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EFFECT OF MICRONUTRIENTS APPLIED TO WINTER WHEAT

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Abstract

Foliar fertilization provides plants with the nutrients needed for optimal development much faster compared to conventional (root) fertilization. Each element has an important role in plant metabolism. To evaluate the influence of micronutrients, the liquid fertilizer whose content is shown in table 1 was experimented in the southern area of Romania on the Izvor variety, for two consecutive years (2020-2022). The research was carried out according to the method of randomized blocks, in three repetitions, with four foliar applications. These were: FA 0 (control), FA 1 (one foliar application) to FA 4 (four foliar applications). Application intervals were seven days, and the first foliar application was made seven days after full emergence. The results indicated that the effect of micronutrients can be significant in terms of yield, 1,000-grain weight and harvest index. Also, the interaction between year and foliar application was significant for chlorophyll b production and 1,000-grain mass. The experimental variant with the 4 foliar applications indicated a 15% increase in productivity. So, foliar application of micronutrients is a more efficient procedure in the field of wheat nutrition compared to the soil application method due to the higher absorption rate. Research shows that foliar fertilization can be an effective method to supplement and stimulate root uptake of elements to increase productivity.

Key words: *chlorophyll, foliar fertilization, micronutrients, productivity, wheat.*

INTRODUCTION

Wheat (*Triticum aestivum*) is the most cultivated plant in the world and the fourth world crop in production after sugarcane, corn and rice. Wheat grains and its derivatives are part of the current diet. The stalks left after harvesting are used as a raw material in the manufacture of cellulose, as well as in animal feed or as organic fertilizer. The dregs, which are residues from the milling industry, represent a concentrated feed, rich in protein and mineral salts.

Climate change became a serious threat and its consequences affect many aspects of life in all regions of the world. They affect food security by reducing the production of cultivated plant species. The high productions of wheat obtained in Romania are primarily conditioned by the precipitations that fell in the appropriate amount since sowing and during the vegetation period, as well as by the fertilization applied to obtain a higher quality wheat.

Wheat reacts positively to the application of fertilizers. For normal growth and development, plants need nutrients. The importance and role of each can lead to a maximum exploitation of the genetic potential of the plants and the obtaining of appropriate harvests. Foliar fertilization is an effective way for nutrient deficiency treatments, to improve plant nutrition status and to help plants surpass stress periods (Haraga & Ion, 2023).

Micronutrients are essential elements that are used by plants in small quantities and it is proven that the yield and quality of agricultural products can be increased by their application.

Each essential element can only do this if it can correctly fulfill its role in plant nutrition and is not in an unbalanced relationship with other elements necessary for the plant. Micronutrient application substantially improves leaf area index, crop growth rate, net assimilation rate, relative growth rate, grain yield, chlorophyll content and biological yield as well as harvest index of wheat (Ganpat, 2019).

Choosing the moment of their application is important to achieve a maximum level of efficiency of their use, which contributes to achieving maximum productivity along with minimizing the impact on the environment. The time of application must be synchronized with the time of maximum need in developing plants. Foliar feeding is recommended to be done during periods of low temperature and relatively high humidity. The best results of feeding can be obtained during cloudy weather, in the early morning or in the evening.

Currently, fertilizers (minerals) are responsible for providing 50% of global food production. In 1960, 1 ha of land provided food for 2 people, while in 2025, 1 ha of land will have to provide food for 5 people. So, increasing yield and producing higher quality crops requires the adoption of new methods of plant nutrition, and foliar fertilization is more effective because it can provide balanced nutrition to plants, enhance photosynthesis and plant stress resistance. According to Vidyashree et al. (2022) micronutrients, both individually and in combination, have a considerable impact on crop growth rate. Plant development is aided by the addition of micronutrients, which promote photosynthesis and other physiological functions.

Micronutrients like Fe and B presents essential roles in plant's life cycle, while iron is important for the respiration and photosynthesis processes (Rawashdeh & Sala, 2015).

