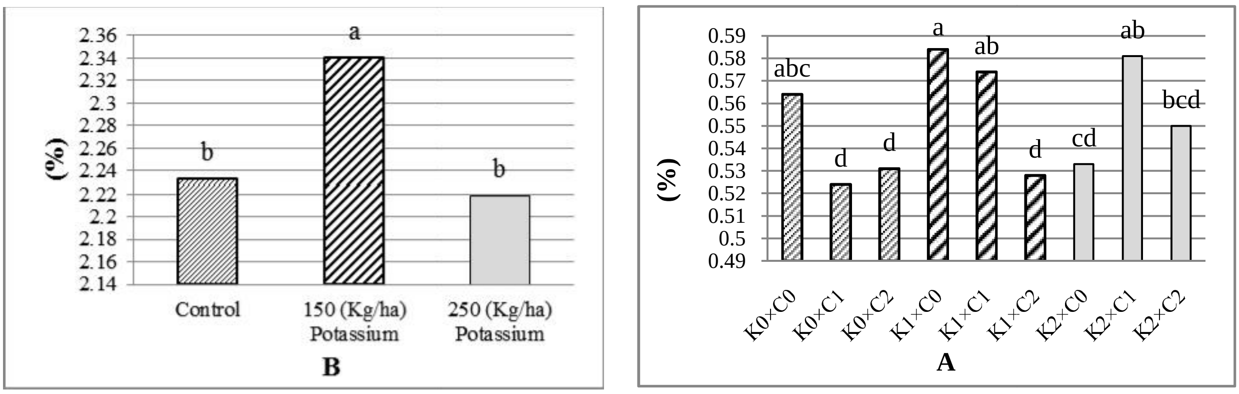

Figure 3. Interactive effects of zinc treatments in levels of potassium (A) on grain K concentration and levels of potassium sulfate intake fertilizer (B) on grain N concentration.

3.2. Grain N concentration

Increasing consumption of potassium K1 treatment compared to that of the control group enhanced the grain N concentration to its maximum amount [39], while high consumption of potassium K2 treatment reduced it to its minimum amount (2.218%), however, it falls in the same statistical group as the treatment group based on the grain N concentration level with no significant difference (Figure 3B). This has been caused by potassium absorption by ILLITE clay minerals due to high potassium concentrations of the soil [47]. Increasing potassium consumption in the absence of stress conditions (I1) generally led to an increase in the grain N concentration; however, this increment in K2 treatment was not significant (Table 3) compared to that of the control group. Accordingly, with increasing stress intensity and potassium consumption, the grain N concentration decreased compared to that of the control group (Figure 4A). Similar results are reportedby Lopez-Bellido et al (2001) and Flagella et al (2010) [19, 36].

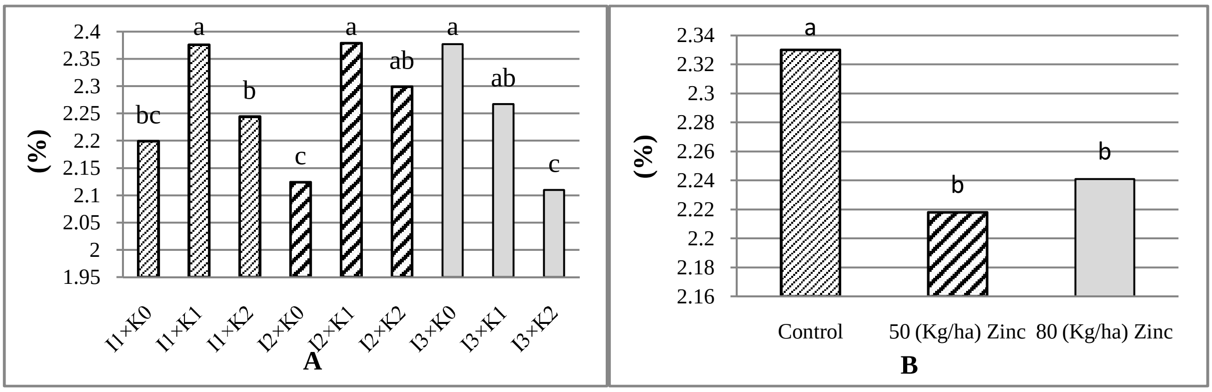

Figure 4. Interactive effects of irrigation treatments in levels of potassium (A) and levels of zinc sulfate intake fertilizer on grain N concentration.

