EFFECTS OF FOLIAR UREA, POTASSIUM AND ZINC SULPHATE TREATMENTS BEFORE AND AFTER FLOWERING ON GRAIN YIELD, TECHNOLOGICAL QUALITY AND NUTRIENT CONCENTRATIONS OF WHEAT

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Abstract. This study was carried out under field conditions to determine the effects of foliar urea, potassium sulphate (K_2SO_4) and zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) treatments at vegetative and generative periods on yield, technological quality and mineral element concentrations of wheat (*Triticum aestivum* L. cv. Altinbasak). Experiments were conducted in two experiment groups (foliar treatments of 0% (Control); 0.5% Urea; 1% Urea; 0.5% $ZnSO_4.7H_2O$; 0.5% Urea+0.5% $ZnSO_4.7H_2O$; 1% Urea+0.5% $ZnSO_4.7H_2O$; 0.5% K_2SO_4 and 1% K_2SO_4 were performed in the first experiment and foliar 0%; 0.5% Urea+0.5% K_2SO_4; 0.5% Urea+1% K_2SO_4; 1% Urea+0.5% K_2SO_4; 1% Urea+1% K_2SO_4 were performed in the second experiment). All treatments increased yield and sedimentation values as compared to the control treatments. In the first experiment, 0.5% urea treatment was prominent for yield, nitrogen and protein and urea+$ZnSO_4.7H_2O$ treatments for grain zinc and iron concentrations. In the second experiment, 1% urea+0.5% K_2SO_4 treatments were prominent for protein and grain nitrogen concentrations and 1% urea+1% K_2SO_4 and 0.5% urea+0.5% K_2SO_4 treatments for yield.
Keywords: *nitrogen, sulphur, micronutrients, gluten, Zeleny sedimentation*

Introduction

Cereals are staple foods, and are significant sources of nutrients in both developed and developing countries. Therefore, nutritional quality of cereals should be improved. Foliar fertilization seems to be a practical way to eliminate nutritional problems and to improve product quality. In this sense, foliar nitrogen (N) treatments had significant effects on yield and quality parameters (Shah et al., 2003; Rahman et al., 2014). Especially, foliar application of urea was demonstrated to be an efficient method of N fertilization in grain cereals in 1950’s (Finney et al., 1957). Foliar applications of potassium (K) (Hamouda et al., 2015) and zinc (Zn) (Habib, 2009) had also positive effects on grain yield and quality of wheat. It was recommended by Wang et al. (2017) that foliar N and K treatments could be used to maximize plant respond to Zn treatments.

Prevention of sulphur (S) release to atmosphere with environmental measures, high-cost and resultant decreasing uses of S fertilizers, again decreasing uses of S-containing N and phosphorus (P) fertilizers, excessive nitrogenous fertilizer uses, breeding of high yield varieties and similar factors have made S deficiency in soils and plants a widespread problem. Insufficient S levels prevent grain cereals from reaching their actual potential in yield, quality and protein content. Insufficient S also hinders efficient use of N applied to soils (Sahota, 2006). It was reported that N and S nutrition had significant effects on grain yield and protein concentration of wheat. Wheat S need is less than N need. However, in sulphur deficiency, non-protein N compounds (free amides: asparagine, glutamine) are accumulated, and synthesis and accumulation of S-containing amino acids (cysteine, methionine) in grains decreased (Zhao et al., 1999a;

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Granvogl et al., 2007). Under S deficiency, these N forms increase and signal is passed from the shoots to roots as if there was sufficient N, thus less N is up taken by the plants from the nutrient ambient. When the plants are nourished with sufficient S, protein N, organic S and SO_4-S concentrations increase, but nitrate and soluble organic acid concentrations decrease (Marschner, 1995). Such findings revealed that S-deficiency destroyed plant N metabolism (McGrath and Zhao, 1996). Nitrogen and S are the basic components of proteins, therefore a balance between N and S is a critical issue for bread making quality of wheat (Randall and Wrigley, 1986). Sulphur not only influences N use and protein quality, but also plays a significant role in baking quality (Ryant and Hřivna, 2004).

Recent studies revealed that cereal grains were poor in mineral element concentrations. For instance, Zn concentrations of wheat grains (generally 25-30 mg kg^{-1}) were quite below the requirements for healthy human nutrition or the recommended levels (Erdal et al., 2002; Cakmak, 2008). Previous studies also indicated that grain Zn and Fe concentrations could be improved with N treatments, and Zn and N treatments had a synergic effect in increasing Zn concentrations of wheat grains (Kutman, 2010; Shi et al., 2010). In another study, increasing Zn and Fe concentrations of wheat grains grown under field conditions were reported with increasing N treatments (Cakmak et al., 2010). When the sufficient Zn levels were supplied to plants, both soil and foliar N treatments were reported to increase grain Zn concentrations (Kutman et al., 2010). Analyses for grain mineral nutrient concentrations revealed that there were significant correlations between grain Zn and Fe concentrations and S concentrations (McDonald and Mousavvi, 2009).

The objective of the present study was to evaluate the effects of urea, K_2SO_4 and $ZnSO_4.7H_2O$ treatments on yield parameters, technological quality and grain nutrient concentrations of Altinbasak bread wheat cultivar.

Materials and methods

Seed and soil materials

Altinbasak bread wheat cultivar commonly grown in Çukurova region was used as the seed material of the present study. Field experiments were conducted over the experimental fields of Eastern Mediterranean Agricultural Research Institute. Experiments were carried out at Dogankent station (36°85′ N, 35°34′ E) during the wheat growing seasons of the years 2014-2015 and 2015-2016. Soil physical and chemical characteristics of the experimental site are provided in *Table 1*.

Table 1. *Soil physical and chemical characteristics of the experiment site for 2014-2015 and 2015-2016 growing seasons*

Growing Season	Texture	pH	Salinity	$CaCO_3$	Org.M.	P	K	SO_4-S	Zn	Fe	Cu	Mn
		(1:2.5)	(mmhos cm^{-1})	%		(mg kg^{-1})						
2014-15	CL	7.85	0.25	15.2	1.45	5.60	426	10.2	0.35	4.60	2.30	4.81
2015-16	CL	8.01	0.02	14.2	1.50	4.95	310	11.2	0.36	4.76	0.67	2.57

CL: clay-loam

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Field experiments

Experiments were conducted in randomized blocks – split plots experimental design with 4 replications. Experiments were set up on 7 November 2014 in the first year and on 14 November 2015 in the second year. Treatment periods (before flowering – BF, after flowering – AF) were placed in the main plots and foliar treatments were placed in sub-plots (1.4 x 5 = 7 m^2). Sowing density was arranged as 450 seed per m^2. At sowing, 70 kg ha^{-1} phosphorus and 160 kg ha^{-1} nitrogen fertilizers were also applied (in DAP and urea forms). Nitrogen was applied at sowing and tillering stages. Weed control was practiced at tillering stage with 200 ml ha^{-1} Terdok 240 EC. At the end of tillering period, 2-4 D Amine was applied against broad-leaf weeds.