Plants consume 16 essential mineral elements. They get carbon and oxygen from the air, hydrogen from water, and the rest from the soil. The lack of a sufficient amount of any nutrient can affect the growth and health of the plant, reducing production. Iron (Fe) has an important role in respiration processes as well as in the life cycle of plants and for normal growth along with B (Fageria, 2007). Magnesium (Mg) is an activator in the photosynthesis process (Israel Zewide & Abde Sherefu, 2021), being present as a central ion in the composition of chlorophyll. Through the yield of photosynthesis, it quantitatively influences production, and through the products of this basic process, it also has an involvement in the quality of plant production. Zinc (Zn) is indispensable for plants. Activates plant growth processes, increases resistance to frost and drought. The lack of zinc leads to a decrease in production, the degradation of grain quality, to the appearance of chlorosis in whitish-yellow bands on the leaves. Zn is required as a structural and functional component of many enzymes and proteins and increases productivity and its components in wheat (Moghadam et al., 2012). Boron is important in pollen viability, flowering, fruiting and seed production.

The present work addresses the effectiveness of the use of foliar fertilizers on the Izvor variety, a variety created by INCDA Fundulea and recommended for expansion in production, especially in areas with a higher frequency of drought in the areas of southern Romania.

MATERIALS AND METHODS

The experiment took place in the southern part of Romania (44°11′12″N 24°15′52″E). According to meteorological data, this region has an increasingly hot summer and a relatively cool dry winter. The research was carried out during two consecutive cultivation seasons (2020-2022). The tested wheat variety was Izvor, which was created by NARDI Fundulea, Romania. The area of each experimental plot was 4m long and 4m wide, i.e. 16 m^2. The soil preparation before sowing was carried out in the second decade of October 2020, respectively 2021. A basic fertilization was applied with 250 kg/ha Diammonium phosphate (DAP 18:46:0), before sowing and 200 kg/ha Ammonium nitrate (NH_4NO_3, 33.5%), 50% at the end of winter and 50% in spring.

To study the effect of micronutrients on this variety, its productivity and components, a dose of 2 liters of liquid micronutrient fertilizer/1000 liters of water was applied by spraying on the leaves and their influence was analyzed according to the data in Table 1.

The first foliar spray was carried out 7 days after full emergence and the second after another 7 days, then the others were applied in the spring at 7 day intervals. Maintenance work was based on standard wheat farming practices.

Table 1. The microelements of liquid fertilizer (mg/L)

Fe (mg)	Mg (mg)	Zn (mg)	Mn (mg)	Cu (mg)	B (mg)	Other microelements
200	550	49	54	30	60	plant growth stimulants, auxins, cytokinins, gibberellins, organic amino acids

Observations were made and data recorded both during the growing season and at harvest in both seasons.

Samples were taken randomly at mid and late growth stages of wheat. Characters such as: leaf color chart (LCC), chlorophyll a, chlorophyll b, carotenoid content, 1,000 grains weight, grain yield and harvest index were evaluated in this work. Samples were collected from plants originating from a square (0.5 m x 0.5 m) and measurements were made with the electronic caliper. Chlorophyll content was measured with an at LEAF CHL BLUE chlorophyll meter with Bluetooth 0131-58 Ver 1.2.

To determine the greenness of the leaves, their color chart (LCC) was used. Based on chart instructions, leaf color was measured 14 days after full emergence in two separate stages. The color chart of the leaves was read between 2 and 4 p.m. For the reading of the color chart of the leaves, 10 leaves chosen at random from the middle part of the experimental plots were used. For this, the longest leaf of each plant was selected and the central part of the leaf was placed on the LCC.

