

## The effect of NPK foliar fertilization on yield and macronutrient content of grain in wheat under Kostanai-Kazakhstan conditions

Coşkun Gülser <sup>a,\*</sup>, Zhenis Zharlygasov <sup>b</sup>, Rıdvan Kızılkaya <sup>a,c</sup>  
Niyazbek Kalimov <sup>b</sup>, İzzet Akça <sup>c,d</sup>, Zhaksylyk Zharlygasov <sup>b</sup>

<sup>a</sup> Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Samsun, Turkey

<sup>b</sup> Ahmet Baytursynov Kostanai State University, Agrarian and Biological Faculty, Kostanai, Kazakhstan

<sup>c</sup> Agrobigen Research & Development Trade Ltd.Co, Samsun Technopark, Samsun, Turkey

<sup>d</sup> Ondokuz Mayıs University, Faculty of Agriculture, Department of Plant Protection, Samsun, Turkey

### Abstract

The objective of this research were to determine the effects of foliar fertilization (20% N: 20% P<sub>2</sub>O<sub>5</sub>: 20% K<sub>2</sub>O) at different growth stages on yield and nutrient contents of spring wheat (*Triticum aestivum* L.) and to reveal proper application time and frequency in Kostanai-Kazakhstan conditions. The field experiment was conducted according to randomized plot design with four replications with a seeding rate of 500 seed per m<sup>2</sup> on the plots having a size of 5.0 m length and 4.0 m width. Foliar applications of the fertilizer at 1% rate were done at tillering (T), stem elongation (S), heading (H) stages of wheat and the combinations of these stages (T+S, T+H, S+H and T+S+H). Wheat yield values varied between the lowest 1.32 t/ha in the control and the highest 2.14 t/ha in the foliar fertilization done at tillering and stem elongation stages (T+S). According to control treatment, increases in grain yields by the foliar fertilization done at the different growth stages were determined as follows; T+S (61.7%) > T+H (47.4%) > T+S+H (41.8%) > S+H (41.6%) > T (38.5%) > S (19.1%) > H (16.6%). There was no significant difference among the macronutrient contents in grain obtained by the foliar fertilization at the different growth stages. N, P and K contents in the grain were close the values cited in the literatures. Ca and Mg contents deficiency in grain were determined due to the acidic soil pH condition of Kostanai-Kazakhstan. Nitrogen, P, K and Ca uptakes by grain, except Mg, generally increased with the all application of foliar fertilization. When the foliar fertilization was done at T+S stages, the highest macro nutrient uptakes by grain in wheat were generally obtained. This research indicated that the first foliar fertilization should be applied at the tillering stage and the best foliar fertilization management for high grain yield and nutrient uptake should be done two times at the combination of tillering and stem elongation stages.

**Keywords:** Wheat, grain yield, foliar fertilization, nutrient uptake.

### Article Info

Received : 10.10.2018

Accepted : 05.06.2019

© 2019 Federation of Eurasian Soil Science Societies. All rights reserved

### Introduction

The nutrients in soil have an important role in the crop nutrition to achieve higher yield, better growth and plant development. Fertilization is one of the most important parts of the crop growing technology and has the highest dynamic effect on the grain wheat yield economically (Ivanova et al., 2007). It is generally assumed that if fertilizers are applied in autumn or spring then all crop nutrient requirements can be met from the soil. It is not always true, for example particularly late in the season when abundant nutrients may

\* Corresponding author.

Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Samsun, Turkey

Tel.: +90 362 3121919

e-ISSN: 2147-4249

E-mail address: [cgulser@omu.edu.tr](mailto:cgulser@omu.edu.tr)

DOI: [10.18393/ejss.575026](https://doi.org/10.18393/ejss.575026)