Before flowering (BF) period; foliar treatments were performed once at stem elongation stage (Zadoks 34-36) and once at booting stage (Zadoks 47-49). After flowering period; foliar treatments were performed once at early milk stage (Zadoks 73-74) and once at early dough stage (Zadoks 83-84) (Zadoks et al., 1974). Any surfactant was not used in the fertilizer solutions (w/v). Generally, a typical foliar Zn fertilizer solution contains 2-5 g zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) per liter (Cakmak and Kutman, 2018). In present study, foliar treatments of the first experiment were: 0% (Control); 0.5% Urea; 1% Urea; 0.5% $ZnSO_4.7H_2O$; 0.5% Urea+0.5% $ZnSO_4.7H_2O$; 1% Urea+0.5% $ZnSO_4.7H_2O$; 0.5% K_2SO_4 and 1% K_2SO_4. Foliar treatments of the second experiment were: 0% (Control); 0.5% Urea+ 0.5% K_2SO_4; 0.5% Urea+1% K_2SO_4; 1% Urea+0.5% K_2SO_4; 1% Urea+ 1% K_2SO_4. Only water was applied to control plots. In the other plots, 1000 ml solution was used for each one of 7 m^2 plots as to homogeneously wet the entire plot at stem elongation and booting stages before flowering and at early milk and early dough stages after flowering.

Plots were harvested by a combine, and total grain yield was expressed in kg per hectare at 11% moisture basis. Harvest date was 29 May 2015 in the first year and 13 June 2016 in the second year. Following harvests from 5 m x 1.4 m (7 m^2) plots, grain yields per hectare were determined. The 1000-grain weights were determined in accordance with Ozkaya and Ozkaya (2005). Grain samples were ground and wet-digested in a microwave digester using 2 ml of 35% H_2O_2 and 5 ml of 65% HNO_3. After the digestion, K, S, Zn and Fe were analyzed by an inductively coupled plasma optical emission spectrometer (ICP-OES; Varian-Vista Pro). LECO TruSpec C/N Analyzer (Leco Corp. St Joseph, MI, USA) operating in accordance with Dumas method was used to determine nitrogen concentrations. Reference leaf samples from National Institute of Standards and Technology (Gaithersburg, MD, USA) were used to check the related element (S, K, Zn and Fe) measurements. Total protein concentration of the grain was calculated as 5.7 x N concentration (Zhao et al., 1999b). Wet gluten concentration was measured in a FOSS NIRS 6500 System according to standard method ICC 155 (International Association for Cereal Chemistry, 1994). Zeleny sedimentation was determined by using ICC method 116/1 (International Association for Cereal Chemistry, 1994).

Soil analysis

Available soil Zn, Fe, manganese (Mn) and copper (Cu) concentrations were determined according to Lindsay and Norvel (1978), available P concentration in accordance with Olsen et al. (1954). Soil K concentrations were measured in accordance with the ammonium acetate (pH: 7, 1N) method of Carson (1980). Soil pH was detected

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according to Jackson (1959). Soil organic matter content was determined following the Walkey-Black wet-etching method (Jackson, 1959). Soil texture was determined according to Bouyoucus (1951). Soil lime content was determined according to Allison and Moodie (1965) and soil salinity was determined from saturation paste extracts according to Wheatstone bridge method (U. S. Salinity Laboratory Staff, 1954). For soil soluble SO_4-S analyses, dried and sieved (< 0.18 mm) 5 g soil sample was placed into 250 ml Erlenmeyer flasks, supplemented with 50 ml 0.1 M LiCI solution and shaken for 30 minutes. Soil suspension was then filtered through filter papers and resultant extract was read at 182.037 nm wave length of an ICP device for soluble SO_4-S quantity (Arkley, 1961).

Weather conditions

A total of 687 mm rainfall was received in the 2014-2015 growing season and 348 mm in the 2015-2016 growing season. While the precipitations of the first year were above the long-term averages (about 25% greater than the averages), precipitations of the second year were quite below the long-term averages (about 38% less than the averages). Temperatures of the experimental years were close to long-term averages (*Table 2*).

Table 2. *Weather conditions of experimental site for 2014-2015 and 2015-2016 growing seasons and long-term averages (1978-2016)*

Parameters	Time	Nov. 2014	Dec. 2014	Jan. 2015	Feb. 2015	Mar. 2015	Apr. 2015	May 2015	Jun. 2015	Total
Rainfall (mm)	Long-term	86.3	115.6	97.4	80.7	60.5	47.7	43.8	16.8	549
	2014-2015	72.5	102.5	153.0	160.0	91.0	19.0	58.0	30.5	687
Temperature (°C)	Long-term	14.7	10.4	9.3	9.9	12.8	17.3	21.5	25.3	
	2014-2015	15.0	13.0	9.0	11.0	14.0	16.0	22.0	24.0	
		Nov. 2015	**Dec. 2015**	**Jan. 2016**	**Feb. 2016**	**Mar. 2016**	**Apr. 2016**	**May 2016**	**Jun. 2016**	**Total**
Rainfall (mm)	Long term	86.3	115.6	97.4	80.7	60.5	47.7	43.8	16.8	549
	2015-2016	0.0	0.0	105.0	64.0	98.0	5.0	71.0	5.0	348
Temperature (°C)	Long term	14.7	10.4	9.3	9.9	12.8	17.3	21.5	25.3	
	2015-2016	13.1	9.1	7.3	12.3	14.0	18.5	19.8	23.0	

Statistical analysis

JUMP software was used for statistical analyses. Following ANOVA, significant factor means were compared by TUKEY's multiple range tests. The significance levels were taken as P<0.05 (*) and P<0.01 (**).

Results and discussion

Effects of treatments on grain yield, 1000-grain weight, protein, wet gluten and Zeleny sedimentation

There were significant differences in the yields of the years because of climate factors (*Table 3*). Rainfalls and temperatures are the most significant climate factors influencing plant growth and development. Total precipitations of the second year (348 mm) were quite lower than the precipitations of the first year (687 mm) (*Table 2*).

