BIO Web of Conferences **125**, 01002 (2024) https://doi.org/10.1051/bioconf/202412501002
ABS 2024

Effects of Vinasse and zinc complex on the yield, crude protein, and gluten of winter wheat

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Abstract. The primary goal of agricultural production is to produce adequate quantity and quality of crops. One crucial aspect of this is providing the appropriate nutrients to plants. In recent times, there has been a growing emphasis on replenishing micronutrients beside macronutrients, as essential microelements, although in smaller quantities, are indispensable for the cultivation of our crops. In our three-year small-plot experiments, the effect of two foliar fertilizers, Vinasse, which is a by-product of alcohol production, and a zinc complex on the yield, crude protein, and gluten content of winter wheat, was investigated. The effects of these formulations when applied as foliar fertilizers separately and together, at doses of 50, 100, 250 and 500 l/ha for Vinasse and 0.5 kg/ha for zinc complex, were examined. Based on the results of the small-plot experiments set up in the fall of 2020 and 2021 and harvested in the summer of 2021 and 2022, it can be concluded that using Vinasse + zinc complex treatments a higher yield and better content indicators were achieved compared to the control plots. The highest dose of Vinasse (500 l/ha) + zinc complex (0.5 kg/ha) had the greatest positive effect on yield values.

1 Introduction

Winter wheat (*Triticum aestivum* L.), which is one of the world's most valuable and widely cultivated cereals, has a production area of around 245–250 million hectares worldwide. Its importance as a national food is only approached by rice. Its wide distribution was made possible by the diverse climatic needs and good adaptability of wheat species and varieties [1].

Wheat is used for food mainly in the form of its flour. Its field of use is wide; they mostly make bread from it, but apart from bread, there are many other ways of use in the baking, pasta and confectionary industries. The multifaceted use also includes the fact that wheat is a high-quality fodder, and its by-products are also valuable. Wheat straw is a valuable bedding material - possibly as a feed substitute – in addition to this its industrial use has also come to the fore (straw cellulose production, energy, etc.). Wheat is also the most important cereal in our country which is grown about on 1 million hectares every year [1].

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Winter wheat was chosen as the subject of this investigation because of its very important role in agricultural production. The study on the supply of plants with different nutrients at the Department of Water Management and Natural Ecosystems of the Albert Kázmér Mosonmagyaróvár Faculty of Széchenyi István University under the direction of Professor Pál Szakál has a long history. According to Buzás [2], plant nutrition plays an enormous (approximately 50–60%) role in the success of the quantitative and qualitative production of plants.

The structure of the plant body could be determined quite precisely with plant analyses carried out using different methods. These elements are usually grouped in various ways based on their quantity and role in the plant. As early as 1957, Vinogradov [3] suggested that the amounts should be used as a basis for the division of nutrients. The elements occurring in larger quantities are called macro elements (N, P, K, Ca, Mg, S), while the elements occurring in smaller quantities are called microelements (Fe, Mn, Cu, Zn, Mo, B). Győri [4] used the term macronutrient only for NPK elements, and called Ca, Mg, S elements "mesonutrients" for the sake of distinction.

The function of micronutrients is partially different from that of macronutrients, as they do not function as basic building blocks. They do not play a primary role in increasing crop yield, but based on their functional role, they are indispensable in plant biochemical processes, e.g. ensuring the smooth operation of enzymes [4]. Most of our country's soils are deficient in zinc and, to a lesser extent, in copper [5]. Due to possibly inhibited transport processes, their absence can often be detected even in plants grown in soils which are well supplied with copper and zinc. Knowing the soil composition, it is also possible to improve the quality in addition to increasing the yield by replacing the microelements showing a deficiency [6, 7]. In domestic copper-deficient soils, the beneficial effect of different types of copper-complex compounds on the fungicide and on the quality and yield of wheat was also proven [8, 9, 10].

