PROVOCATION STUDY OF A LONG-TERM EXPERIMENT IN WINTER WHEAT USING ZN FOLIAR FERTILIZERS APPLIED AT DIFFERENT TIMES

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Abstract. *Due to extreme climatic conditions, we must increase our attention to prevent yield loss and the quality of deterioration caused by abiotic stress effects. Nowadays, the drought stress that weighs on our area requires unusual changes both in breeding and agrotechnical aspects. Therefore, to achieve a reasonable nutrient replenishment, provision of macroelements (nitrogen, phosphorus, potassium) for the cultivated plants is not enough, but we have to replace the microelements, depending on the environmental conditions. The different microelements, such as zinc, copper and molybdenum, in Hungarian soils are available in different amounts and conditions, and their availability depends on many external factors such as phenological phase, soil condition, temperature, etc. Therefore, in my studies, we apply zinc foliar fertilizers in three different doses during different phenological phases of winter wheat (bushing and flag leaf expansion). By the substitution of zink, we aim to reduce the abiotic stress effects of the plant during the vegetation, with which we also expect an indirect effect on the yield and content parameters of the treated plants. The specificity of our experiment is that there has been a long-term wheat monoculture experiment at the study site since 1998. The properties of winter wheat cultivars are studied in four different nutrient levels, where the ratios of nitrogen, phosphorus and potassium are: 60: 0: 0, 90:30:30, 120: 60: 60 and 150: 60: 60. We perform the same three treatments on all nutrient levels. In addition to the control plots, the first treatment was applied in 1l/ha and the second 2l/ha in the process of bushing, and the third treatment was applied in two installments, 1l/ha in the process of bushing and 1l/ha in flag leaf extension. After the harvest, we measure the yield, and among the content parameters, the protein and the gluten content. In the first year of the experiment, although foliar fertilizer treatments did not show a significant effect on the yield, an interaction between zinc and nutrient levels was discovered. Nor can we detect a significant difference between the different foliar fertilizer treatments and the control plots in terms of content parameters either. Although we did not obtain positive results for the zinc treatments, we can see a correlation between changes in the proportion of macronutrients and the efficiency of zinc for all parameters studied.*

Keywords: *Winter wheat, Foliar application, Zn, Long term experiment*

INTRODUCTION

Today, sustainability is playing an increasingly important role in modern agriculture. However, a number of previous negative experiences have contributed to the development of this new and useful approach. Climate change, which has a long-term impact on our environment and, at the same time, on efficient agricultural production potential, is already having obvious consequences. Desertification, extreme weather conditions, lack of crop rotation, excessive use of pesticides and fertilizers now also pose problems for researchers and growers that can no longer be remedied by many years of production experience and entrapment. In addition to radical attitudes, continuous innovation in agricultural production is needed to meet the needs of a growing population with the least possible environmental impact.

In order to meet the growing demand for food raw materials globally and increasingly determining agricultural production, the main goals of breeders include the breeding of plant varieties that can be grown well even in extreme weather conditions, have good adaptability and are resistant to pathogens and pests. However, we can effectively contribute to reducing negative impacts and increasing yields not only through breeding, but also through specific agrotechnical practices (soil cultivation, nutrient supplementation, plant protection, water management) developed for each crop species, or even for each variety and growing area. Among abiotic stress effects, changes caused by micronutrient deficiencies are almost negligible in different parts of the plant, but can result in yield losses of up to 10-30%, depending on sensitivity. Different microelements such as zinc, copper and molybdenum are present in different amounts and in different states in the soil of Hungary. The uptake of macro- and micro-nutrients from the soil depends on a number of factors: the phenological phases of the plant, the physico-chemical properties of the soil, climatic factors, the cultivation method, etc. If one of these conditions is not met, even adequate amounts of nutrients in the soil become unavailable to the plants, and deficiency diseases may occur. Nowadays, therefore, smart nutrient supplementation practices not only mean providing macro-nutrients (nitrogen, phosphorus, potassium) to crops to achieve adequate yields (KRISTÓ ET AL. 2007., KRISTÓ ET AL. 2008.), but also require supplementation of micro-nutrients, depending on the environmental conditions.

Winter wheat is one of the dominant crops in domestic production. In recent decades, wheat production technology has changed significantly, inputs have decreased and weather anomalies due to climate change have a major impact on the yield. However, a variety that has been bred over many years can only reach its genetic potential if the site and growing conditions are suited to its needs(JAKAB ET AL. 2018, KRISTÓ ET AL. 2019.).