be present in the soil but unavailable to a crop due to dry conditions. In this case, soil nutrient supply combined with internal re-translocation may not always be adequate for setting and filling the maximum number of grains, and crops might benefit from supplementary foliar applications of nutrients (Barracough and Haynes, 1995). Many studies showed that foliar fertilization at different growing stages of wheat increased grain yield over the control (Bhutto et al., 2016; Jarecki et al., 2017; Mikos-Szymańska, 2018). Rusek et al. (2016) found that the average yields of wheat were significantly higher about 30% after urea-superphosphate and concentrated superphosphate with urea fertilizers over the non-fertilized plots. They determined that N and P fertilization increased the N, protein and gluten contents in grains and had the positive effect on wheat quality. Czuba (1993) reported that nitrogen use efficiency (up to 160%) through foliar application was greater than soil application of urea. Sarandón and Gianibelli (1990) determined that foliar application of urea at the end of tillering increased dry matter yield, grain yield, harvest index and total N uptake by wheat and maximum grain yield was obtained with the application of N at sowing plus a foliar application at the end of tillering. In a field experiment by Khan et al. (2009), foliar application of urea in different concentrations and at different stages increased yield and yield components of wheat. Potassium nitrate is readily available and widely used in horticulture (Weinbaum, 1988), and in view of the well-known synergisms between N and K during uptake and translocation in plants, it would seem to be an ideal source of macronutrients for late, supplemental foliar feeding. Munson (1982) reported that nutrient uptake by wheat was 125 kg/ha N, 22 kg/ha P, 92 kg/ha K, 16 kg/ha Ca, 14 kg/ha Mg, and 14 kg/ha S when 8 t/ha of dry matter was produced. In a greenhouse study, low concentrations of KNO<sub>3</sub> (20 mM) sprayed on wheat at anthesis considerably increased grain numbers (Prakash and Joshi, 1973). In addition to their benefits, foliar fertilization may also help reduce the denitrification, leaching and immobilization, frequently related to N fertilization to the soil system (Gooding, 2005) by improving N use efficiency to a greater extent (Czuba, 1993). It is also reported that the foliar application of urea, applied at and after anthesis, is beneficial over soil treatments in increasing grain N content of wheat (Zhigulev, 1992). Gülser et al. (2017) reported that the application of 1.0% rate of foliar fertilization (10% N, 5% P<sub>2</sub>O<sub>5</sub>, 5% K<sub>2</sub>O) only at stem extension stage or together with tillering stage increased the yield components and raw protein contents of grains in wheat plant.

The objectives of this research were to determine the effects of foliar fertilization (20% N: 20% P<sub>2</sub>O<sub>5</sub>: 20% K<sub>2</sub>O) at different growth stages on yield and nutrient contents of spring wheat (*Triticum aestivum* L.) and to reveal proper application time and frequency in Kostanai-Kazakhstan conditions.

## Material and Methods

This research was carried out at the experimental field of Kostanai Agricultural Research Institute in Kazakhstan. Soil properties of the experimental field were determined on the soil samples taken from the field randomly before seeding. Soil samples taken from the field were air dried and sieved from a screen with 2 mm opening size to prepare for analysis. Sand, silt, clay contents of the soil samples were determined by Hydrometer method (Bouyoucos, 1962). Soil pH values were measured in soil suspension (1:1 w:v) by glass electrode pH meter and EC values were determined in the same soil suspension (1:1 w:v) by EC meter (Rowell, 1996). Soil organic matter (OM) contents were determined by modified Walkley-Black method, (Walkley and Black, 1934). Lime (CaCO<sub>3</sub>) contents of soils were determined by Scheibler calcimeter according to Nelson (1982). Some properties of the soil used in this research are given in Table 1. The soil of experimental field had sandy clay loam (SCL) textural class, moderate in organic matter content, acidic in soil pH, non-saline and limeless (Soil Survey Staff, 1993).

Table 1. Some properties of the experimental soil.

Clay, %	25.87	pH(1:1)	5.45
Silt, %	11.04	EC, dS/m	1.272
Sand, %	63.09	Organic matter, %	3.18
Texture	SCL	Lime (CaCO <sub>3</sub> ), %	1.06

Average climatic data of temperature and rainfall for long term in Kostanai are given in Figure 1. According climatic data, the highest mean temperature is on July (27°C) while the lowest mean temperature is on January (-23°C). The total precipitation per year is about 347 mm and the region receives the highest mean precipitation on July (61 mm) and the lowest precipitation is on December (10 mm).