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Table 3. *Analysis of variance for investigated parameters*

Source of variation	d.f.	Grain Yield	1000 Grain Weight	Protein	Wet Gluten	Zeleny Sed.	Grain N	Grain K	Grain S	Grain Zn	Grain Fe
Ist Experiment											
Year (A)	1	<.0001**	<.0001**	<.0001**	0.0555	0.0015**	<.0001**	<.0001**	0.0054**	0.0048**	0.0114*
Error 1	6	0.4507	0.9987	0.7636	0.9012	0.7267	0.7672	0.5821	0.9405	0.6595	0.9987
Application Time (B)	1	0.5819ns	0.7290ns	0.3378ns	0.6061ns	0.8653ns	0.3407ns	0.2529ns	0.3918ns	0.6281ns	0.8007ns
A x B	1	0.9842ns	0.7237ns	0.5931ns	0.3854ns	0.4843ns	0.5926ns	0.8254ns	0.9394ns	0.7842ns	0.9800ns
Error 2	6	0.0105	<.0001	0.0564	<.0001	0.3030	0.0552	0.5931	<.0001	0.0071	<.0001
Applications (C)	7	0.0041**	0.8750ns	<.0001**	0.0507ns	0.0205*	<.0001**	0.0068**	0.0615ns	<.0001**	0.0020**
A x C	7	0.0921ns	0.7622ns	0.0055**	0.1209ns	0.2446ns	0.0053**	0.9935ns	0.2177ns	0.2241ns	0.1259ns
B x C	7	0.0020**	0.7639ns	0.0898ns	0.0191*	0.1328ns	0.0867ns	0.7819ns	0.1521ns	0.5063ns	0.4446ns
A x B x C	7	0.9795ns	0.5557ns	0.0003**	0.2436ns	0.3321ns	0.0003**	0.9989ns	0.4522ns	0.0020**	0.8867ns
General	84										
C. Total	127										
IInd Experiment											
Year (A)	1	<.0001**	0.0042**	0.0031**	0.0814ns	0.0026**	0.0030**	<.0001**	0.0011**	<.0001**	0.0006**
Error 1	6	0.8896	0.6189	0.3242	0.7276	0.9771	0.3218	0.0129	0.796	0.4032	0.9991
Application Time (B)	1	0.6087ns	0.4619ns	0.0746ns	0.2460ns	0.2698ns	0.0718ns	0.3427ns	0.3155ns	0.2919ns	0.3185ns
A x B	1	0.2722ns	0.4599ns	0.0411*	0.4927ns	0.7885ns	0.0420*	0.6947ns	0.5212ns	0.5940ns	0.4196ns
Error 2	6	0.0235	<.0001	0.0178	0.0002	0.0143	0.0182	0.8969	0.0131	0.7854	0.0013
Applications (C)	4	0.0335*	0.2004ns	0.0002**	0.2359ns	<.0001**	0.0002**	0.1854ns	0.1817ns	0.0463*	0.3065ns
A x C	4	<.0001**	0.3736ns	0.0154*	0.0301*	0.9519ns	0.0150*	0.9801ns	0.8747ns	0.2447ns	0.0718ns
B x C	4	0.3588ns	0.6439ns	0.1211ns	0.6182ns	0.2951ns	0.1236ns	0.2147ns	0.9896ns	0.3313ns	0.1020ns
A x B x C	4	0.7770ns	0.6757ns	0.5963ns	0.1620ns	0.5572ns	0.6122ns	0.9950ns	0.2286ns	0.2415ns	0.1291ns
General	48										
C. Total	79										

*: p<0.05; **: p<0.01; NS: not significant

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Therefore, yields of the second year were lower than the yields of the first year in both experiments (*Table 4*). Considering the treatment periods, the differences in yields of before flowering (BF) and after flowering (AF) periods were not significantly different (*Table 4*).

In the first experiment, effects of treatments on yields were found to be significant (*Table 3*). With regard to general averages of treatments, yields of 0.5% Urea+0.5% $ZnSO_4.7H_2O$ and 0.5% $ZnSO_4.7H_2O$ treatments were placed in the same statistical group with the control treatment (*Table 5*). The greatest yield (974 kg da^{-1}) was obtained from 0.5% Urea treatments (*Table 5*). Jakhro et al. (2000) reported that urea treatments increased plant height, number of tillers, spike lengths, harvest index, grain yield, hay yield and protein content of wheat grains. Khan et al. (2009) applied 4% urea at 6 different concentrations and at consecutive 3 stages (tillering, stem elongation and booting) and reported 32% increase in wheat grain yield. Considering the general averages of treatments of the first experiment, it was observed that foliar zinc treatments did not result in significant differences in yields. Foliar urea and zinc combined treatment (1% Urea+0.5% $ZnSO_4.7H_2O$) slightly increased yields as compared to the control treatment (*Table 5*). With regard to general averages of the treatments of the second trails, 0.5% Urea+0.5% K_2SO_4 and 1% Urea+1% K_2SO_4 treatments resulted in significant increases in yields as compared to the control treatments (*Table 5*). In the first experiment, foliar K_2SO_4 treatments (0.5% K_2SO_4, 1% K_2SO_4) before flowering slightly increased grain yields as compared to the control treatment (*Table 5*). Such a positive impact probably resulted from both K and S. Thusly, foliar potassium treatments had positive effects on physiological parameters especially in grain-fill period (Zareian et al., 2013) and yield values (Hamouda et al., 2015). Similarly, Gupta et al. (2004) reported significant increases in yield and yield components with S treatments. It was reported in a study carried out in Germany, yield increase rates improved by 17% with S treatments and the yield increase supplied by S treatments varied between 5-30% (Zhao et al., 2002). Zinc sulphate and K_2SO_4 sources are commonly preferred in foliar fertilization practices (Singh et al., 2013).

While the treatments did not result in significant differences in 1000-grain weights of the first and second experiments, years created significant differences (*Table 3*). In the first experiment, 1000-grain weight of the first year (45.8 g) was greater than the second year (33.9 g). Similar decrease trends were also observed in the second experiment (*Table 4*). The differences between the treatment periods (BF and AF) were not found to be significant in both experiments (*Table 3*). General averages of 1000-grain weights in before and after flowering periods were not significant in both experiments (*Table 5*).