There is a lot of talk about circular farming nowadays, and the perfect example of this is the agricultural use of Vinasse, since one of the "wastes" from sugar beet-based sugar production is returned to crop production. The zinc complex which was used in this study embodies the transformation and recycling of waste. From the zinc-containing waste, zinc-tetramine-sulfate is produced by chemical transformation, and then it is made suitable for application as foliar fertilizer, thus, ultimately for nutrient replacement.

During the experiments, it was investigated how foliar fertilization with Vinasse and zinc complex solutions affected the yield and content indicators of winter wheat.

The word Vinasse comes from the Latin word vinacaeus and originally meant wine yeast. Vinasse is a secondary product processed during the production of molasses-based spirits. After the fermentation of the molasses, the spirit is extracted from the mash. The remaining material during distillation is the molasses liquor with 8–10% dry matter. This substance is concentrated in a vacuum still and then marketed as Vinasse, not only in Hungary, but also in other European countries. Vinasse is a dark brown, thickly flowing, viscous liquid with a characteristic smell. Due to its high dry matter content (approximately 60 %), the material is chemically stable and can be stored in its original state for years. It can be easily diluted and it can be dissolved well in water. Vinasse's soil fertility-enhancing effect is manifested in the fact that it increases the soil's macro- and microelement and organic matter content. It stimulates the microbiological life of soils, helps the decomposition of stem residues, and improves soil water management.

The other used foliar fertilizer is a zinc complex (zinc-tetramine-sulfate Zn $(NH_3)_4{}^{2+}SO_4{}^{2+}$). Plants can absorb zinc from the soil in the form of Zn2+ ions or as a chelate-type organic compound. Almost 50% of the world's soils suitable for growing cereals are classified as potentially deficient in zinc. According to [5], 46% of Hungarian soils are poorly supplied with zinc. Several factors influence the absorption of zinc forms that are available and can be taken up by plants (e.g. soil chemistry, lime content, phosphorus content) [11, 12].

From a biological point of view, zinc is one of the most important metal ions and it is indispensable for all forms of life, which actively participates in protein metabolism and the growth regulation of plants by stimulating auxin production [11]. The two best-known zinc-containing enzymes are carboxyl peptidase-A and carbonic-anhydrase. Through the activation of peptidases, it also affects nitrogen metabolism [13].

Zinc deficiency symptoms of plants can be the following ones: intervascular chlorosis, mainly on young leaves; the appearance of reddish-brown or bronze patterns on the leaves; small leaves; due to the lack of auxin, dwarf stems and rosette formation; restrained growth, shortened taste intervals; and in the case of severe zinc deficiency, root tip death ("dieback").

2 Materials and methods

Location of the research was the Experimental farm of Albert Kázmér Faculty of Agricultural and Food Sciences of Széchenyi István University. The Mv.Nádor winter wheat variety (*Triticum eastivum* L.) was used during this research.

2.1 Characteristics of the experimental area

The soil type of the production area is Danube alluvial soil. Soil layer thickness of the experimental area was considerable, about 120–140 cm. The characteristics of the soil of the experimental area are presented in Table 1.

Table 1. Features of the soil of the experimental area

FEATURES	VALUES
pH	7.30–7.55
Total salt content (%)	0.00–0.08
$CaCO_3$ content (%)	16.00–18.00
Liquid limit according to Arany	39–42
Humus content (%)	2.50–3.00
The absorbable zinc content (mg/kg)	0.40–1.50

2.2 Climatic characteristics of the experimental area

The experiments were also influenced by meteorological factors. The climate of the area is a temperate, humid continental type. The average annual temperature is around 11 ^{0}C. The data of the experimental area came from the meteorological station in Mosonmagyaróvár, operated jointly by HungaroMet (National Weather Service) and Széchenyi István University [14], and it is located in the Experimental farm area (Figures 1 and 2).