To determine the amount of carotenoids, the pigments were extracted with methanol and the amount of light absorbed was measured using a spectrophotometer. For this procedure, a puncture was used and three leaf parts from the middle part were selected for extraction. Then the selected pieces were placed in 20% methanol solution and kept in the refrigerator for 24 hours. After this time, the pigments were separated by an extraction pump and placed inside a spectrophotometer to determine the percentages of carotenoids based on their wavelength.

At harvest, the mass of 1,000 grains and the harvest index were determined. The mass of 1,000 grains was performed by counting ten samples of 1,000 grains each and weighing them with balances. In order to calculate the harvest index, five plants were harvested from each plot, kept in the farm for 24 hours, until the moisture content reached about 13%. After threshing, the grain and straw weights were determined and then the harvest index was calculated as a percentage of the economic yield divided by the biological yield.

The variance analysis has been done at the end of each year, in compliance to experimental design. The diagrams were made using Microsoft office word and Excel software. The collected data were subjected to analysis of the variance method performed utilizing the ANOVA program to determine the statistical significance of the effect of foliar application treatments. When the F-values was significant, LSD test was performed for means comparison.

RESULTS AND DISCUSSIONS

Many researchers have reported the positive effects of foliar application to increase yield and yield component. The results obtained after performing the calculations using the variance analysis method showed that the effect of the foliar treatment with micronutrients was significant for some of the characters analyzed in the thermal and the rainfall regime of the area. The 2020-2021 agricultural year was less favourable, but good for cereals, while 2021-2022 was characterized as an extremely dry year in Oltenia, with the phenomenon of moderate pedological drought setting in, which reduced the harvest (https://gov.ro).

The values for chlorophyll *a* and *b*, the content in carotenoids, the greenness of the leaves, the production, the mass of 1000 grains and the harvest index are presented in Tables 2 and 3. The highest content in chlorophyll *a* was recorded in the variant FA 4 (0.58 mg. g^{-1}fwt), while the lowest content was achieved in the FA 2 variant (0.31 mg. g^{-1}fwt) (Figure 1). Chlorophyll *b* content was affected by foliar application of micronutrients, so the difference between chlorophyll *b* content and the control was significant.

Table 2. The effect of micronutrients foliar application on yield and yield characteristics of wheat (average 2021-2022)

Treatments	Chlorophyll *a* (mg.g^{-1}fwt)	Chlorophyll *b* (mg.g^{-1}fwt)	Leaf greenness	Carotene (mg.g^{-1}fwt)	Grain yield (kg/ha)	TGW (g)	Harvest index (%)
FA 0	0.38 d	0.93 c	2.56 d	0.306 c	7000 e	40.2 d	34.4 b
FA 1	0.37 d	1.10 b	3.54 abc	0.315 c	7926 d	41.8 c	35.1 b
FA 2	0.31 e	0.95 c	3.45 bc	0.260 d	8130 c	42.5 bc	40.0 a
FA 3	0.41 cd	1.0 c	3.80 ab	0.336 c	8410 b	43.6 ab	40.6 a
FA 4	0.58 a	1.44 a	3.85 a	0.431a	8516 a	45.0 a	42.0 a

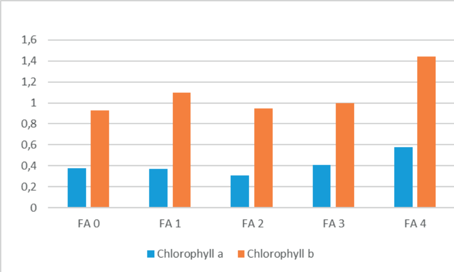

Figure 1. Effect of foliar application of micronutrients on chlorophyll *a* and *b* content

Leaf chlorophyll is a key indicator of leaf greenness determination and it is a characteristic often used to investigate leaf nutrient deficiencies and its changes (Ali et al., 2017). The interaction between foliar application and experimental year was not significant for leaf greenness. Based on the results obtained in the two years, FA 4 (3.86) had the highest number on the leaf color chart, followed by FA 3, and the lowest value was achieved by the control (2.7) (Figure 2).