Winter wheat is one of the most important crops in domestic production. For a long time, its cultivation area has been close to 1 million hectares per year, the yield exceeds 5 million tons per year, and the average yield is around 5.5 tons / hectare, depending on the vintage. Over the past decades, wheat production technology has changed significantly, inputs have decreased and weather anomalies due to climate change have a major impact on the yield. However, a variety that has been bred over many years can only reach its genetic potential if the site and growing conditions are suitable for the needs of the variety (SZABÓ. 1987). With the exception of extreme growing areas in Hungary, winter wheat can be grown economically throughout the country, but among the agrotechnical factors, the judicious fertilization of winter wheat has a significant effect on yield (PEPO. 1995). Proper nutrient replenishment requires knowledge of the amount and dynamics of the nutrients taken up by the plant, the effect of the pre-sowing, the nutrient supply capacity of the soil and the growing objectives. According to the nutrient uptake dynamics of wheat, the plant takes up 90% of the nutrients needed to form the crop until the beginning of the calving period. In addition to the macroelements, the role of essential microelements is not negligible, as their deficiency can reduce the efficiency of nitrogen-phosphorus-potassium fertilization (BERGMANN AND NEUBERT. 1976). Their deficiency also reduces yields, increases the stress effect and may result in susceptibility to pathogens (JAGODIN. 1984; BERGMANN AND NEUBERT. 1976). Numerous domestic and foreign research and practice show that wheat is one of the most important crops that can sustainably meet the food needs of a growing population, based on its cultivability, adaptability and positive value-added properties.

In the soil, the uptake of individual nutrients through the roots depends on a number of factors. They can bind to soil particles to varying degrees (e.g., clay content, pH), and the physical state of the soil (moisture content, compaction, aeration) can also affect the amount of nutrients available and uptake by plants (WOJTKOWIAK ET AL., 2014). In addition, the different nutrients interact: antagonism between some and synergism between others. Plants are able to take up nutrients not only through the roots, but also, to a lesser extent, through the leaves. Foliar fertilizers, or plant conditioners, are not considered as pesticides, but are important additives in nutrient replenishment (HARNOS ET AL., 2009). For some elements, foliar feeding is more efficient and economical under certain physiological conditions (SCHMIDT ET AL. 2005; SZAKÁL ET AL., 2006). In addition to basic fertilization with macroelements, foliar fertilization with complex or individual elements is becoming increasingly important (IZSÁKINÉ, 1987). Foliar fertilisers are used when there is a relative or absolute deficiency of a nutrient in the production area and the crop would suffer significant damage until the fertiliser doses applied to the soil are used up. The use of foliar fertilizers has become increasingly common in intensive agricultural practice, as they provide rapid and direct nutrient supply to plants at almost any phenological stage of the plant. In addition to macronutrients, micronutrients play a particularly important role in wheat production. The role of the latter is mainly reflected in the smooth functioning of life processes. If they are lacking, yields can be reduced and quality deteriorate. The importance of micronutrients is determined primarily by the physiological needs of the plant, but the quantity that can be found and absorbed in the soil must also be taken into account. Among the trace elements, zinc (Zn) is an essential element, essential for the life processes of living organisms. In wheat, the importance of zinc is in seed formation and root growth and in maintaining disease resistance. In the past decades, Zn deficiency has been a serious problem in arable land (PÉNTEK A., 2016). It is an essential microelement for plants, a significant enzyme component and enzyme activator. It is actively involved in protein metabolism and plant growth regulation by stimulating auxin production. It ensures the stability of membranes in cells (KÁDÁR I., 1979). Substances released as a result of zinc deficiency (sucrose, flavorings, extracts) attract plant-damaging pathogens to the leaf. Based on this, it can be said that zinc fertilization also contributes to disease control. It is present in small amounts in the soil, its mobility is poor, and it tends to increase with decreasing pH. The plant takes up Zn2 + ion or chelated form from the soil (MENGEL, 1976). Several studies have confirmed the antagonistic interaction of zinc and phosphorus in soil. Studies on this began in the first half of the 20th century. Nevertheless, THORNE (1957) concluded that, although phosphates act against the solubility of zinc in soil, it is doubtful that the formation of Zn deficiency can be explained by direct Zn precipitation by phosphates. In Hungary, POLLHAMMERNÉ (1973, 1981) carried out successful copper and zinc fertilization experiments to improve the quality of winter wheat. PECZNIK (1976) also used copper and zinc compounds in his experiments and demonstrated their positive effect on quality. RÓZSA AND HER COLLEAGUES (2011) investigated the effect of a basic zinc carbonate complex on winter wheat. Their experiments have shown that zinc has a positive effect on both the yield and quality parameters of winter wheat. The observations of TÓTH ET AL. (2018) in the border of Bogyiszló, on a weakly acidic, strongly zinc-deficient potassium-deficient loam soil, showed similar results. In Turkey, studies by İLKNUR A. (2017) showed that elevated doses of zinc had a positive effect on wheat nutritional parameters, especially its baking values. Similar results were obtained by PECK ET AL. (2008). In their studies, zinc foliar fertilization was used to influence the protein content of wheat.