The average monthly temperatures of the growing seasons of the winter wheat in 2020–2021 and 2021–2022 were compared to the thirty-year (1991–2020) average (Figure 1.). In the diagram, it can be seen that the autumn period in 2021 and 2022 was around the thirty-year averages. The winter months were warmer in both years (2021, 2022), the spring months were slightly cooler, and the summer was warmer than the long-term average. Based on the analysis of the National Meteorological Service, the average annual temperature in Hungary in 2022 was a national average of 11.8^{0}C, which was 1.1^{0}C warmer than the 1991–2020 climate normal value [15]. The annual average temperature in Mosonmagyaróvár was 12.0^{0}C in 2022.

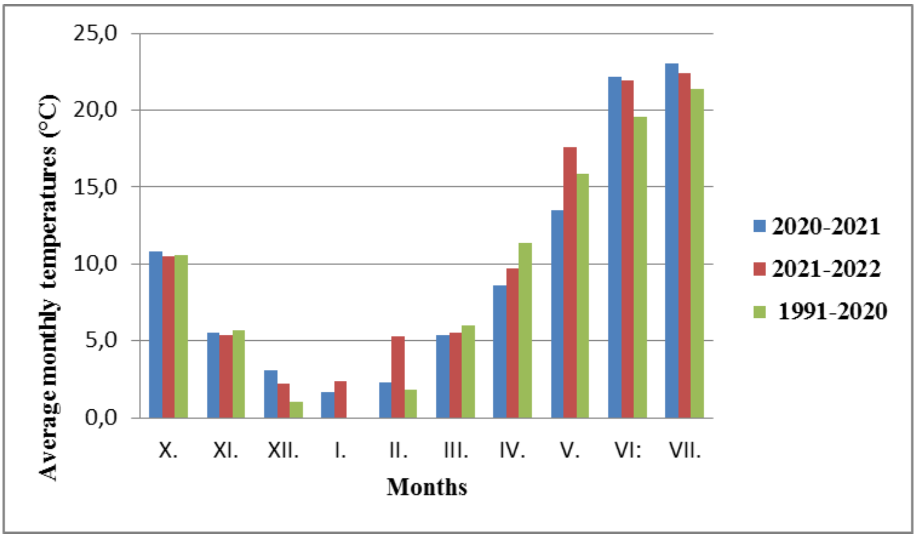

Fig. 1. Average monthly temperatures (^{0}C) of the growing seasons of 2020–2021 and 2021–2022 compared to the thirty-year (1991–2020) averages in Mosonmagyaróvár.