In the first experiment, treatments resulted in significant differences in grain protein concentrations of both periods. The highest protein concentration was found in the second year with 1% urea application of BF period. Together with decreasing 1000-grain weights, grain protein concentrations increased in the second year (concentration effect) as compared to the first year. Similar findings were also observed in the second experiment (*Table 4*). With regard to averages of treatments, the greatest grain protein concentration in the first experiment was obtained from 0.5% urea treatment (12.9%) and the lowest value was observed in control treatment (12.1%) (*Table 5*). In the first experiment, as the averages of treatments, all treatments increased grain protein concentrations as compared to the control treatments (*Table 5*).

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Table 4. *Effects of different foliar fertilizer treatments, applied before and after flowering, on grain yield, 1000-grain weight and protein content of Altınbaşak bread wheat cultivar*

Appl. Time	**Applications**	**Grain Yield (kg ha^{-1})**			**1000 Grain Weight (gr)**			**Protein (%)**		
		1st Year	**2nd Year**	**Mean**	**1st Year**	**2nd Year**	**Mean**	**1st Year**	**2nd Year**	**Mean**
					Ist Experiment					
Before Flowering	Control	10248	8340	9294 ab	44.40	34.02	39.21	11.94 ıjk	12.10 h-k	12.02
	Urea 0.5 %	10430	9030	9730 a	46.46	33.79	40.12	12.36 d-k	13.43 a	12.89
	Urea 1 %	10503	8660	9581 ab	45.90	33.63	39.77	12.23 f-k	12.67 b-ı	12.45
	$ZnSO_4$ 0.5 %	9863	8273	9068 b	45.72	34.19	39.96	11.87 jk	12.84 a-h	12.35
	Urea 0.5 % +$ZnSO_4$ 0.5 %	9820	8533	9176 ab	43.94	33.83	38.88	12.27 e-k	13.12 abc	12.70
	Urea 1 % +$ZnSO_4$ 0.5 %	9993	8237	9115 ab	44.66	34.30	39.48	11.90 jk	13.21 abc	12.55
	K_2SO_4 0.5 %	10313	9110	9711 ab	45.85	34.04	39.94	12.24 f-k	13.01 a-e	12.63
	K_2SO_4 1 %	10593	8837	9715 ab	45.94	33.50	39.72	12.02 ıjk	12.67 b-ı	12.34
	Mean	**10220**	**8628**	**9424**	**45.36**	**33.91**	**39.64**	**12.10**	**12.88**	**12.49**
After Flowering	Control	10233	8453	9342 ab	46.46	34.04	40.25	11.81 k	12.57 c-j	12.19
	Urea 0.5 %	10472	9028	9750 a	46.92	33.93	40.43	12.62 c-j	13.09 a-d	12.85
	Urea 1 %	10450	8818	9634 ab	46.36	33.97	40.17	12.24 f-k	12.97 a-f	12.61
	$ZnSO_4$ 0.5 %	10433	8653	9543 ab	45.79	34.25	40.02	12.24 f-k	12.86 a-g	12.55
	Urea 0.5 % +$ZnSO_4$ 0.5 %	9868	8790	9329 ab	46.59	34.25	40.42	12.09 ıjk	13.01 a-e	12.55
	Urea 1 % +$ZnSO_4$ 0.5 %	10563	8818	9690 ab	46.45	32.96	39.70	12.17 g-k	12.89 a-g	12.53
	K_2SO_4 0.5 %	10020	8585	9302 ab	45.59	34.63	40.11	12.51 c-k	12.51 c-k	12.51
	K_2SO_4 1 %	10270	8388	9329 ab	45.60	33.21	39.41	12.04 ıjk	13.41 ab	12.73
	Mean	**10288**	**8691**	**9489**	**46.22**	**33.9**	**40.06**	**12.21**	**12.91**	**12.56**
	General mean	**10254 a**	**8659 b**		**45.8 a**	**33.9 b**		**12.16 b**	**12.90 a**	
	CV (%)	**3.92**			**3.84**			**2.16**		
					IInd Experiment					
Before Flowering	Control	9800	8030	8915	42.08	31.91	37.00	11.90	12.97	12.43
	Urea 0.5 % + K_2SO_4 0.5 %	9893	8430	9161	43.31	31.73	37.52	11.74	13.78	12.76
	Urea 0.5 % + K_2SO_4 1 %	9450	8548	8999	43.07	32.80	37.94	11.91	13.08	12.50
	Urea 1 % + K_2SO_4 0.5 %	9923	8313	9118	40.58	33.31	36.94	12.47	13.92	13.20
	Urea 1 % + K_2SO_4 1 %	10423	8413	9418	43.09	33.37	38.23	11.66	13.43	12.55
	Mean	**9898**	**8347**	**9122**	**42.43**	**32.62**	**37.53**	**11.94 b**	**13.44 a**	**12.68**
After Flowering	Control	9595	8398	8996	37.11	31.55	34.32	13.13	13.08	13.10
	Urea 0.5 % +K_2SO_4 0.5 %	9865	8598	9231	40.60	33.18	36.89	12.04	13.26	12.65
	Urea 0.5 % +K_2SO_4 1 %	9540	9068	9304	39.89	33.22	36.56	13.01	13.51	13.26
	Urea 1 % +K_2SO_4 0.5 %	9938	8365	9151	39.29	33.29	36.29	14.02	13.67	13.84
	Urea 1 % +K_2SO_4 1 %	10155	8338	9246	40.63	31.91	36.27	12.31	13.23	12.77
	Mean	**9819**	**8553**	**9186**	**39.50**	**32.63**	**36.07**	**12.90 ab**	**13.35 a**	**13.13**
	General mean	**9858 a**	**8450 b**		**40.9 a**	**32.6 b**		**12.42b**	**13.39 a**	
	CV (%)	**3.50**			**5.98**			**4.15**		

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Table 5. *Effects of different foliar fertilizer treatments and combinations on general mean of grain yield, 1000-grain weight, protein, wet gluten and Zeleny sedimentation of Altınbaşak bread wheat cultivar*