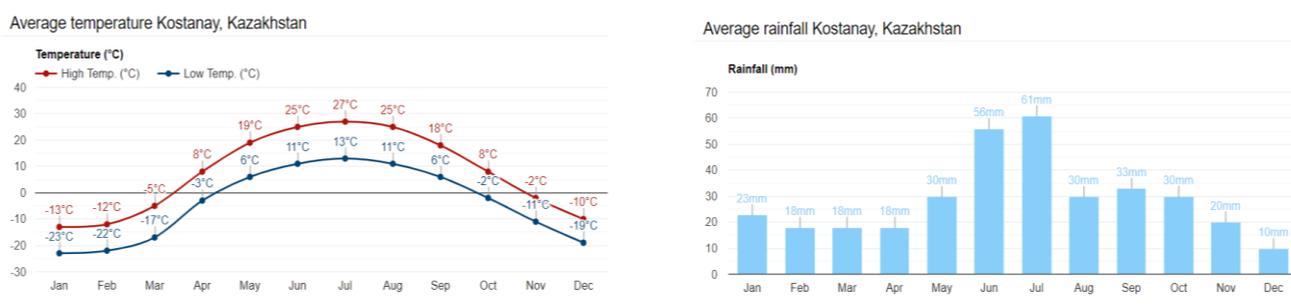


Figure 1. Climatic data for long term in Kostanai, Kazakhstan

A field experiment was conducted at the fields of Kostanai Agricultural Research Institute with randomized complete plot design having three replications. The plot size was kept 20 m<sup>2</sup> (5x4m) and 2 m spacing among the parcels was left to avoid edge effect. After ploughing and land leveling, seeds of spring wheat variety Omskaya-18 at a recommended rate of 500 seeds per m<sup>2</sup> were sown throughout the plots in 26.05.2016. In the control plots, only basic recommended NPK fertilization for wheat in Kostanai conditions was applied from soil and there was not foliar fertilization. Also, the basic NPK fertilization was applied for the experimental plots including foliar fertilization. The foliar fertilizations at 1% rate of totally water soluble fertilizer (20% N: 20% P<sub>2</sub>O<sub>5</sub>: 20% K<sub>2</sub>O) produced by Agrobigen R&D using with nano-technological methods were applied with spraying 0.5 L fertilizer solution to plant leaves in each plot to wet all plants completely at tillering (T), stem elongation (S), heading (H) stages of wheat and at the four combination times of these stages (T+S, T+H, S+H and T+S+H). The foliar fertilizations were applied at tillering stage in 25.06.2016, stem elongation stage in 12.07.2016 and heading stage in 23.07.2016.

In order to determine the foliar fertilization effect, ripened plants were harvested in 27 August, 2016. Plants from all plots were sampled to measure yield and yield criteria parameters and to analyze plant nutrient contents. Plant samples were dried at 65°C with aeration until reaching a constant weight. Dried plant samples were grained using a stainless steel grinder to make samples ready for analysis. Grained seed samples were placed in the oven at 450±50°C for 8 hours. Seed ashes were treated with 10 N HNO<sub>3</sub> and filtrated using blue band filter paper according to Jones (2001). Total nutrient contents of seed samples were determined in filtrated solutions by the following methods at the laboratory of Soil Science and Plant Nutrition Department of Ondokuz Mayıs University, Samsun-Turkey; total nitrogen (N) contents by Kjeldahl method, total Phosphorus (P) contents with the vanado-molybdophosphoric acid color method spectrophotometrically; total potassium (K), calcium (Ca) and magnesium (Mg) contents using Perkin Elmer A400 Atomic Absorption Spectrophotometer (Jones, 2001). Variance analyses and correlations for the data were done using SPSS programme and significant differences between the treatment means were shown Duncan test.

## Results and Discussion

### Effect of NPK foliar fertilization on grain yield in wheat

Foliar fertilization with 1% rate of NPK (20:20:20) at different grown stages of wheat under Kostanai-Kazakhstan conditions significantly increased the grain yield over the control application (Figure 1A). While the lowest grain yield (1.32 t/ha) was obtained in the control, the highest grain yield (2.14 t/ha) was obtained with the foliar fertilizations at the combination of T+S stages. Although the increase in grain yield by foliar fertilization made only at S and H stages was not significant, the foliar fertilization in T stages significantly increased grain yield over the control. The foliar fertilization made more than one times at the combination of wheat grown stages significantly increased the grain yield compared with the control. The percentage increases in grain yield according to the control are given in Figure 1B. Percentage increment effect of foliar fertilization at different growth stages on grain yield over the control were determined as the following order; T+S (61.7%) > T+H (47.4%) > T+S+H (41.8%) > S+H (41.6%) > T (38.5%) > S (19.1%) > H (16.6%). Khan et al. (2009) found that the wheat grain yield was increased by 32% when 4% urea solution was applied as foliar spray at tillering, stem elongation and boot stage. Jarecki et al. (2017) reported that three times foliar fertilization increased wheat grain yield over the control. Mikos-Szymańska et al. (2018) determined that the standard NPK soil fertilization plus calcium micronized suspension foliar fertilization at tillering and stem elongation stages had the highest grain yield in spring wheat compare to control by 15.7%. In another study, Maitlo et al. (2006) found that the foliar application of urea done at tillering and ear head emergence stages by the integrated application of urea through broadcasting significantly increased the