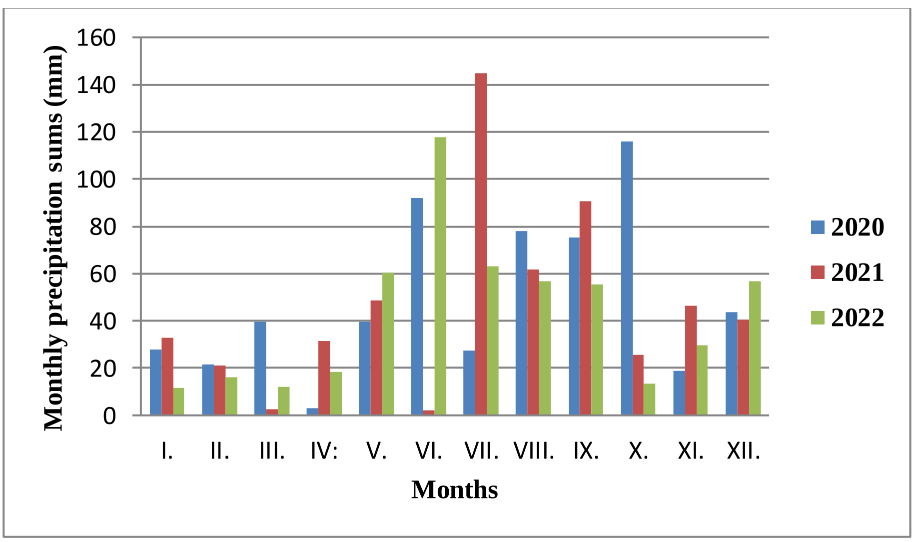

Fig. 2. Monthly precipitation sums in Mosonmagyaróvár 2020-2022

The average of the yearly precipitation sums of the last 30 years (1991–2020) was around 580 mm in Mosonmagyaróvár. We could measure a yearly precipitation sum which was close to the long-term average (582.5 mm), but in 2021 it was slightly below the thirty-year average (548.5 mm). In 2022 only 511.5 mm of precipitation fell in Mosonmagyaróvár.

The amount of precipitation that fell during the year 2022 was 497 mm on the national average based on the homogenized data, making it the 17th driest year since 1901 [15]. During 2022, only about 80 % of the normal amount of precipitation fell in country average, and the distribution was very extreme both spatially and temporally. In Mosonmagyaróvár a decrease of 11.8% could be experienced compared to the 30 years average (580 mm).

2.3 Features of the experiments

Small plots of arable land were set up to analyze the impact of Vinasse and zinc-complex foliar fertilizers. The experimental layout was a randomized block with four replications. The size of the experimental plots was 10 m².

Winter wheat was sown on 10.15.2020 and 10.14.2021, and harvested on 7.7.2021 and 7.4.2022, respectively.

The treatments and foliar fertilizing were carried out with a hand sprayer when the winter wheat was in the stem elongation phase: 05.06.2021 and 04.14.2022.

2.4 Treatments, examinations

After mechanical harvesting of the small-plot plant stands, 1 kg sample was taken from each plot, which formed the basis of further tests. After harvesting the plot weight was measured from which the yield of the given treatment can be deduced. The crude protein and wet fat contents of the samples were examined with the Perten Inframatic 9200 fast analyzer under non-destructive conditions at the Department of Water Management and Natural Ecosystems. The analyzer used during the measurement (NIR) performs the measurement in the near-infrared range, between 1100–1400 nm, based on the principle of transmission.

The treatments of the experiment were the following:

1. Control: these plots did not receive any foliage fertilizer
2. Nitrosol 28% N-content liquid fertilizer 100 l/ha: this is the foliar fertilizer generally used by farmers. It made possible to compare the effect of this foliar fertilizer on winter wheat with the other products.
3. Zinc complex 0.5 kg/ha
4. Vinasse 50 l/ha
5. Vinasse 100 l/ha
6. Vinasse 250 l/ha
7. Vinasse 500 l/ha
8. Vinasse 50 l/ha + zinc complex 0.5 kg/ha
9. Vinasse 100 l/ha + zinc complex 0.5 kg/ha
10. Vinasse 250 l/ha+ zinc complex 0.5 kg/ha
11. Vinasse 500 l/ha+ zinc complex 0.5 kg/ha

3 Discussion

Figure 3 shows the effects of different treatments on winter wheat yield. It can be seen that the high-dose Vinasse treatment supplemented with the zinc complex gave the highest yield value in both years. After performing the t-test, it was found that the difference in the averages in both experimental years was significant at P =5%.