In the treatment of maximum stress (I3), N concentrations declined to 4.63% and 11.23% by an incline in potassium consumption (K1 and K2) compared to the control group, respectively. Also the increment of N concentration at drought stress has been reported by [26]. Generally, wheat grain N concentration enhances with moderate increase in potassium consumption in non-water stress conditions, however, in case of excessive potassium consumption even under adequate humidity Conditions, grain N concentration takes a negative gradient [24, 55]. Additionally, the grain N concentration increased by the enhancement of zinc consumption compared to the control group. However, no significant difference was found between treatments 50Kg/ha (Zn1) and 80Kg/ha (Zn2) (Figure 4B). Several researchers have reported on the increase of grain nitrogen due to zinc consumption [6, 12, 31, 33, 34, 39, 41, 44, 48].

Generally, under zinc deficiency conditions, RNA polymerase enzymatic activities and transport of amino acids into seeds decrease, while RNA degradation increases, as a result of which protein synthesis reduces drastically [27, 45]. The application of zinc of these problems can be avoided [13, 45, 61, 62 73]. The reason for the incline of nitrogen absorption has been known to be related to zinc consumption due to the increment of shoot dry weight [23].

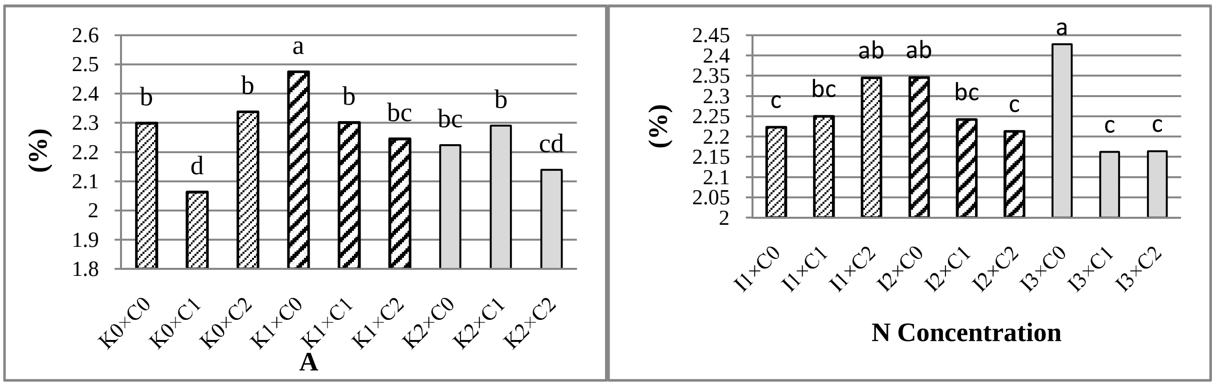

Figure 5. Interactive effects of zinc treatments in levels of potassium (A) and interactive effects of irrigation treatments in levels of zinc (B) on grain N concentration.

Also, in an experiment conducted on the use of zinc sulfate, wheat grain protein content has been observed to be increased from 10.6% to 14% [60]. In our research, the grain N concentration was found to decrease from 50 to 80 kg/ha with increasing zinc consumption in both potassium treatments (K1 and K2) (Figure 5A). The highest and lowest values of the grain N concentration were achieved by K1 and Zn0

(2.475%), and Zn1 and K0 (2.063%), respectively. This is due to the dilution effect caused by enhanced grain performance and the effect of potassium consumption on the increase of Nadsorption and transfer to the grain [51, 52] Moreover, the grain N concentration incremented only in non-water stress conditions created by increasing zinc consumption compared to that of the control group (Figure 5B). Generally, wheat grain N concentration decrease in the treatments of stress (I2 and I3) by an incline in zinc consumption (Z1 and Z2) compared to the control group.

3.3. Grain P concentration

The effect of zinc sulfate intake and interactive effects of irrigation treatments in levels of potassium were significant ($P < 0.01$) on grain P concentration (Table 3). An increase in Zn consumption causes wheat grain phosphorus concentration to reduce to 0.440% (Figure 6A). Maximum reduction of 0.420% happened in Zn2 treatment. Nevertheless, based on the effects on the grain P concentration, Zn2 and Zn1 treatments lay in the same statistical group with no significant differences. Decreased grain P concentration with increasing zinc has also been reported by Savabeghi et al (2003) and Savabeghi and Malakouti (2000) [57, 58].