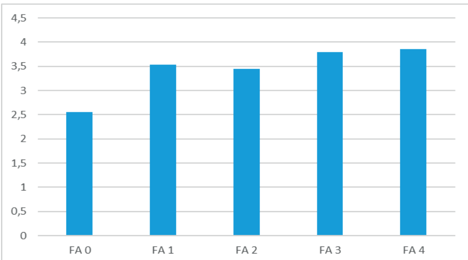

Figure 2. Effect of foliar application with micronutrients on leaf greenness

The highest carotene content was recorded in FA 4 (0.431 mg. g^{-1}fwt) and the lowest in FA 2 (0.255 mg. g^{-1}fwt) based on the comparison of the average of statistical data over two years (Figure 3).

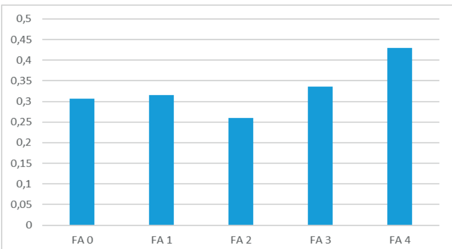

Figure 3. Effect of foliar application with micronutrients on carotene content

In the treatments with some biofertilizers on sweet corn, these does not leaded to a significant increase in the total content of carotenoids (Soare et al., 2023).

Grain production was significantly lower in the control compared to the micronutrient treatments. However, there were no remarkable differences between grain production and foliar application of micronutrients. The highest grain yield was recorded in FA 4 (8516 kg/ha), and the lowest in the control (7000 kg/ha) (Figure 4). 1,000 grains weight was also affected by foliar applications of micronutrients and significant difference was observed between foliar treatments and control at 1% probability level (Table 4). Also, the interaction effect between foliar application and year showed a significant difference. Moreover, the mean comparison over the two years indicated that the highest 1,000 grains weight was obtained in FA 4 (45.0 g) and the lowest was recorded by the control (40.2 g) (Figure 5).

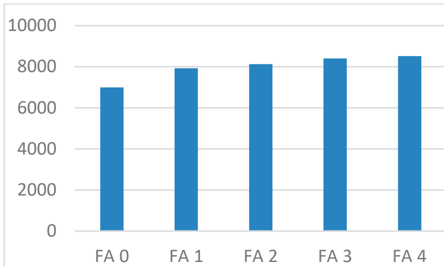

Figure 4. Effect of foliar application of micronutrients on yield (kg/ha)

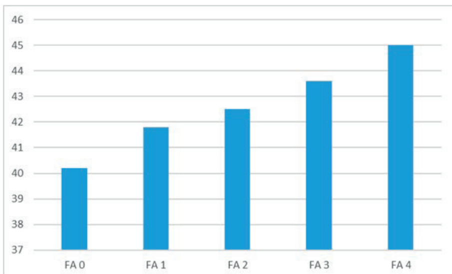

Figure 5. Effect of micronutrient foliar application on TGW (g)

Productivity enhancement due to macronutrients may play a role in increasing 1,000 grains weight. The response of Izvor wheat variety to these various treatments had an impact on TGW, although Constantinescu et al. (2020) sustain that the 1,000 grains weight is not influenced by the fertilization level but is influenced by the variety because it is a genetic impregnated character.

Evaluation of the efficiency of other three accepted inputs for organic agriculture on wheat, sunflower, maize and soybean also evidenced positive effects on yield parameters in comparison with control variant (Madjar et al., 2022).

The interaction between foliar application and experimental year, for chlorophyll *b*, carotenoid content and 1,000 seed weight, was also significant. The comparison of the average of the two consecutive years indicated that the highest content in chlorophyll *b* was recorded in the FA 4 variant (1.44 mg. g^{-1}fwt), and the lowest amount in the control variant (0.93 mg. g^{-1}fwt).