wheat grain yield (4.11 t/ha) over soil application urea alone (3.47 t/ha). Gülser et al. (2017) determined that total biological wheat yield varied between the lowest 5.44 t/ha in control treatment and the highest 7.38 t/ha in 1.0% rate of NPK (10:5:5) foliar fertilization treatment at stem extension stage. In this study, similarly it was found that 1% foliar fertilizations of NPK (20:20:20) at different growing stages showed significant increments in wheat grain yield over the control. It was determined that if one or more foliar fertilization will be applied regarding the growing stages of wheat, the first one should be applied at the tillering stage and the best foliar fertilization management for high grain yield was the combination of tillering and stem elongation stages.

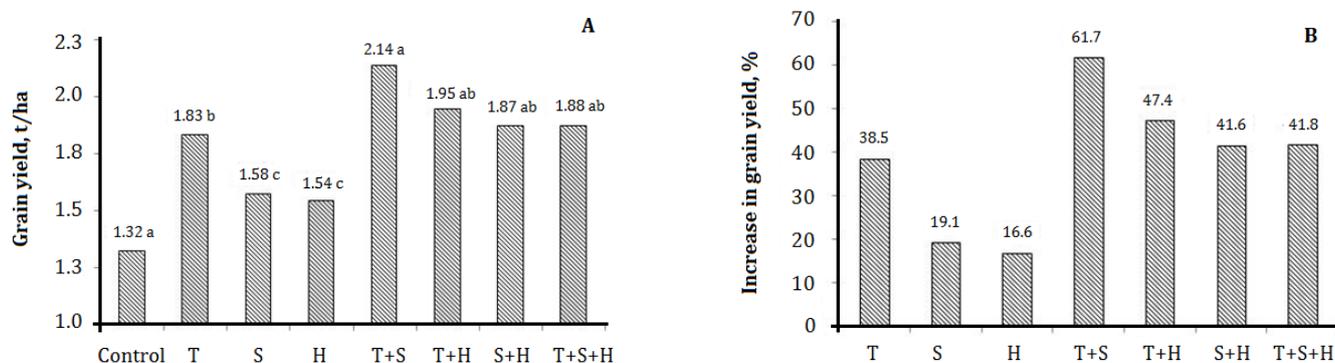


Figure 1. Effect of foliar fertilization at tillering (T), stem elongation (S) and heading (H) stages on wheat grain yield (A) and percentage increase in grain yield according to control (B).

### Effect of foliar fertilization macronutrient content and uptake by grain in wheat

The foliar fertilization at 1% rate of NPK (20:20:20) had no significant effect on macronutrient content of grain (Table 2). Smith et al. (2018) reported that increased grain yield by the N and P fertilization generally diluted grain nutrient concentration for P, Zn, Ca, K, Mg, and Mn. In this study, similarly N and Mg concentrations in grain generally decreased by the foliar fertilization and the concentrations of the other elements almost stayed stable due to dilution effect of increasing yield. While the highest N content (1.938%) was obtained in the control treatment, N content of grain generally decreased by the foliar fertilization. The highest P (0.404%) and K (0.563%) content were determined by the foliar fertilization applied at H stage. On the other hand, the highest Ca (0.017%) and Mg (0.089%) content were found by the foliar fertilization applied at T+S+H and S stage, respectively. Tiryakioğlu et al. (2014) found that there were high genotype effects for all macronutrients and plant organs and N, P, K, and Mg decreased during grain filling in all plant parts except the grain. They reported that the rate of decrease varied depending on plant organs and nutrients and grain nutrient concentration, except nitrogen content, increased up to physiological maturity, in contrast to the other nutrients, Ca content increased or remained stable depending on the plant organs. In this study generally, N and Mg concentrations in grain reduced with the application of foliar fertilization over the control when comparing with the other nutrients (Table 2). Ostrowska and Porebska (2017) indicated that N, Ca, Mg contents and Ca:Mg ratio of grain in wheat were 2.07%, 0.05%, 0.08% and 0.6, respectively. They reported that the Mg content higher than that of Ca in cereal grain and consequently the Ca:Mg ratios were lower than 1. The ratio of Ca:Mg is an indicator of Mg deficiency in plant and an imbalanced Ca:Mg ratio often negatively influences product quality (Gerendás and Führs, 2013). The ratio of Ca:Mg in cereals is an important parameter for human and animal health and the Mg content higher than that of Ca in cereal grain and consequently the Ca:Mg ratios are lower than 1. The low Ca content in plants is caused by intensive N fertilization in acidic soils (Ostrowska and Porebska, 2017). In this study, Ca content in grain was similarly low under the acidic soil condition.