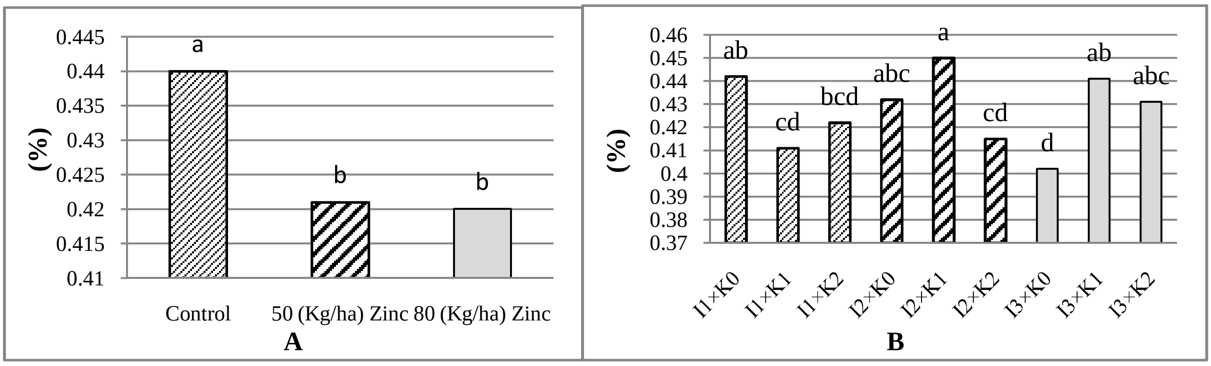

Figure 6. Effect of zinc sulfate intake fertilizer (A) and interactive effects of irrigation treatments in levels of potassium (B) on grain P concentration.

Also, Schwartz et al (1987) observed that zinc application causes reduced phosphorus concentration in barley [59], indicating negative interaction of zinc and the plant phosphorus content [17, 20, 22]. The interaction occurs in absorption and transport phases in the soil for plant physiological use [30, 40]. With zinc fertilizer, grain phytic acid content and thus phytic acid/zinc ratio decrease. Phytic acid ($C6H18O24P6$) is the storage form of grain organic phosphorus, the amount of which is influenced by environmental and plant factors such as plant nutrition [57, 66]. Research results Masoni et al (2007), reveal that wheat phosphorus and nitrogen concentrations decline gradually with time [42]. An optimal level of phosphorus per soil has been identified to be 30 to 50 mg/kg [5]. Yet, Karimian 1995, no significant effect of zinc on phosphorus in corn was observed [31]. Also, Alfoldi et al. 1994, reported thegrain P concentration tended to decrease with increasing N concentration [1].

In case of not being exposed to limited moisture conditions (I1), grain phosphorus concentration enhances by increasing potassium consumption. With this condition, reductions of the grain phosphorus concentrations for each of K1 and K2 treatments were obtained to be 7.01 and 4.52% compared to the control group, respectively (Figure 6B). Accordingly, increasing stress intensity (of I1 to I2) and potassium consumption (K1) enhanced the grain P concentration to its highest value. This result is compatible with Daly Aissa and Mhiri (2002) [15]. Also, Maleki et al. 2011, reported at drought stress the level of P was raised as compared to control [40].Water deficit during seed development increased grain protein, P, N and micronutrient concentrations except for Fe [26]. Still, this increment was not significant in K1 and K2. In this study, the lowest value of 0.402% was achieved for the grain phosphorus concentration with increasing severity of SWD (I3) without potassium consumption.

4. Conclusions

Enhanced potassium concentration in the soil and reduced soil moisture induced by depletion treatment (90% of soil available water) increased the grain potassium due to proper ventilation, leading to incline of the grain N concentration; however, potassium increase to 250 kg/ha decreased this concentration. Moreover, zinc sulfate consumption of up to 50 kg/ha caused enhancement of potassium transfer to the grain and subsequent increase in its potassium concentration. Nonetheless, the interactive effects of zinc and potassium reduced the grain N concentration. Accordingly, the grain phosphorus concentration decreased due to increased zinc consumption. Furthermore, inclined soil potassium did not enhance the grain phosphorus concentration in sufficient soil moisture conditions (50% depletion of soil available water). However, severe stress conditions (soil water depletion of 90%) associated with increased potassium consumption resulted in improved P concentration of the grain.