	Applications	General Mean				
		Grain Yield	**1000 G. Wt.**	**Protein**	**Wet Glu.**	**Zeleny Sed.**
		(kg ha^{-1})	**(g)**	**(%)**		**(ml)**
Ist Experiment	Control	9318 b	39.7	12.1 c	25.6	50.1 b
	Urea 0.5 %	9740 a	40.3	12.9 a	26.7	54.6 ab
	Urea 1 %	9607 ab	40.0	12.5 b	26.7	55.6 a
	$ZnSO_4$ 0.5 %	9305 b	40.0	12.5 b	25.6	52.7 ab
	Urea 0.5 % + $ZnSO_4$ 0.5 %	9253 b	39.7	12.6 ab	26.6	54.1 ab
	Urea 1 % + $ZnSO_4$ 0.5 %	9403 ab	39.6	12.5 b	26.2	55.1 ab
	K_2SO_4 0.5 %	9507 ab	40.0	12.6 b	26.5	55.7 a
	K_2SO_4 1 %	9522 ab	39.6	12.5 b	26.1	55.5 a
IInd Experiment	Control	8956 b	35.7	12.8 b	27.7	48.5 b
	Urea 0.5 % + K_2SO_4 0.5 %	9196 a	37.2	12.8 b	27.3	56.5 a
	Urea 0.5 % + K_2SO_4 1 %	9151 ab	37.3	12.9 b	27.7	54.5 a
	Urea 1 % + K_2SO_4 0.5 %	9134 ab	36.6	13.5 a	29.0	59.5 a
	Urea 1 % + K_2SO_4 1 %	9332 a	37.3	12.7 b	27.8	56.8 a

In the second experiment, the greatest grain protein concentration was obtained from 1% Urea + 0.5% K_2SO_4 treatments (13.5%) and the other treatments had similar protein concentrations with the control treatments (*Table 5*). Present protein concentrations (*Table 4*) were all within 11-14% limit values specified by Mailhot and Patton (1988) for bread making. Grain protein concentrations of the 23 bread wheat genotypes varied between 7.99-13.31% (Soboka et al., 2017).

In the first experiment, the greatest wet gluten concentration (27.09%) was obtained from 1% urea treatment of AF period (*Table 6*). Similarly, increasing wet gluten levels were reported with increasing nitrogen doses (Erekul et al., 2012). In present study, the lowest wet gluten concentration (24.85%) was obtained from 0.5% $ZnSO_4$ treatment of BF period (*Table 6*). In the second experiment, wet gluten concentrations did not change with treatments (*Table 6*). In both experiments, greater wet gluten concentrations were observed in the second year, but the differences in wet gluten concentrations of the years were not significant (*Table 6*). Considering the general averages of the treatments, effects of treatments on wet gluten concentrations were not found to be significant in both experiments (*Table 5*).

The sedimentation values of the wheat cultivar in this research, characterizing the swelling capacity of gluten, exceeded the nominal value (20 ml) for bread wheat in both years (*Table 6*). In both experiments, Zeleny sedimentation values of treatment periods were not found to be significant (*Table 3*), but the treatments were found to be significant (*Table 3 and 5*). In the first experiment, the greatest Zeleny sedimentation value was obtained from 1% Urea, 0.5% K_2SO_4 and 1% K_2SO_4 treatments and the lowest value was obtained from the control treatments (*Table 5*). Slightly greater Zeleny sedimentation values were observed from single $ZnSO_4.7H_2O$ and combined urea treatments as compared to the control treatment (*Table 5*). The increases in Zeleny sedimentation values with the separate urea and K_2SO_4 treatments of the first experiment as compared to the control treatments were also observed with urea and K_2SO_4 combined treatments of the second experiment (*Table 5*). Zeleny sedimentation

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values should be above 37 ml for a quality bread making. The greater the values over this value, the greater the quality will be. While 43 ml is assessed as moderately well, the values over 50 ml were assessed as the 1st Class wheat. In another study, Zeleny sedimentation (ml) values were classified as; > 30 ml very well; 25-30 ml well; 20-25 ml moderate and <20 ml poor (Unal, 2002). In present study, all treatments of both experiments yielded Zeleny sedimentation values above 50 ml (*Table 5*).

It was reported in a previous study that urea treatments applied at flowering period significantly increased protein, Zeleny sedimentation and wet gluten values of bread wheat cultivars (Varga and Svečnjak, 2006). Late period urea treatments were also reported to increase protein and wet gluten contents of wheat cultivars (Peltonen, 1992).

Table 6. *Effects of different foliar fertilizer treatments, applied before and after flowering, on wet gluten and Zeleny sedimentation of Altınbaşak bread wheat cultivar*

Appl. Time	Applications	Wet Gluten (%)			Zeleny Sedimentation (ml)		
		1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
Ist Experiment							
Before Flowering	Control	25.83	25.85	25.84 ab	48.25	50.88	49.56
	Urea 0.5 %	25.34	27.69	26.51 ab	50.50	59.75	55.13
	Urea 1 %	26.10	26.46	26.28 ab	52.25	61.13	56.69
	$ZnSO_4$ 0.5 %	24.28	25.41	24.85 b	47.25	56.50	51.88
	Urea 0.5 % + $ZnSO_4$ 0.5 %	25.72	27.80	26.76 ab	49.25	60.00	54.63
	Urea 1 % + $ZnSO_4$ 0.5 %	25.67	26.03	25.85 ab	50 25	55.00	52.63
	K_2SO_4 0.5 %	26.24	27.65	26.95 ab	53.75	54.88	54.31
	K_2SO_4 1 %	24.03	26.11	25.07 ab	57.50	58.50	58.00
	Mean	**25.40**	**26.63**	**26.01**	**51.13**	**57.08**	**54.10**
After Flowering	Control	23.74	27.16	25.45 ab	49.00	52.25	50.63
	Urea 0.5 %	26.01	27.85	26.93 ab	52.00	56.19	54.09
	Urea 1 %	26 07	28.11	27.09 a	53.00	56.00	54.50
	$ZnSO_4$ 0.5 %	24.99	27.82	26.41 ab	47.50	59.63	53.56
	Urea 0.5 % + $ZnSO_4$ 0.5 %	24.96	27.85	26.41 ab	53.00	54.13	53.56
	Urea 1 % + $ZnSO_4$ 0.5 %	25.30	27.99	26.64 ab	56.00	59.25	57.63
	K_2SO_4 0.5 %	25.23	26.73	25.98 ab	56.25	58.00	57.13
	K_2SO_4 1 %	24.22	29.60	26.91 ab	49.25	56.88	53.06
	Mean	**25.07**	**27.89**	**26.48**	**52.00**	**56.54**	**54.27**
	General mean	**25.23**	**27.26**		**51.56 b**	**56.81 a**	
	CV (%)	**4.67**			**8.96**		
IInd Experiment							
Before Flowering	Control	25.16	28.50	26.83	41.75	52.75	47.25
	Urea 0.5 % + K_2SO_4 0.5 %	23.22	30.09	26.66	49.75	62.88	56.31
	Urea 0.5 % + K_2SO_4 1 %	26.14	27.92	27.03	46.50	55.38	50.94
	Urea 1 % + K_2SO_4 0.5 %	26.80	31.08	28.94	54.25	65.00	59.63
	Urea 1 % + K_2SO_4 1 %	27.13	26.15	26.64	51.25	59.88	55.56
	Mean	**25.69**	**28.75**	**27.22**	**48.70**	**59.18**	**53.94**
After Flowering	Control	27.28	29.97	28.62	44.00	55.38	49.69
	Urea 0.5 % + K_2SO_4 0.5 %	27.19	28.88	28.03	53.50	59.88	56.69
	Urea 0.5 % + K_2SO_4 1 %	27.07	29.64	28.36	52.50	63.75	58.13
	Urea 1 % + K_2SO_4 0.5 %	28.73	29.32	29.02	56.50	62.25	59.38
	Urea 1 % + K_2SO_4 1 %	29.11	28.96	29.03	52.00	64.00	58.00
	Mean	**27.88**	**29.35**	**28.61**	**51.70**	**61.05**	**56.38**
	General mean	**26.78**	**29.05**		**50.20 b**	**60.11 a**	
	CV (%)	**7.45**			**9.39**		