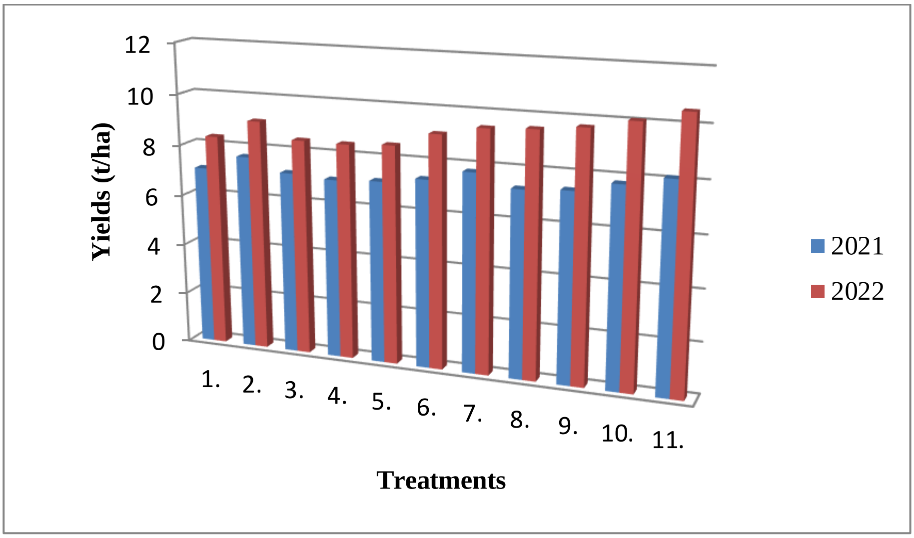

Fig. 3. Yield of winter wheat samples (t/ha) in 2021–2022

Figure 4 shows the effect of different treatments on the crude protein content of winter wheat. In the experiments conducted in 2021 and 2022, all treatments resulted in a higher crude protein content compared to the control. The highest crude protein content was obtained as a result of higher doses of Vinasse + zinc complex treatments.

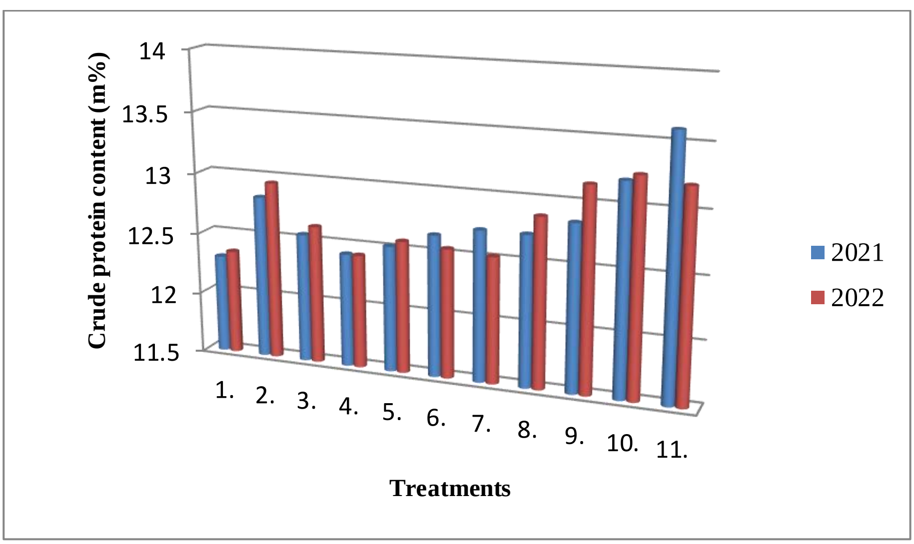

Fig. 4. Crude protein content of winter wheat samples (m%) in 2021 and 2022.

Performing the t-test on the averages, we found that the 10th treatment (Vinasse 250 l/ha + 0.5 kg/ha zinc complex) was significant at P=5%, while the 11th treatment (Vinasse 500 l/ha + 0.5 kg/ha zinc complex) was significant at P=1 % in both experimental years.

As it is well known, a higher crop yield coincides a lower protein content of the grain, so it is very important to plan the crop yield as the plant approaches the period of grain formation. The main goal of controlling protein quality is to develop the high molecular weight and long-chain gluten protein in the plant. Gluten proteins - such as gliadin, glutenin, albumin and globulin - ensure the unique elasticity and good processability of wheat products (flour, pasta).

One of the most important quality indicators of wheat is its wet bran content. The gluten is due to the combination of gliadin and glutenin in wheat grains. Gliadin gives wheat flour elasticity and stickiness, while glutenin gives it strength and resistance.