In my research I compare the yield and content values of four winter wheat cultivars. The treatments will examine the effect of zinc-containing foliar fertilizers applied twice in the phenological phase in three different doses in a long-term cereal monoculture experiment.

MATERIALS AND METHODS

Growing area

The experiments are set up in a small plot monoculture fertilization trial in four nutrient levels in four replications in a random block design, conducted since 1998 at the Szeged-Öthalom site of the National Agricultural Research and Innovation Centre.

The topography is flat, the soil is slightly alkaline, with a deep saline meadow chernozem, with an organic matter content of between 2.8 and 3.2%. Moderate N, good P2O5, good K2O, gold like concentration (KA): 42.

In 2019, an extended soil survey was conducted in the area, which revealed that the soil in the experimental area was zinc deficient, so foliar fertilizer treatments were designed to supplement the micro-nutrient zinc.

Soil preparation started on the 10th of October with disc harrowing, followed two days later by ploughing, rolling and combining.

The sowing date was 17th of October 2020. The net plot size was 9 m^2 in all cases, the gross plot size was 12 m^2 and the row spacing was 12 cm (8 rows per plot). Sowing was carried out with a Wintersteiger Oyord plot seeder.

Varieties of winter wheat

In the experiment, the results were averaged over four different varieties of winter wheat.

Cellule is a medium-large winter wheat with a spiny kernel and milling quality. Yield potential: 9-12 t/ha, stable, high yields even in dry years, resistant to fungal diseases.

Ns Zvezdana: a middle-aged, malting-quality variety, bred in Novi Sad. Good winter hardiness and resistance to fungal diseases (mainly leaf and stem rust, powdery mildew). Average yield potential: 5,6-7,7 t/ha.

Gk Petur: an intensive variety with excellent nutrient response, capable of high yields and malting quality, whatever the vintage. It produces excellent yields mainly in the north-eastern regions and for many years in Romania, and is moderately resistant to diseases. It has been the variety tested in the current monoculture trial since its inception. Yield potential: 6,5-8,5 t/ha.

Gk Pilis: an early maturing winter wheat variety, with a high yield and A1 quality. It is prolific and has excellent bushing ability. Good resistance to the main diseases, powdery mildew, leaf and stem rust. Yield potential: 6,5-8,5 t/ha

Foliar fertilizer treatments

In the experiment, 4 treatments were performed as follows: application of the control (non-foliar fertilized) and a mono microelement-containing foliar fertilizer composition in three different doses during bushing and flag leaf spreading.

The tested foliar fertilizer contains a concentrated amount of a microelement that can alleviate the rate of crop loss due to unfavorable environmental conditions for wheat and the deterioration of quality parameters (eg gluten content, protein content).

Crop harvesting

Harvesting was carried out with a Wintersteiger-type plot combine on 9th of July 2020, at full maturity. At harvest, the wheat harvested by the combine was collected in bags and the yield per plot was determined using a digital scale. For quality testing, 600-600 g samples were taken from each replicate of each treatment per variety in individually marked paper bags and the crude protein content and wet protein content were determined using a Foss Infratec1241 NIR grain analyser. Statistical evaluation of the data was carried out using the two-factor analysis of variance method with the aid of Microsoft Excel. The probability level was P=0.05 as used in agricultural practice.