The highest harvest index was achieved at FA 4 (42%), but which was not significantly different from the other treatments applied by spraying the leaves. The lowest harvest index was obtained in the control variant (34%).

Table 3. Variance analysis of the micronutrients foliar application effect on plant characters of Izvor wheat variety (average 2021-2022)

SOV	DF	Leaf greenness	Chlorophyll *a* (mg.g^{-1}fwt)	Chlorophyll *b* (mg.g^{-1}fwt)
Year	1	ns0.04	0.004ns	0.0118 ns
Error 1	4	0.34	0.003	0.0026
Foliar application	4	0.89	0.046**	0.0178**
FA x year	4	0.069 ns	0.004 ns	0.0071**
Error 2	16	0.09	0.004	0.0015
Total	29			
CV (%)		8.27	12.47	9.69

ns, *, ** = not significant, significant at P level of 0.05 and 0.01

Table 4. Variance analysis of the micronutrients foliar application effect on yield and plant characters of Izvor wheat variety (average 2021-2022)

SOV	DF	Carotene (mg. g^{-1}fwt)	Grain yield (kg/ha)	TGW (g)	Harvest index (%)
Year	1	0.0032ns	7036.2ns	5.336ns	0.22ns
Error 1	4	0.0085	1721.4	1.08	4.22
Foliar application	4	0.4149**	9348**	11.8**	90.90**
FA x year	4	0.0191**	1983.9ns	4.04**	5.98ns
Error 2	16	0.0045	3688.05	1.19	3.28
Total	29				
CV (%)		8.0	15.30	3.95	3.50

ns, *, ** = not significant, significant at P level of 0.05 and 0.01

The statistical results showed that the influence of foliar application of micronutrients was significant in terms of grain yield, 1,000 grains weight and harvest index. Also, the interaction between year and foliar application was significant in terms of chlorophyll *b* and TGW production. According to these data, it can be concluded that in the variant FA 4 where the grain production was 8516 kg/ha, compared to the control variant which achieved only 7000 kg/ha, it shows an improvement of about 15%.

The average wheat grain yield on farms from southern Romania is 6.0 t. In 2022, only 4.3 t/ha were obtained, 25% lower than in 2021 due to the drought. Also, some products, administered foliar had a positive influence on millet yields (Enea et al., 2023).

Foliar fertilization helps to establish the nutritional balance of plants, with visible effects in a short time after application, and optimizes yield, eliminating variability from one year to another. To increase the efficiency of the use of active substances, the method of application is of particular importance for the superior utilization of fertilizers in the wheat crop.

The wider expansion of fertilization with liquid fertilizers is determined by the advantages they confer. They allow partial or even total satisfaction of the macro- and microelements required for wheat culture.

Foliar fertilization can contribute to reducing the effect of drought, a phenomenon with significantly increased incidence in recent years, ensuring the normal development of plant nutrition (Burlacu et al., 2007).

Chlorophyll is an essential factor in the process of photosynthesis and so improves the wheat yield (Ciulcă et al., 2020). Also, chlorophyll is one of the most important photosynthetic pigments and controls the photosynthetic potential of plants by capturing light energy from the sun. The micronutrients (Zn, B and Mn) are essentially involved in metabolism of rice and wheat plants, including chlorophyll synthesis, photosynthesis, enzyme activation and membrane integrity (Nadeem & Farooq, 2019).

Based on the statistical results, the chlorophyll *a* content was significantly affected by the foliar application of micronutrients compared to the control variant (Table 3). It is possible that foliar fertilization, which plays a crucial role in chlorophyll synthesis, has significant effectiveness in increasing the chlorophyll content of wheat plant cells. In a similar study by Sarwar et al. (2013) but on rice, it was reported that its phenological response to different levels of micronutrients under calcareous soil conditions in all treatments was significant and the use of zinc alone or in combination with boron led to increased chlorophyll content. Concomitant intake of essential micronutrients appears to affect the percentage formation of chlorophyll. This also has a particular influence on the rate of photosynthesis by increasing light absorption and accelerating the relevant processes, so in some of the uses, micronutrients have a direct role in improving nitrogen fixation.