5. Acknowledgements

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6. References

1. Alfoldi, Z., Pinter.L., Feil. B:**Nitrogen, phosphorus and potassium concentrations in developing maize grains.** J. Agron. Crop. Sci. 1994, 172, 200–206.
2. Alloway BJ:**Zinc in soils and crop nutrition.** 2004, IZA Publications, Brussels.
3. Arefi F:**Effect ofzinc andboronon yield andnitrogen, phosphorusandpotassium incorn**. Journalof agricultural knowledge 2008, 5(2) ,Summer.
4. Ashraf MY, Sarwar G:**Salt tolerance potential in some members of Brassiaceae. Physiological studies on water relations and mineral contents.** In prospects for saline agriculture. Academic Publishers Netherlands 2002, 237-245.
5. Baethgen WE, AlleyMM:**Optimizing soil and fertilizer nitrogen use by intensively managed winter wheat II. Critical levels and optimum rates of nitrogen fertilizer.** Agron. J. 2005, 81, 120–125.
6. Balali MR, MalakoutiMJ:**Effects of different methods of micronutrientapplication on the uptake of nutrients in wheat grains in 10 provinces**. Iranian Journal ofSoil and Water Sciences, Soil & Water Res2002, 15(2): 1-11.
7. Batten GD, Fettell NA, MeadJA, KhanMA:**Effect of sowing date on the uptake and utilisation of phosphorus by wheat (cv. Osprey) grown in central New South Wales.** Aust. J. Exp. Agric. 1999, 39, 161–170.
8. Bélanger G,Ziadi N: **Phosphorus and nitrogen relationships during spring growth of an aging timothy sward.** Agron. J. 2008, 100, 1757–1762.
9. Bolland, M .D .A. and R .F. Brennan. 2005. **Critical phosphorus concentrations for oats, barley, triticale, and narrow-leaf lupin.** Commun. Soil Sci. Plant Anal. 36, 1177–1186
10. Borges, R. and A. P. Mallarino. 2001. **Deep banding phosphorus and potassium fertilizers for corn managed with ridge tillage.** Soil Sci. Soc. Am. J.:65: 376-484.
11. Brar, M .S. and G .S Sekhon. 1976. **Interaction of zinc whit other micronutrient cations. 1- Effect of copper on zinc 65 absorption by wheat seedling and its translocation within theplant and soil.***Plant and Soil*. 45 (1): 137-143.
12. Brown, P .H., I. Cakmak and Q. Zhang. 1993. **Form and function of zinc in plants.** Pp93-106. In: A. D. Robson (ed.). Zinc in *Soil and Plants*. Kluwer Academic publishers,Dordrecht, the Netherlands.
13. Cakmak, I. 2008. **Enrichment of cereal grains with zinc: agronomic or genetic biofortification?** Plant Soil 302, 1-17.
14. Campbell, C .A., R .P. Zentner, F. Selles, B .G. McConkey and F .B. Dyck. 1993. **Nitrogen management for spring wheat grown annually on zero-tillage: yield and nitrogen use efficiency.** Agron. J. 85, 107-114.
15. Daly Aissa, A. and A. Mhiri. 2002. **Fertilisation phospho-potassique du blé dur en culture intensive en Tunisie.** Cah. Agri. 11, 6-7.
16. Ebrahimi, R. F., P. Rahdari, M. S. Vahed and P. Shahinrokhsar. 2012. **Rice response to different methods of potassium fertilization in salinity stress condition.** International Journal of Agricultural and Crop Science, 4, 798-802.
17. Fageria, N. K. 2002. **Influence of micronutrients on dry matter yield and interaction with other nutrients in annual crops**. Pesq. agropec. Bras. Brasília, v. 37, n. 12, p. 1765-1772