Table 2. Effect of foliar fertilization on macronutrient content of wheat grain

Foliar fertilizations at grown stages	N, %	P, %	K, %	Ca, %	Mg, %	Ca:Mg
Control	1.938	0.356	0.532	0.013	0.078	0.169
Tillering (T)	1.803	0.377	0.529	0.013	0.058	0.229
Stem elongation (S)	1.858	0.393	0.504	0.014	0.089	0.156
Heading (H)	1.878	0.404	0.563	0.015	0.055	0.272
T+S	1.899	0.351	0.544	0.014	0.063	0.227
T+H	1.849	0.334	0.534	0.015	0.044	0.345
S+H	1.870	0.342	0.456	0.015	0.061	0.249
T+S+H	1.897	0.358	0.543	0.017	0.057	0.292

The foliar fertilization at 1% rate of NPK (20:20:20) significantly increased N, P, K and Ca uptakes by grain in wheat, except Mg uptake. The N uptake by grain varied between the lowest (25.6 kg/ha) in the control and the highest (40.6 kg/ha) in the foliar fertilization at T+S stages (Figure 2). Increments in N uptake over the control were significant in the foliar fertilization done at T, T+S, T+H, S+H and T+S+H stages ( $p>0.01$ ). Increasing total N uptake also reflects the increase total protein content in grain of wheat plant. Siuliauskas et al. (2001) found that 30 kg N/ha, applied as foliar spray during heading and at the beginning of milky ripeness increased wheat yield upto 8.54 t/ha and protein content up to 15.29%. Khan et al. (2009) reported that integrated application of N through soil and foliage facilitated the higher N uptake in plants. They determined that the highest mean N uptake of 149.9 kg/ha was in the treatment where 6% urea solution sprayed at tillering, stem elongation and boot stage, which was significantly higher than all other treatments. In another study, Maitlo et al. (2006) found that the 2.5% foliar application of urea done at tillering and ear head emergence stages by the integrated application of urea through broadcasting significantly increased the N uptake by grain (59.36 kg/ha) over soil application urea alone (25.96 kg/ha). Gülser et al. (2017) reported that the highest raw protein content (18.5%) and the yield components in wheat was determined over the control with the application of 0.5% rate of foliar fertilization (10% N, 5%  $P_2O_5$ , 5%  $K_2O$ ) at tillering plus stem extension stages. Similarly in this study, the highest protein amount or N uptake by grain in wheat was determined with the foliar fertilization done at the T+S stages.

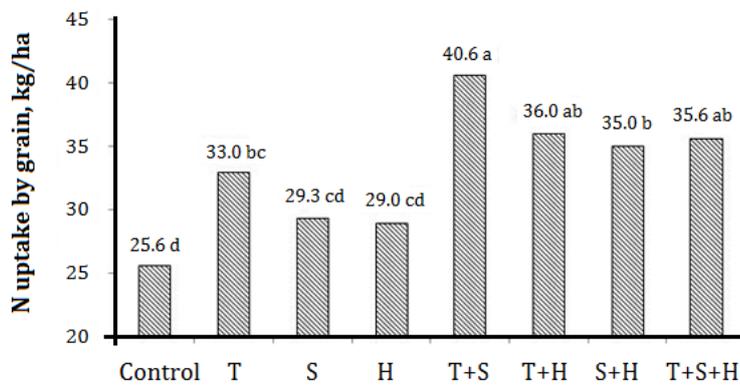


Figure 2. Effect of NPK foliar fertilization at tillering (T), stem elongation (S) and heading (H) stages on N uptake by grain in wheat ( $p>0.01$ ).