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Effects of treatments on grain nitrogen (N), potassium (K), sulphur (S), zinc (Zn) and iron (Fe) concentrations

With regard to effects of different foliar fertilizer treatments applied before and after flowering on grain N, K, S, Zn and Fe concentrations, it was observed that years created significant differences (*Table 3*). Because of greater precipitations of the second year (*Table 2*), nutrients concentrated in the grains and greater values were observed in the second year (*Table 7 and 8*).

Treatment periods did not have significant effects on grain N, K, S, Zn and Fe concentrations in both experiments (*Table 3*). Treatment periods did not have significant effects on grain K concentrations in both experiments (*Table 3*). In the first experiment, the greatest grain K concentration was obtained from 0.5% K_2SO_4 treatment. In the second experiment, treatments did not have significant effects on grain K concentrations (*Table 9*).

With regard to effects of general averages of treatments on N concentrations, it was observed that all treatments increased N concentrations as compared to the control treatment (*Table 9*). In the first experiment, the greatest N concentration (2.26%) was observed in 0.5% urea treatment and the lowest N concentration (2.12%) was observed in control treatments (*Table 9*). In the second experiment, the greatest N concentration was obtained from 1% Urea + 0.5% K_2SO_4 treatments (*Table 9*). Especially in the second experiment, AF treatments were more effective on mean N (*Table 7*) and protein concentrations (*Table 4*) than BF treatments. Thusly, N treatments close to flowering were reported to influence N uptake and protein contents (Banziger et al., 1994).

The critical extractable S level is commonly reported as 10 mg S kg^{-1}, but is known to vary from 8 to 25 mg kg^{-1} (Mukhopadhyay and Mukhopadhyay, 1995) and 8 to 12 mg kg^{-1} as reported by Tandon (1991) depending on soil, crop, extractant and laboratory procedures. For wheat, the critical level for soil available S concentration was reported as 12 mg kg^{-1} (Rodríguez et al., 2001; Alfaro et al., 2006). According to the survey study results in Ankara, Turkey, more than 50% of the soil, plant straw and grain samples contained lower S than the critical limits (Inal et al., 2003). As the average of the first and the second year, there was 10.7 mg/kg available S in soil (*Table 1*). This value did not result in S deficiency. In both experiments, treatment periods, treatments and interactions did not have significant effects on S concentrations (*Table 3*). Grain S concentrations lower than 1.2 mg g^{-1} and grain N:S ratios higher than 17:1 appear to be critical values for S deficiency (Randall et al., 1981). In present study, S concentrations of both experiments were greater than 1.2 mg g^{-1} and N:S ratios were lower than 17:1. Sulphur plays a significant role in methionine (21% S) and cysteine (27% S) formation, chlorophyll and protein synthesis, seed oil contents and nutritive quality accumulation (Tandon, 1986; Jamal et al., 2005). Sulphur status of wheat grain also influences quality parameters (Marschner, 1997; Zhao et al., 1999a; McGrath, 2003; Honermeier and Simioniuc, 2004). Grain N:S ratio influences bread-making quality and rheological characteristics of the dough.

In recent studies, a new strategy called as "*agronomic biofortification"* have come into prominence. In this strategy, selection, breeding and molecular methods are employed and improvement of grain micro nutrient contents and bio-availabilities are targeted. Such a strategy gained a great support because of sustainability and widespread impacts (Ortiz- Monasterio et al., 2007; Cakmak, 2008).

Table 7. *Effects of different foliar fertilizer treatments and combinations, applied before and after flowering, on grain K, N, S concentrations and N/S ratio of Altınbaşak bread wheat cultivar*