18. Fageria, N .K. 1989. **Tropical soils and physiological aspects of crops.** Brasilia,Goiânia, Brazil: EMBRAPA / CNPAF.
19. Flagella, Z., M .M Giuliani, L. Giuzio, C. Volpi and S. Masci. 2010. **Influence of water deficit on durum wheat storage protein composition and technological quality.** European Journal of Agronomy 33, 197–207.
20. Fornasieri, F. O., E. L. Coutinbo, V. M. Vieira, and L. B. Lemos. 1994. **Response of popcorn *(Zeamays L.)* to phosphorus and zinc fertilizer.** Jaboticabal, 22: 205-215.
21. Golldack, D. Q., F. Michalowski, U. R. Kamasani and H. J. Bohnert. 2003. **Salinity stress tolerant and sensitive rice regulate AKT1- type potassium channel transcript differently.** PIant Mol Biology, 51, 71-81.
22. Graham, R. D., R. M. Welch, D. L. Grunes, E. E. Cary, and W. A. Norvell. 1987. **Effect of zinc deficiency on the accumulation of boron and other mineral nutrients in barley.** Soil Sci. Soc. Am. J. 51: 652 - 657.
23. Gupta, B. and B. Haung. 2014. **Mechanisim of salinity tolerance in plants: Physiollogical, biochemical, and molecular characterization.***International Journal of Genomics, 2014*, Article ID 701596.
24. Gupta, V. K. and B. Singh.1985. **Residual effect of zinc andmagnesium on maize crop.** J.Indian Soc. Soil Sci. 33: 204 -207.
25. Guttieri, M. J., R. Ahmad, J. C. stark and E. souza. 2000. **End-use quality of six hard red springwheat cultivars at different irrigation level.** Crop sci. 40: 631-635.
26. Haberle, J., P. Svoboda and I. Raimanova.2008. **The Effect of Post-anthesis WaterSupply onGrain Nitrogen Concentration andGrain Nitrogen Yield of Winter Wheat.***Plant Soil Environ.*,54: 304-312.
27. Hemantaranjan, A. and O .K. Grag. 1988. **Iron and zinc fertilization with reference to thegrain quality of *triticum aestivum* L.** J. of *Plant Nutri*. 11(6-11): 1439-1450.
28. Hoppo, S.D., D .E. Elliott and D .J. Reuter. 1999. **Plant tests for diagnosing phosphorus deficiency in barley (Hordeum vulgare L.).** Aust. J. Exp. Agric. 39, 857–872.
29. Hossein, E. and H. Faiyad. 1996. **The combinedeffect of Zn andcobalt on corn growth andnutrients uptake in Alluvial soilEgyptian.** J. Soil Sci., 36: 47 -58.
30. Hotz, C. and K .H. Brown. 2004. **Assessment of the risk of zinc deficiency in populations and options for its control.** Food Nutr. Bull. 25, S91–S204.
31. Karimian, N. 1995. **Effect ofnitrogen and phosphorus on zincnutrition of corn in a calcareoussoil.** J. Plant Nutr. 18: 2261 -2271.
32. Kausar, A., M. Y. Ashraf and M. Niaz. 2014. **Some physiological and genetic determinants of salt tolerance in sorghum (Sorghum bicolor (L.) Moench): Biomass production and nitrogen metabolisim.** Pakistan Journal of Botany, 46(2), 515-519.
33. Kisiel, R.D., D. Borzacka and D. Kaliszewicz. 1998. **Effect of nitrogen & copperfertilizer application on yield and direct production costs of wheat.** Acta AcademicaAgricultural Technical Olsten sis oconmico 31: 33-45.
34. Lazim, I.T., N .S. Mutradha and A .M. Salih. 1989. **Wheat (*Triticum aestivum* L.)response to Zn applications and its critical level in soils central part of turkey.** J. of Agriand Water Resources-Res. Soil and Water Resources. 8 (1): 81-92.
35. Liang, B.C., A .F. MacKenzie and T .Q. Zhang. 1996. **Grain yields and grain nitrogen concentration of corn as influenced by fertilizer nitrogen rate.** J. Agron. Crop Sci. 177, 217–223.
36. Lopez-Bellido, L., R .J .Lopez-Bellido, J .E. Castillo and F .J. Lopez-Bellido. 2001. **Effects of long-term tillage, crop rotation and nitrogen fertilization on bread-making quality of hard red spring wheat.** Field Crops Research 72, 197–210.
37. Malakouti, M. J. AndM. Lotfollahi. 1999.**Increasethequality and quantityofagricultural products,improve the public health.** TatDepartmentofAgriculture, Karaj, Iran.
38. Malakouti, M. J. And Gh. Savaghebi. 1999.**Practical methodsto reducephytic acidinbreadwheatforquality improvement.** Research Institute ofSoiland water. TechnicalJournal No (99).
39. Malakouti, M. J. and M. Nafisi. 1994. **Fertilization of dry land and irrigated soils (Translation).** Univ. tarbiat modares Press. 342 p.
40. Maleki, S., M. Chaichi, R. Mazaheri, T. **Afshari and Gh. Savabeghi. 2011. Barley Grain**