The P uptake by grain varied between the lowest (4.65 kg/ha) in the control and the highest (7.45 kg/ha) in the foliar fertilization at T+S stages (Figure 3). Increments in P uptake over the control were significant in the all foliar fertilization treatments ( $p>0.05$ ). The K uptake by grain also varied between the lowest (7.05 kg/ha) in the control and the highest (11.58 kg/ha) in the foliar fertilization at T+S stages (Figure 3). Increments in K uptake over the control were significant in the foliar fertilization done at the T, T+S, T+H, T+S+H stages ( $p>0.01$ ). Maitlo et al. (2006) determined that the 2.5% foliar application of urea done at tillering and ear head emergence stages by the integrated application of urea through broadcasting significantly increased the P and K uptakes by grain (20.00 kg/ha and 24.65 kg/ha) over soil application urea alone (16.89 kg/ha and 20.89 kg/ha), respectively.

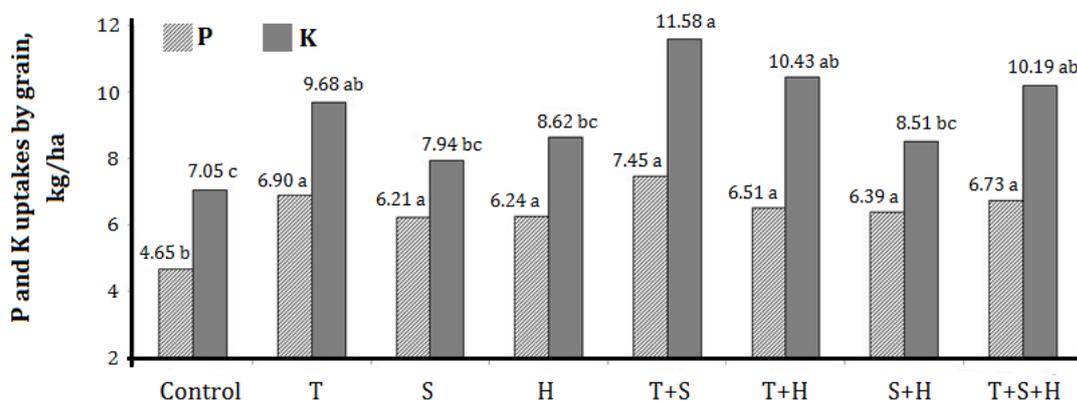


Figure 3. Effect of NPK foliar fertilization at tillering (T), stem elongation (S) and heading (H) stages on P ( $p>0.05$ ) and K ( $p>0.01$ ) uptakes by grain in wheat.

While the Ca uptake significantly increased by the foliar fertilization ( $p > 0.01$ ), there was no significant effect of foliar fertilization on Mg uptake over the control (Figure 4). It was found that the highest Ca uptake (0.31 kg/ha) was obtained by the foliar fertilizations done at the T+S and T+S+H stages, the lowest Ca uptake (0.17 kg/ha) was determined in the control. Except the foliar fertilization done at H and T+H stages, Mg uptake by grain generally increased by the foliar fertilization compared with the control. The highest Mg content (1.40 kg/ha) was determined with the foliar fertilization done at S stage. [Klikocka \(2018\)](#) reported that the uptake of K, Mg and Ca by grain significantly increased in direct proportion to the increase of the N fertilization dose and was the highest after application of 120 kg N/ha (K–22.55, Mg–8.36 and Ca–2.28 kg/ha).

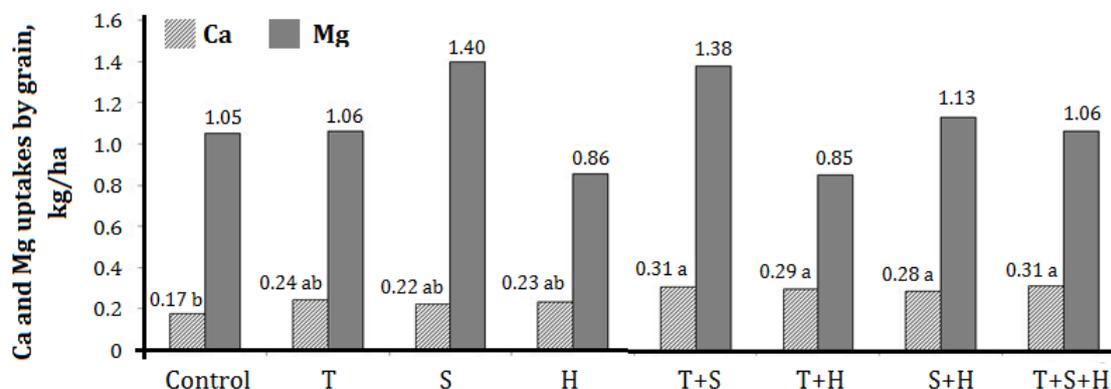


Figure 4. Effect of NPK foliar fertilization at tillering (T), stem elongation (S) and heading (H) stages on Ca ( $p > 0.01$ ) and Mg uptakes by grain in wheat.