RESULTS AND DISCUSSIONS

Yields

Figure 1st shows the effect of fertilizer treatments on yields for the average of the winter wheat varieties studied. Compared to the plots treated with nitrogen alone, the 90-30-30 NPP treatment increased winter wheat yield by 10%, the 120-60-60 NPP treatment by 23% and the 150-60-60 NPP treatment by 27%, which was statistically confirmed at the 5% significance level. A statistically significant difference was also found between 60-0-0 and 120-60-60 and 150-60-60 nutrient levels and between 90-30-30 and 150-60-60 nutrient levels.

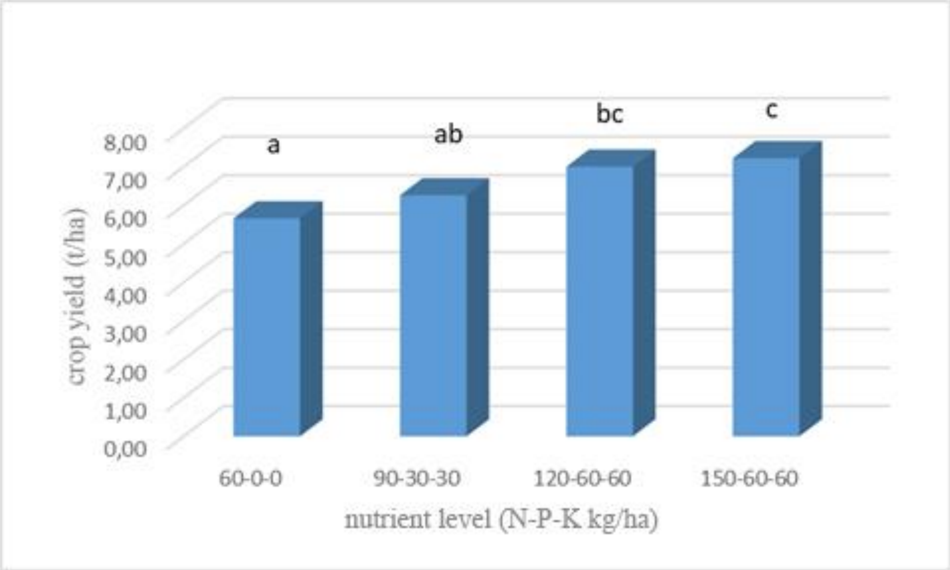

Figure 1. Evolution of yield (t/ha) with different fertilizer treatments

Figure 2nd shows that there is no significant difference in yield between the treatments when examining the effect of foliar zinc fertilizer treatments. It is also observed that the control plots as a whole produced a higher average yield compared to the treated plots. Compared to the control, the first treatment resulted in a yield reduction of 0.9%, the second in a yield reduction of 2% and the third in a yield reduction of 0.9%.

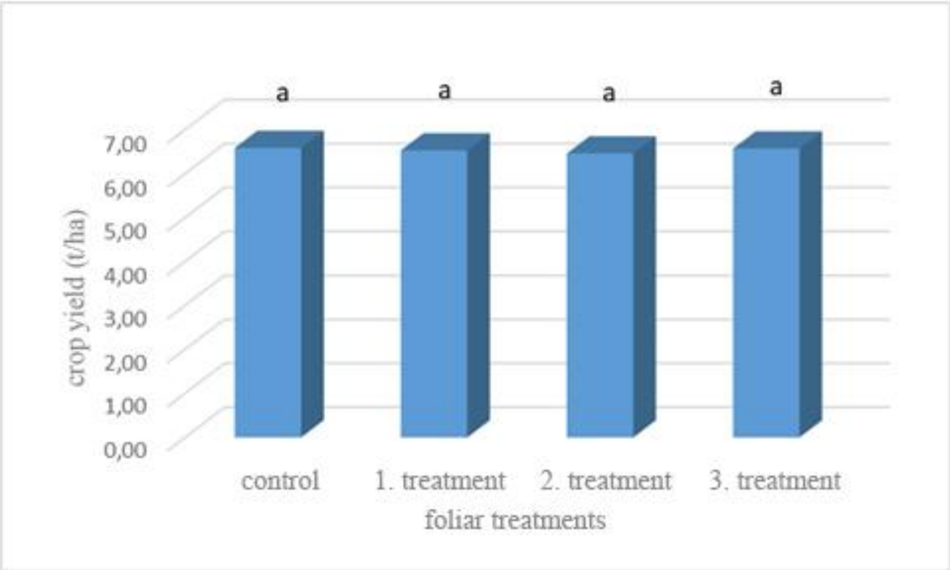

Figure 2. Yield trends (t/ha) for the treatments tested, averaged over the varieties