The stimulation of the photosynthesis process was highlighted by Sîrbu et al. (2022) which reported an increase of yields and also the concentrations measured for chlorophyll *a* and *b* and carotene in wheat crop. The leaf chlorophyll content provides a key indicator of the photosynthetic capacity and in combination with measurements such as leaf area index has been found to be a critical for productivity and prevailing stress in vegetation (Boegh et al. 2002).

Carotenoids are composed of carotenes and xanthophylls, and represent another key photosynthetic pigment group. According to the data presented in Table 3, the amount of carotenoids registered a significant improvement when micronutrients were used, compared to the control variant.

The interaction between foliar fertilization and year of experiment was also significant at the same level. Facilitative processes related to nitrogen metabolism, improvement in the rate of decomposition and synthesis, and acceleration of nitrogen reduction reactions are some of the factors that contributed to the importance of the leaf color chart in the foliar spray treatments compared to the control. The results indicated a significant increase in the productivity of fertilizers used during the growing season.

Related to the effective factors for increasing grain production that foliar application of micronutrients could directly play, we can refer to facilitating the process of ear formation, improving grain formation and ripening, activating enzymes responsible for protein synthesis. In this experiment, the effect of foliar application of micronutrients on wheat yield index was significant at the 1% probability level (Table 3). By affecting the indices related to production and its components, it is evident that the harvest index, which is directly related to grain yield, was also affected by micronutrient spraying. Therefore, increasing grain production is likely to have a direct influence on the harvest index percentage. In this sense and in a study carried out on rice, Ghasemi et al. (2014) reported that the highest harvest index and maximum 1,000-grain weight were obtained by the interaction of zinc, iron and manganese sulfate fertilizers. Khan et al. 2010 reported that foliar application with Fe, Mn, Zn, Cu and B micronutrients increased some morphological characters such as plants height, TGW, harvest index, grain yield, etc. The results obtained in these experiment are in accordance with Gomaa et al. (2015) which showed that the highest grain and yield components and quality of wheat grain obtained by foliar application of both Zn and Fe. Also, Ali et al. (2009) and Moghadam et al. (2012) reported that foliar application of B and Zn increased the yield and yield components of wheat. Raza et al. (2014) mentioned that foliar application of B has positive effect on grain yield, number of grains per spike and 1000-grain weight.

The influence of micronutrients can be much more obvious if they are applied to plants grown on less fertile soil. Foliar application of micronutrients is a more effective procedure in the field of wheat nutrition compared to the soil application method due to the higher absorption rate. Due to the low mobility of micronutrients in the soil structure as a result of physico-chemical constraints (abnormal pH and EC in most farms, which is due to the inappropriate use of basic fertilizers on the soil at the beginning and in the middle of the growing season), spraying the leaves with nutrients essential is a determining factor for plant nutrition and increased wheat production. Application of micronutrients can certainly increase the rate of uptake of essential nutrients, especially when leaf surface area is less. Results obtained from this study showed that thanks to the microelements contained in the foliar fertilizer, the plants develop in optimal conditions and fight more effectively against potential stress factors. The lack or deficiency of one or more nutrient deficiencies represents a factor/s that influences the yield. The determination of the appropriate dosage of nutrients helps to increase the variety yield and also ensures crop health, consistency of soils and of the environment.

CONCLUSIONS

Foliar fertilization can be an easy way to correct certain nutrient deficient and at the same time a safe way to make better use of basic fertilization.

Foliar application of liquid fertilizer to Izvor wheat variety leaded to the obtaining of significant statistically increases in production compared to control variant as a result of the intensification of some physiological processes. This experiment could be put in the practice by farmers relatively easy and fertilization with micronutrients led to better growth and development of wheat plants, even in less favorable conditions.

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