The grain yield showed insignificant negative correlations with N (-0.218), P (-0.395), K(-0.163), Mg(-0.264) and insignificant positive correlation with Ca (0.042) contents. However, the significant correlation coefficients between the grain yield and uptake of macroelements by grain showed the following order; N (0.966\*\*) > K (0.752\*\*) > Ca (0.651\*\*) > P (0.631\*\*). [Klikocka et al. \(2018\)](#) determined that the correlation coefficients between grain yield and the content of macroelements decreased in the order Mg > Ca > K > P and the strength of the relationship between grain yield and uptake of macroelements by grain had the following order P > Mg > K > Ca.

## Conclusion

The 1% rate of foliar fertilization (20% N: 20% P<sub>2</sub>O<sub>5</sub>: 20% K<sub>2</sub>O) applied at the different growth stages increased the grain yield of wheat. The highest grain yield (2.14 t/ha) was determined with the foliar fertilization applied at the tillering plus stem elongation (T+S) stages compared with the control (1.32 t/ha). Increased grain yield by the foliar fertilization generally diluted macro nutrient content in grain. Therefore, there was no significant difference in macronutrient content in grain among the foliar fertilization done at the different growth stages and their combinations. Although N, P and K contents in the grain were close the values cited in the literatures, Ca and Mg contents were lower than the values indicated in the different studies. It shows that there are Ca and Mg deficiency in the gain grown under the acidic soil pH condition of Kostanai-Kazakhstan. The Ca:Mg ratio in grain for all treatments was lower than 1. Besides the basic N, P, K fertilizers, foliar or soil fertilizers including Ca and Mg should be used for wheat growth in this region. Macro nutrient uptakes by grain, except Mg, generally increased with the all foliar fertilization. The highest macro nutrient uptakes by grain in wheat were generally obtained with the foliar fertilization done at the T+S stages due to the highest grain yield. It can be suggested that if one or more foliar fertilization will be applied during the growing stages of wheat, the first one should be applied at the tillering stage and the best foliar fertilization management for high grain yield and nutrient uptake was the combination of tillering and stem elongation stages.

## Acknowledgements

The authors would like to thank the Agrobigen R&D Ltd.Co., Turkey (Project No. AGROBIGEN.2016.01.01) for financial support.

## References

[Barracough, P.B., Haynes, J., 1995. The effect of foliar supplements of potassium nitrate and urea on the yield of winter wheat. \*Fertilizer Research\* 44\(3\): 217–223.](#)