Table 1st shows the results as a function of nutrient levels and zinc foliar fertilizer treatments. No statistically significant difference between treatments was obtained for any of the nutrient levels, but higher yields (3-27%) were obtained with increasing nutrient levels, both for the control and treated plots. At the lowest nutrient level (60-0-0), the lowest yield (5.6 t/ha) was obtained when comparing the results of the control and the three foliar fertilizer treatments. The second nutrient level (90-30-30) showed an increase in yield (7-13%) compared to the results of the first nutrient level, but without significant difference. At the third nutrient level (120-60-60), significantly higher yields (22-27%) were obtained in the control plots and in the first and third treatments compared to the lowest nutrient level. However, at the fourth nutrient level (150-60-60), the control and all treatments together gave significantly higher yield differences (24-30%) compared to the lowest nutrient level (60-0-0).
The treatments produced better yields than the control in only one case, at the 60-0-0 nutrient level. This yielded the lowest yield of 5.6 t/ha, while the highest yield was also obtained in the control plots at the 150-60-60 nutrient level. The results obtained show the effectiveness of increasing nutrient levels, but we could not measure a clear, verifiable effect on yield between treatments.

Table 1.

Yield trends (t/ha) for the treatments and nutrient levels tested

SD_5%=1,23	treatments			
nutrient levels	control	1.treatment	2.treatment	3.treatment
60-0-0	5,60	5,73	5,68	5,65
90-30-30	6,35	6,28	6,10	6,33
120-60-60	7,10	7,03	6,83	7,08
150-60-60	7,30	7,10	7,25	7,25

1.1. Results of the grain nutrient contents

The crude protein content and the gluten content were measured. The results were compared with the average of the cultivars, nutrient levels and foliar treatments.
The protein and gluten content has measured at the average of the 4 different winter wheat varietes. The results has been compared by the nutrient levels and the leaf fertilizer treatments.

1.1.1. Protein

Figures 3rd and 4th show the evolution of protein content by nutrient levels and foliar fertilizer treatments for the average of the varieties studied. Statistically proven, only for the different nutrient levels were significant differences in the average protein content of the varieties found. The protein content of the grain increased with increasing nutrient levels. Compared to the 60-0-0 nutrient dose, the 90-30-30 nutrient level was observed to be 0.75% higher, the 120-60-60 nutrient level 0.92% higher and the 150-60-60 nutrient level 1.38% higher in protein content, and only between the 90-30-30 and 120-60-60 nutrient levels no statistically significant difference was found (Figure 4).