Mineral Analysis as Affected by Different Fertilizing Systems and by Drought Stress.*J. Agr. Sci. Tech. (2011) Vol. 13: 315-326*

41. Marschner , H.1995. **Mineral nutrition of higher Plants. 2nd ed. Academic Press.** 890 P. .,Stutgart ,Germany.
42. Masoni A., L. Ercoli, Mariotti M and I. Arduini. 2007. **Post-anthesis accumulation and remobilization of drymatter, nitrogen, and phosphorus in durum wheat as affected by soil type.** European Journal of Agronomy 26: 179-186.
43. Mikkelsen, R.L. 2000. **Nutrientmanagement for organicfarming: A case study.** J. Nat.Resour. Life Sci. Educ. 29:88–92.
44. Ming, C. and C.R. Yin. 1992. **Effect of manganese and zinc fertilizer on nutrient balanceand deficiency diagnosis of winter wheat crops in pot experiment. International symposiumon the Role of Sulfur, Magnesium and Micronutrients in Balanced Plant Nutrition.** (editedby Portch, S.). pp. 369-379. Washington, USA, Sulfur Institute.
45. Mobasser, H., H. Heydari and H. Madani. 2010.**Effects ofpotassium, copperandzinc onyieldin stress conditions, thenew agriculturalyear**V,No. 2,Winter89.
46. Mohammad, W., M .M. Iqbal and S .M. Shah. 1990. **Effect of mode of application of zincand iron on yield of wheat (CV. Pak-81). Sarhad** J. of Agric. 6(6): 615-618.
47. Momeni, A. and M. R. Pahlevan.2008.**Mappingof soil fertilitydigitalaveragetheplain. Agriculture and Natural ResourcesResearch Centerof Sistan.** Issue1400
48. Nan, Z., J. Li, J. Zhang and G. Cheng. 2002. **Cadmium and zinc interactions and theirtransfer in soil-crop system under actual field conditions.** Sci. Total Environ. 285: 187-195.
49. Olsen, R.A., and T. Kurtz. 1982. **Crop N requirements, utilization and fertilization. P. 567- 604. In F. J. Stevenson.** Nitrogen in agricultural soils. Agronomy Monoger. 22. ASA, CSSA, and SSSA Madison WI
50. Otteson, B.N., M. Mergoum and J .K. Ransom. 2008. **Seeding rate and nitrogen management on milling and baking quality of hard red spring wheat genotypes.** Crop Science 48, 749–755.
51. Pahlevan, M. R. 2005.**The effectof different methods ofirrigationandwatersurfaceprofilesof salinityandnutrientuptakebywheatplain. ThesisYarshd.** Gorgan University.
52. Pahlevan, M. R. 2010.**Influence ofsurfaceirrigationmethodsonthe yield and qualityof wheatandhumidityprofiles.** Agriculture and Natural ResourcesResearch Centerof Sistan. Issue1529.
53. Rashid, A., Z. I. Awan and J. Ryan. 2005. **Diagnosing phosphorus deficiency in spring wheat by plant analysis: proposed critical concentration ranges.** Commun. Soil Sci. Plant Anal. 36, 609–622.
54. Rezaei, M., A. Movahedi and F. KHormali. 2011. **Potassium quantity – intensity (Q/I) curves for two soils as affected by Zeolite additions.** Agronomy Journal (Pajouhesh & Sazandegi) No 91 pp: 27-34.
55. Saad, A. O. M. 1988. **Growth photosynthetic pigments content and yield of wheat plant as influenced by time of potassium application.** Egyption J.of Agron. 11(1-2): 53-62.
56. Saifullah, A. M., M. Ranjha, M. Yaseen and M. E. Akhtar. 2002. **Response of wheat to potassium fertilization under field conditions.** Pakistan Journal of Agricultural Science, 39(4), 91-93.
57. Savaghebi, Gh and M. Malakoti. 2000.**Theinteractionof potassiumandzincconcentrationsand nutrient uptakeofwheat(Part One). Proceedings ofthe pathtowardsself-sufficiencyinwheatbalanced nutritionandpublichealth.**DisseminationofAgricultural Education. Pp336-319
58. Savaghebi, Gh.,M. J. Malakouti andM. D. Ardalan.2003.**Effectof zincandzinc concentration inwheatseedresponsesincalcareous soils,**JournalofAgricultural Sciences. Volume34, Issue2, Pages 482-471
59. Schwartz, S.M., R. M. Welch, D. L. Grunes. E. E. Cary, W. A. Norvell, M. D. Gilbert and M. P. Meredith. 1987; **Effect of zinc phosphorus and root zone temperature on nutrient uptake by barley.** Soil Science Society of America Journal 51:371-375.