- Bhutto, M., Shah, A.N., Leghari, U.A., Jatoi, G.H., Khaskheli, M.A., Khanzada, A., 2016. Growth and yield response of wheat (*Triticum Aestivum* L.) as affected by foliar fertilization of zinc. *Science International (Lahore)* 28(4): 4189-4192.
- Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal* 54(5): 464-465.
- Czuba, R., 1993. The results of leaf nutrition of field crops. Part II. Response of plants to foliar application of micronutrients or nitrogen combined with micronutrients. *Roczniki Gleboznawcze - Soil Science Annual* 44(3/4):79-87 [in Polish].
- Gerendás J., Fühns, H., 2013. The significance of magnesium for crop quality. *Plant and Soil* 368(1-2): 101-128.
- Gooding, M.J., 2005. Foliar urea fertilisation and the management of yield and quality in wheat. Proceedings of the International Fertiliser Society No. 573. Available at [Access date: 10.10.2018]: <http://www.fertiliser-society.org/Proceedings/US/Prc573.HTM>
- Gülser, C., Kızılkaya, R., Küren, N., Oy, G., Yalçın, U., 2017. The effect of foliar fertilizer produced from biogas waste on yield and protein content of wheat. ICAFOF, International Conference on Agriculture, Forest, Food Sciences and Technologies, 15-17 May 2017., Cappadocia, Turkey, Book of Proceedings. p 260.
- Ivanova, A., Nankova, M., Tsenov, N., 2007. Effect of previous crop, mineral fertilization and environment on the characters of new wheat varieties. *Bulgarian Journal of Agricultural Science* 13 (1): 55–62.
- Jarecki, W., Buczek, J., Bobrecka-Jamro, D., 2017. Response of spring wheat to different soil and foliar fertilization. *Journal of Central European Agriculture* 18(2): 460–476.
- Jones, Jr.J.B., 2001. Laboratory guide for conducting soil tests and plant analysis. CRC Press, New York, USA. 363p.
- Khan, P., Memon, M.Y., Imtiaz, M., Aslam, M., 2009. Response of wheat to foliar and soil application of urea at different growth stages. *Pakistan Journal of Botany* 41(3): 1197-1204
- Klikocka, H., Marks, M., Barczak, B., Szostak, B., Podleśna, A., Podleśny, J., 2018. Response of spring wheat to NPK and S fertilization. The content and uptake of macronutrients and the value of ionic ratios. *Open Chemistry* 16(1): 1059–1065.
- Maitlo, A., Hassan, Z.U., Shah, A.N., Khan, H., 2006. Growth, Yield and Nutrient Uptake of Wheat (*Triticum aestivum* L.) in relation to Foliar and Soil Application of Urea. *International Journal of Agriculture and Biology* 8 (4):477-481.
- Mikos-Szymańska, M., Borowik, M., Wyzińska, M., Rusek, P., 2018. Effects of different fertilizer treatments on grain yield and yield components of spring wheat. *Research For Rural Development* 2: 100-106.
- Munson, R.D., 1982. Potassium, calcium, and magnesium in the tropics and subtropics. International Fertilizer Development Center. Technical Bulletin Series T-23. Muscle Shoals, TN, USA. 62p.
- Nelson, R.E., 1982. Carbonate and gypsum. In: Methods of Soil Analysis, Part 2, Chemical and microbiological properties, Second Edition. Number 9, Page, A.L., Keeney, D. R., Baker, D.E., Miller, R.H., Ellis, R. Jr., Rhoades, J.D. (Eds.). ASA-SSSA, Madison, Wisconsin, USA. pp. 181-198.
- Ostrowska, A., Porębska, G., 2017. The content of calcium and magnesium and the Ca:Mg ratio in cultivated plants in the context of human and animal demand for nutrients. *Journal of Elementology* 22(3): 995-1004.
- Parkash, V., Joshi, Y.C., 1973. Influence of foliar feeding of kinetin and potassium nitrate on the grain setting of wheat. *Agrochimica* 17: 238-242.
- Rowell, D.L. 1996. Soil Science: Methods and Applications. Longman, London, UK. 368p.
- Rusek, P., Mikos-Szymańska, M., Karsznia, M., Sienkiewicz-Cholewa, U., Igras, J., 2016. The effectiveness of nitrogen-phosphorus fertilization in winter wheat (*Triticum aestivum* L.) cultivation. *Bulgarian Journal of Agricultural Science* 22(5): 752–755
- Sarandón, S.J., Gianibelli, M.C., 1990. Effect of foliar urea spraying and nitrogen application at sowing upon dry matter and nitrogen distribution in wheat (*Triticum aestivum* L.). *Agronomie* 10(3):183-189.
- Siuliauskas, A., Vaguseviciene, I., Liakas, V., 2001. Additional fertilization of winter wheat through leaves. *International Conference on Sustainable Agriculture in Baltic States*. 28-30 June 2001, Tartu, Estonia.
- Smith, E.G., Janzen, H.H., Ellert, B.H., 2018. Effect of fertilizer and cropping system on grain nutrient concentrations in spring wheat. *Canadian Journal of Plant Science* 98(1): 125-131.
- Soil Survey Staff, 1993. Soil Survey Manual. USDA Handbook No:18 Washington, USA.
- Tiryakioğlu, M., Yildirim, M., Karanlık, S., 2014. Macronutrient concentration and remobilization in spring wheat organs during grain filling. *Turkish Journal of Agriculture and Forestry* 38: 488-494.
- Walkley, A., Black, I.A., 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37(1): 29-37.
- Weinbaum, S. 1988. Foliar nutrition in fruit trees. In: Plant growth and leaf applied chemicals. Neumann, P.M. (Ed.). CRC Press, Boca Raton. USA. pp. 81-100.
- Zhigulev, A.K., 1992. Effect of foliar application of nitrogen fertilizers on yield and quality of winter wheat grain. *Agrokimiya* 3(3): 3-9.