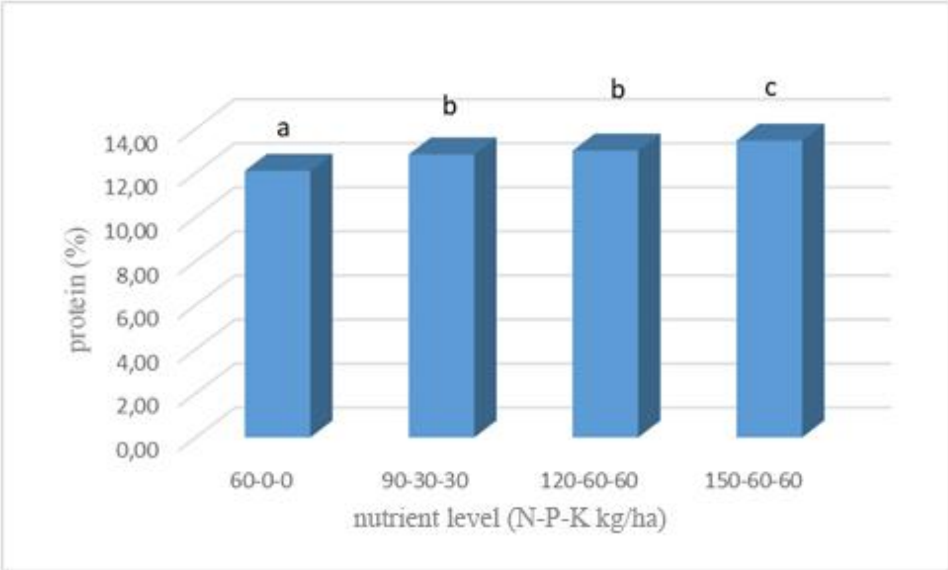

Figure 3. Protein content of grain yield (%) at different nutrient ratios

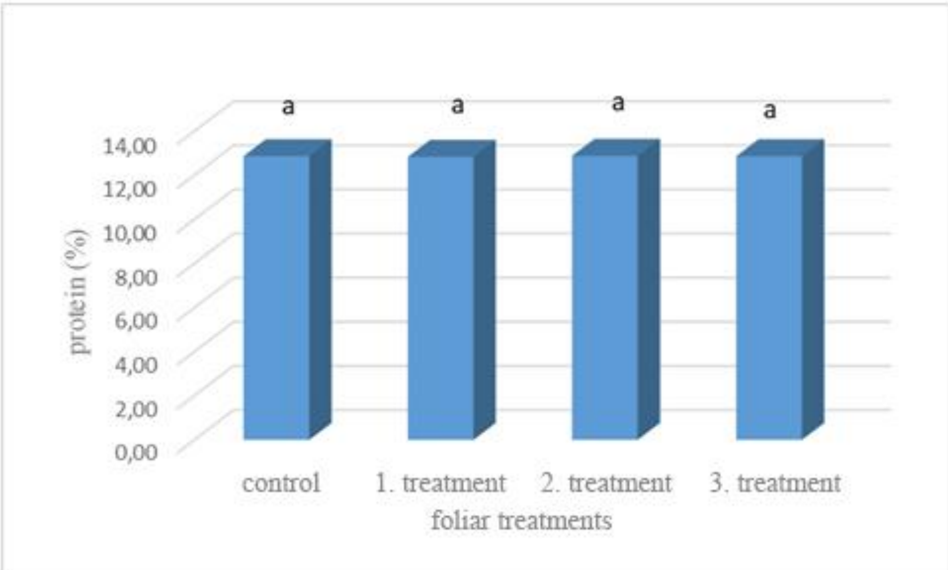

Figure 4. Protein content of grain yield (%) for different foliar treatments

The increase in nutrients increased the protein content of the crop in both control and treated plots (0.7-1.3%), but no significant difference was obtained between the two values. Except for the 150-60-60 nutrient level, where treatments 2 (13.54%) and 3 (13.53%) produced higher protein content compared to the control (13.43%), the control plots had the higher results for all other nutrient levels. When looking at the results of the treatments, a significant difference was obtained between the control and the lowest nutrient levels of the different treatments and the results for all other nutrient levels. There was statistical evidence that the addition of P and K increased the protein content in the crop regardless of the foliar fertilizer treatments applied (Table 2).

Table 2.

Crude protein content of grain yield (%) at different nutrient rations and foliar treatments

$SD_5\%$=0,5	Treatments			
nutrient levels	control	1.treatment	2.treatment	3.treatment
60-0-0	11,98	12,06	12,17	12,19
90-30-30	12,94	12,78	12,88	12,78
120-60-60	13,12	13,08	12,93	12,95
150-60-60	13,43	13,41	13,54	13,53

1.1.2. Gluten

Figure 5th shows the evolution of the grain yield gluten content at each nutrient level, averaged over the varieties tested. The highest average value (29.1%) was obtained at the 150-60-60 nutrient level, while the lowest (24.56%) was obtained at the 60-0-0 nutrient level. A statistically significant difference was observed between 60-0-0 and all other nutrient levels. However, no significant difference was found between the results of the 90-30-30 and 120-60-60 nutrient levels and between the results of the 120-60-60 and 150-60-60 nutrient levels, as the nutrient levels increase, the grain yield will also be higher. Compared to the 60-0-0 nutrient level, we measured a 2.6% increase in gluten content at the 90-30-30 nutrient level, a 3.4% increase at the 120-60-60 nutrient level and a 4.4% increase at the 150-60-60 nutrient level.