60. Sedri,M.h. andM .j. Malakoti. 1998.**Determinethe critical levelsof micronutrientsinwheat fieldsin Kurdistan.**Journal ofSoilandWater. SoilandWaterResearchInstitute. Tehran. Iran.

61. Sirjani, A., H. Farahbakhsh , N. Pasandi and A. Karami. 2011.**Effect ofbiofertilizer, zincandnitrogenyieldquality and quantity ofwheat,**Journal ofSoilScience (soil andwater). 5 (2).

62. Souza, S.R., E. M. Stark and M.S. Fernandes. 1999. **Foliar spraying of rice with nitrogen: effect on protein levels, protein fractions, and grain weight**. Journal of Plant Nutrition 22, 579–588.

63. Stein, A.J. 2010. **Global impacts of human mineral malnutrition**. Plant Soil 335, 133–154.

64. Tisdales, L. W., L. Nelson, J. D. Beaton and J. L. Havlin. 1993. **Soil fertility and fertilizers. 5Edition.** Macmilan Publishing Company. P 634.

65. Tzortzakis, N. G. 2010. **Potassium and calcium enrichment alleviate salinity-induced stress in hydroponically grown endives.** Hort. Sci. (Prague), 37, 155-162.

66. Vaughn, B., K.A. Barbarick, D.G. Westfall and P.L. Chapman. 2001. **Tissue nitrogen levels for dry land hard red winter wheat.** Agron. Tissue nitrogen levels for dry land hard red winter wheat. Agron. J. 82:561–565.

67. Vyas, S. P ., B. K. Garg, S. Kathju and A. N. Lahiri. 2001. **Influence of potassium on water relations, photosynthesis nitrogen metabolism and yield of cluster bean under soil moisture deficit stress.** Indian J. Plant Physoil. 6:30-37

68. Vyn, T.J. and K. J. Janovicek. 2001. **Potassium placement and tillage system effects on corn response following long-term no till.** Agron J. 93:487-495.

69. Wajid, S.A. 2004. **Modeling development, growth and yieldof wheat under different sowing dates, plant populationsand irrigation levels.** Ph.D. Thesis, Dept of Agron.University of Agriculture, Faisalabad, Pakistan.

70. Wang, M., Q. Zheng, Q. Shen and S. Guo. 2013. **The critical role of potassium in plant stress response.** International Journal of Molecular Sciences, 14, 7370-7390.

71. Welch, R.M. and R. D. Graham. 2004. **Breeding for micronutrients in staple food crops from a human nutrition perspective.** J. Exp. Bot. 55, 353-364

72. Wuest, S.B. and K.G. Cassman. 1992. **Fertilizer-nitrogen use efficiency of irrigated wheat: I. Uptake efficiency of replant versus late-season application**. Agronomy Journal 84, 682–688.

73. Yilmaz. and Cakmak. 1997. **Effect of different Zinc application methods on grain yield and zinc concentration in wheat cultivars grown on zinc deficient calcareous soils**,j. plant Nutr.20(4),460- 471

74. Ziadi N., G. Blanger, A. N. Cambouris, N. Tremblay, M. C. Nolin and A. Claessense. 2008. **Relationship betweenPhosphorus and nitrogen concentration in spring wheat.** Agronomy Journal 100(1): 80-86.

75. Ziadi, N., G. Bélanger, A. N. Cambouris, N. Tremblay, M. C. Nolin and A, Claessens. 2007. **Relationship between P and N concentrations in corn.** Agron. J. 99, 833–84.