Appl. Time	Applications	K (%)			N (%)			S (%)			N/S
		1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	1st Year	2nd Year	Mean	Mean*
Ist Experiment											
Before Flowering	Control	0.339	0.365	0.352	2.10 ıjk	2.12 h-k	2.11	0.139	0.156	0.148	0.139
	Urea 0.5 %	0.346	0.375	0.361	2.17 d-k	2.36 a	2.26	0.131	0.152	0.142	0.131
	Urea 1 %	0.332	0.360	0.346	2.15 f-k	2.22 b-ı	2.18	0.140	0.154	0.147	0.140
	$ZnSO_4$ 0.5 %	0.327	0.355	0.341	2.08 jk	2.25 a-h	2.17	0.123	0.153	0.138	0.123
	Urea 0.5 % + $ZnSO_4$ 0.5 %	0.333	0.355	0.344	2.15 e-k	2.30 abc	2.23	0.138	0.157	0.148	0.138
	Urea 1 % +$ZnSO_4$ 0.5 %	0.338	0.363	0.351	2.09 jk	2.32 abc	2.20	0.131	0.162	0.146	0.131
	K_2SO_4 0.5 %	0.348	0.373	0.361	2.15 f-k	2.28 a-e	2.21	0.132	0.154	0.143	0.132
	K_2SO_4 1 %	0.341	0.363	0.352	2.11 ıjk	2.22 b-ı	2.16	0.142	0.154	0.148	0.142
	Mean	**0.338**	**0.363**	**0.351**	**2.12**	**2.26**	**2.19**	**0.135**	**0.155**	**0.145**	**15.2**
After Flowering	Control	0.338	0.363	0.351	2.07 k	2.21 c-j	2.14	0.141	0.161	0.151	14.2
	Urea 0.5 %	0.338	0.365	0.352	2.21 c-j	2.30 a-d	2.25	0.146	0.157	0.152	15.0
	Urea 1 %	0.328	0.358	0.343	2.15 f-k	2.27 a-f	2.21	0.134	0.154	0.144	15.4
	$ZnSO_4$ 0.5 %	0.332	0.360	0.346	2.15 f-k	2.26 a-g	2.20	0.133	0.155	0.144	15.3
	Urea 0.5 %+ $ZnSO_4$ 0.5 %	0.331	0.355	0.343	2.12 ıjk	2.28 a-e	2.20	0.138	0.168	0.153	14.5
	Urea 1 %+ $ZnSO_4$ 0.5 %	0.332	0.353	0.343	2.14 g-k	2.26 a-g	2.20	0.131	0.160	0.146	15.2
	K_2SO_4 0.5 %	0.353	0.380	0.367	2.20 c-k	2.20 c-k	2.20	0.149	0.164	0.156	14.1
	K_2SO_4 1 %	0.332	0.355	0.344	2.11 ıjk	2.35 ab	2.23	0.138	0.163	0.150	14.9
	Mean	**0.336**	**0.361**	**0.349**	**2.14**	**2.27**	**2.20**	**0.139**	**0.160**	**0.150**	**14.8**
	General mean	**0.337b**	**0.362a**		**2.13 b**	**2.26 a**		**0.137 b**	**0.158 a**		
	CV (%)		**4.62**			**2.16**			**5.77**		
IInd Experiment											
Before Flowering	Control	0.357	0.388	0.373	2.09	2.28	2.18	0.147	0.171	0.156	13.8
	Urea 0.5 % +K_2SO_4 0.5 %	0.341	0.368	0.355	2.06	2.42	2.24	0.134	0.161	0.149	15.2
	Urea 0.5 % + K_2SO_4 1 %	0.360	0.398	0.379	2.09	2.29	2.19	0.142	0.169	0.152	14.2
	Urea 1 % + K_2SO_4 0.5 %	0.351	0.383	0.367	2.19	2.44	2.31	0.138	0.166	0.155	15.3
	Urea 1 % + K_2SO_4 1 %	0.345	0.373	0.359	2.05	2.36	2.20	0.139	0.163	0.149	14.6
	Mean	**0.351**	**0.382**	0.367	**2.09 b**	**2.36 a**	**2.23**	**0.140**	**0.164**	**0.152**	14.6
After Flowering	Control	0.354	0.385	0.370	2.30	2.29	2.30	0.149	0.165	0.16	14.7
	Urea 0.5 % + K_2SO_4 0.5 %	0.359	0.390	0.375	2.11	2.33	2.22	0.148	0.164	0.154	14.3
	Urea 0.5 % + K_2SO_4 1 %	0.355	0.385	0.370	2.28	2.37	2.33	0.144	0.162	0.156	15.2
	Urea 1 % + K_2SO_4 0.5 %	0.354	0.383	0.369	2.46	2.40	2.43	0.149	0.173	0.157	15.2
	Urea 1 % + K_2SO_4 1 %	0.348	0.373	0.361	2.16	2.32	2.24	0.143	0.158	0.153	14.9
	Mean	**0.354**	**0.383**	0.369	**2.26 ab**	**2.34 a**	**2.30**	**0.146**	**0.166**	**0.156**	14.8
	General mean	**0.352**	**0.382**		**2.18 b**	**2.35 a**		**0.143 b**	**0.165 a**		
	CV (%)		**4.88**			**4.16**			**6.23**		

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Table 8. *Effects of different foliar fertilizer treatments and combinations, applied before and after flowering, on grain Zn and Fe concentrations of Altınbaşak bread wheat cultivar*

Appl. Time	Applications	Zn (mg kg^{-1})			Fe (mg kg^{-1})		
		1st Year	2nd Year	Mean	1st Year	2nd Year	Mean
				Ist Experiment			
Before Flowering	Control	19.3 e	23.6 e	21.5	22.6	33.8	28.3
	Urea 0.5 %	21.6 e	23.0 e	22.2	27.2	33.0	30.0
	Urea 1 %	21.8 e	22.2 e	22.0	30.5	30.8	30.6
	$ZnSO_4$ 0.5 %	33.9 cd	41.4 abc	37.7	27.1	37.4	32.3
	Urea 0.5 % + $ZnSO_4$ 0.5 %	38.0 abc	42.3 abc	40.2	32.2	38.3	35.2
	Urea 1 % + $ZnSO_4$ 0.5 %	35.2 c	45.0 a	40.1	29.6	40.2	35.1
	K_2SO_4 0.5 %	18.7 e	22.7 e	20.7	27.1	33.2	30.2
	K_2SO_4 1 %	22.9 e	23.2 e	23.0	24.6	30.1	27.4
	Mean	**26.4**	**30.4**	**28.4**	**27.6**	**34.7**	**31.1**
After Flowering	Control	19.2 e	24.3 e	21.9	26.3	34.5	30.5
	Urea 0.5 %	17.5 e	23.2 e	20.4	27.1	31.2	29.2
	Urea 1 %	19.7 e	22.8 e	21.4	27.0	28.4	27.8
	$ZnSO_4$ 0.5 %	40.7 abc	38.7 abc	39.8	29.1	35.0	32.1
	Urea 0.5 % + $ZnSO_4$ 0.5 %	35.5 bc	44.0 ab	39.8	27.4	36.4	32.0
	Urea 1 % + $ZnSO_4$ 0.5 %	37.4 abc	39.6 abc	38.5	27.6	37.3	32.4
	K_2SO_4 0.5 %	17.1 e	25.5 de	21.3	28.2	37.6	33.0
	K_2SO_4 1 %	18.0 e	23.1 e	20.6	23.2	32.2	28.1
	Mean	**25.7**	**30.2**	**27.9**	**27.0**	**34.2**	**30.6**
	General mean	**26.0 b**	**30.3 a**		**27.3 b**	**34.4 a**	
	CV (%)		**10.97**			**15.08**	
				IInd Experiment			
Before Flowering	Control	18.0	27.0	22.5	25.4	37.5	31.4
	Urea 0.5 % + K_2SO_4 0.5 %	19.3	28.3	23.8	21.6	35.3	28.4
	Urea 0.5 % + K_2SO_4 1 %	20.0	28.5	24.3	22.0	35.6	28.8
	Urea 1 % + K_2SO_4 0.5 %	19.4	27.5	23.5	24.3	40.9	32.6
	Urea 1 % + K_2SO_4 1 %	18.1	27.6	22.8	21.5	33.8	27.7
	Mean	**19.0**	**27.8**	**23.4**	**22.9**	**36.6**	**29.8**
After Flowering	Control	18.2	25.8	22.0	23.4	38.6	31.0
	Urea 0.5 % + K_2SO_4 0.5 %	18.3	31.7	25.0	23.3	38.3	30.8
	Urea 0.5 % + K_2SO_4 1 %	17.9	26.8	22.3	32.3	36.0	34.2
	Urea 1 % + K_2SO_4 0.5 %	19.1	27.5	23.3	24.9	37.8	31.3
	Urea 1 % + K_2SO_4 1 %	18.4	26.1	22.2	28.6	34.5	31.6
	Mean	**18.4**	**27.6**	**23.0**	**26.5**	**37.0**	**31.8**
	General mean	**18.7 b**	**27.7 a**		**24.7 b**	**36.8 a**	
	CV (%)		**8.98**			**12.72**	