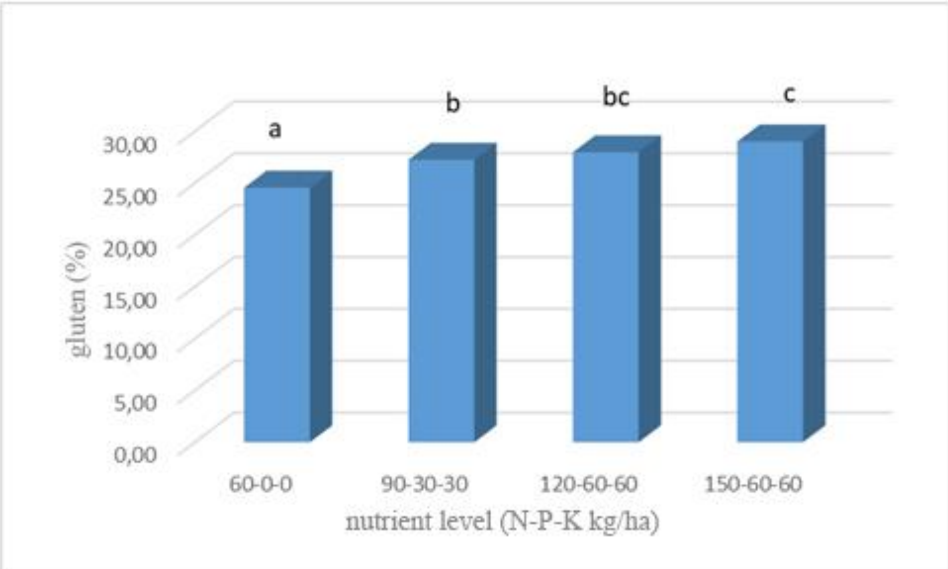

Figure 5. Gluten content (%) of grain yield at different nutrient ratios

In Figure 6th, the average of the foliar fertilizer treatments is shown for the tested varieties. The values varied between 27.04-27.3 %, which did not show statistically significant differences.

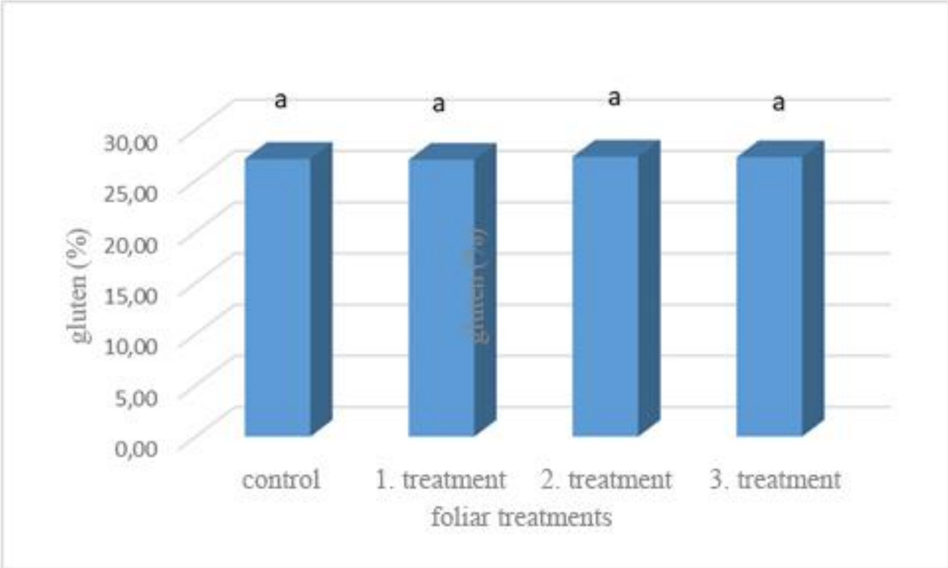

Figure 6. Gluten content (%) of grain yields under different treatments

No significant difference was obtained between the values obtained for the control and treated plots at any nutrient level. Only at the 150-60-60 nutrient levels, we obtained higher values (0.39%) in the treated plots (treatments 2nd and 3rd) than in the control. When examining the different treatments, we found that the lowest nutrient levels without phosphorus and potassium gave the poorest results, and we showed statistically that adding and increasing phosphorus and potassium significantly increased the grain yield in terms of gluten content.

Table 3.

Gluten content (%) of grain yields at different nutrient rates and foliar treatments

$SD_5\%$=1,58	Treatments			
Nutrien levels	control	1.treatment	2.treatment	3.treatment
60-0-0	23,70	24,62	24,98	24,93
90-30-30	27,64	26,58	27,54	27,21
120-60-60	28,29	28,18	27,61	27,81
150-60-60	28,83	28,78	29,21	29,21

CONCLUSIONS

In the first year results, there was no detectable effect of foliar zinc fertilizer on either yield or yield. In all cases, increasing nutrient levels increased both yield and content. Although no positive results were obtained with zinc treatments in the study, a correlation between the change in the ratio of macroelements and the efficiency of zinc was observed for all the parameters studied.

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