Figure 5 shows the effects of the different treatments on the wet gluten content. For this quality indicator as well, the treatment with Vinasse + zinc complex resulted in the highest values, but it is noteworthy that the foliar fertilization with only zinc complex also exceeded the content values of winter wheat grown on untreated plots.

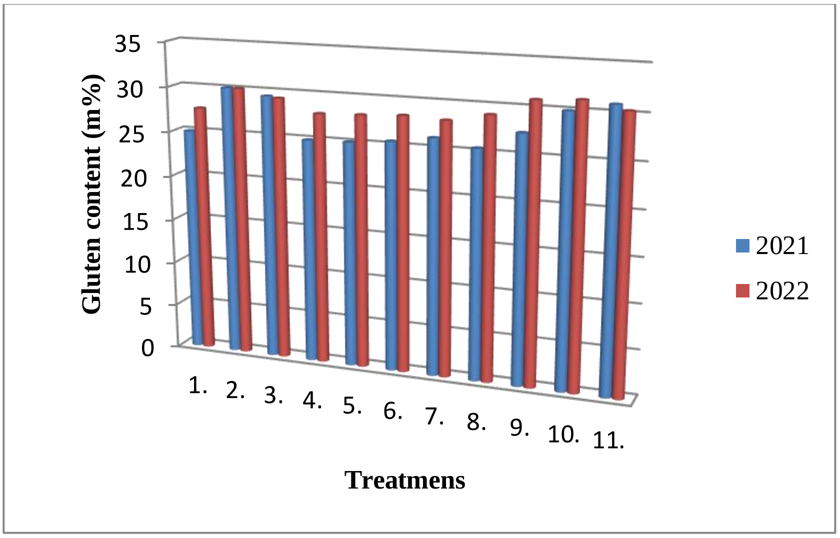

Fig. 5. Gluten content of winter wheat samples (m%) in 2021 and 2022

The t-test was performed again on the averages of the gluten content, and for those values the highest level of significance was obtained in both experimental years (P=0.1%). Therefore, the deviation of the averages of the wet gluten content compared to the control values is significant at the highest level, regardless of standard deviation.

4 Conclusion and recommendation

Based on the results of the small-plot experiments set up in the fall of 2020 and 2021 and harvested in the summer of 2021 and 2022, it can be concluded that using Vinasse + zinc complex treatments a higher yield and better content indicators were achieved compared to the control plots. The highest dose of Vinasse (500 l/ha) + zinc complex (0.5 kg/ha) had the greatest effect on yield values.

The crude protein content was increased with the highest value compared to the control due to the high dose of Vinasse + zinc complex. After performing the t-test on the averages, it was found that the 10th treatment (Vinasse 250 l/ha + zinc complex 0.5 kg/ha) was significant at P=5%, the 11th treatment (Vinasse 500 l/ha + zinc complex 0.5 kg/ha) was significant at P=1%.

In the winter wheat experiment, the gluten content of the plots was also increased to the greatest extent by the high-dose foliar treatment 11 (Vinasse 500 l/ha + zinc complex 0.5 kg/ha). The highest level of significance (P=0.1%) could be proven for these averages, so the deviation of the averages was significant at the highest level regardless of standard deviation.

As a conclusion, it can we stated that in the small-plot experiment carried out in 2021 and 2022, the high-dose 11th treatment (Vinasse 500 l/ha + zinc complex 0.5 kg/ha) had a positive effect on the yield of winter wheat. A closer correlation was obtained for the internal content indicators, since the significance level was P=1% for the crude protein content, and P=0.1% for the gluten content. The small-plot experiments were set up again in 2022 in an unchanged form.

Based on the experiments carried out, it can be recommended to use high doses of Vinasse and zinc complex in field conditions, if the goal is to increase the quality indicators (crude protein and gluten content) of winter wheat in an environmentally friendly way.

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