Considering the effects of different foliar fertilizer treatments before and after flowering periods on grain Zn and Fe concentrations, it was observed that both the years and the treatments were found to be significant (*Table 3*). Treatment periods (BF and AF) were not found to be significant (*Table 3*). In *Table 8*, 0.5% $ZnSO_4.7H_2O$,

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1% Urea+0.5% $ZnSO_4.7H_2O$ and 0.5% Urea+0.5% $ZnSO_4.7H_2O$ treatments resulted in significant increases in grain Zn concentrations as compared to the other treatments for both years and BF-AF periods. Similarly, higher grain Zn concentration results were obtained from the general averages of treatments (*Table 9*). Zinc sulphate heptahydrate and urea combination was more effective on grain Zn concentrations as compared to single $ZnSO_4.7H_2O$ treatment (*Table 8 and 9*).

Table 9. *Effects of different foliar fertilizer treatments and combinations on general mean of grain N, K S, Zn and Fe concentrations of Altınbaşak bread wheat cultivar*

	Applications	General Mean				
		K	**N**	**S**	**Zn**	**Fe**
		(%)			**(mg kg^{-1})**	
Ist Experiment	Control	0.352 ab	2.12 c	0.149	21.7 b	29.4 ab
	Urea 0.5 %	0.357 ab	2.26 a	0.147	21.3 b	29.5 ab
	Urea 1 %	0.345 b	2.20 b	0.146	21.7 b	29.2 ab
	ZnSO4 0.5 %	0.344 b	2.18 b	0.141	38.7 a	32.2 ab
	Urea 0.5 % + $ZnSO_4$ 0.5 %	0.344 b	2.21 ab	0.150	39.9 a	33.6 a
	Urea 1 % + $ZnSO_4$ 0.5 %	0.347 ab	2.20 b	0.146	39.3 a	33.7 a
	K_2SO_4 0.5 %	0.364 a	2.21 b	0.149	21.0 b	31.6 ab
	K_2SO_4 1 %	0.348 ab	2.20 b	0.149	21.8 b	27.7 b
IInd Experiment	Control	0.371	2.24 b	0.158	22.2 b	31.2
	Urea 0.5 % + K_2SO_4 0.5 %	0.365	2.23 b	0.151	24.4 a	29.6
	Urea 0.5 % + K_2SO_4 1 %	0.375	2.26 b	0.154	23.3 ab	31.5
	Urea 1 % + K_2SO_4 0.5 %	0.368	2.37 a	0.156	23.3 ab	31.9
	Urea 1 % + K_2SO_4 1 %	0.360	2.22 b	0.151	22.5 ab	29.1

It was stated in previous studies that when the sufficient Zn levels were supplied to the growth ambient for plants, both soil and foliar N treatments increased grain Zn concentrations (Kutman, 2010; Kutman et al., 2010; Cakmak et al., 2010). Yılmaz et al. (1997) indicated that soil, foliar, seed and combined Zn treatments yielded significant increases in plant and grain Zn concentrations. It was also reported that foliar zinc treatments improved Zn concentrations of the grains and especially of the endosperm (Jiang et al., 2007; Cakmak et al., 2010; Xue et al., 2012; Zhang et al., 2012).

As compared to control treatments in the second experiment, combined urea and K_2SO_4 treatments yielded significant increases in grain Zn concentrations (*Table 9*). Especially, the effects of 0.5% Urea + 0.5% K_2SO_4 treatments were more remarkable. Such a value was still behind the effects of urea+ $ZnSO_4.7H_2O$ treatments of the first experiment on Zn concentrations.

Orman and Ok (2012) reported that S treatments did not have significant effects on grain Zn concentrations under sufficient Zn conditions, but increased grain Zn concentrations under insufficient Zn conditions. In the same study, S treatments did not have significant effects on grain Fe concentrations under both sufficient and insufficient Zn conditions. Considering the general averages of the treatments of the first experiment, the greatest Fe concentration was obtained from combined urea and $ZnSO_4.7H_2O$ treatments and the lowest Fe concentration was obtained from 1% K_2SO_4 treatment (*Table 9*). Similar findings were also reported by the other researchers (Cakmak et al., 2010; Kutman, 2010; Kutman et al., 2010; Shi et al., 2010). In a study conducted by Kutman (2010), increasing N treatments increased Zn and Fe concentrations by up to 100%. Such an impact of N on Zn concentrations disappeared

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under insufficient Zn conditions; on the other hand, combined high N and Zn treatments resulted in synergic effect. Significant correlations were reported between the N transported to the grain by remobilization and Zn and Fe supplied to the grain by remobilization (Kutman et al., 2011). There are also some genetic findings about the close relationships between the nitrogen transported from aged leaf tissues into the grain and grain Zn and Fe concentrations (Uauy et al., 2006; Distelfeld et al., 2007; Waters et al., 2009).

Conclusion

It was concluded based on present findings that foliar fertilizer treatments generally had positive impacts on quality of wheat grains. In this sense, it was observed in both experiments that all treatments increased yield and sedimentation values as compared to the control treatments. In the first experiment, 0.5% urea treatment was prominent for yield, nitrogen and protein and urea+$ZnSO_4.7H_2O$ treatments for grain zinc and iron concentrations. In the second experiment, 1% urea+0.5% K_2SO_4 treatments were prominent for protein and grain nitrogen and 1% urea+1% K_2SO_4 and 0.5% urea+0.5% K_2SO_4 treatments for yield. Further research is recommended to be conducted with greater number of wheat genotypes about the effects of combined urea, K_2SO_4 and $ZnSO_4.7H_2O$ treatments on wheat yield, quality and grain Zn and Fe levels.

Conflict of interests. The author has not declared any conflict of interests.

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