EVALUATION OF EFFECTIVENESS INDICATORS OF THE APPLICATION OF FOLIAR FERTILIZERS IN THE SUSTAINABLE ECONOMIC DEVELOPMENT OF WHEAT WINTER PRODUCTIVITY

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ABSTRACT

The paper introduces the investigation results on the influence of seed treatment by plant growth stimulant Vita Cereals and foliar feeding by Nanovit Cereals and Urea ammonium nitrate on the winter wheat plants' growth, development, yield and grain quality indicators. It has been established that foliar feeding plays a vital role in all critical winter wheat life cycle and growth processes, including cell division and protein synthesis, as well as increasing enzyme activity. The research was conducted in 2023-2024 at the LLC "Organic-D" fields, Vinnytsia region, Ukraine. The study soil was a light loamy grey forest soil. In plots where winter wheat seeds were treated with Vita Cereals, the number of grains per year was 47-50, and the weight of 1000 grains in the studied varieties ranged from 37.7 to 39.5 g. The yield of the studied winter wheat varieties directly depended on the application of foliar treatments and the varietal characteristics of the wheat. Thus, when seeds were treated and foliar top dressing was applied on the experimental plots, the yield of the varieties ranged from 5.4 to 5.8 t/ha. Meanwhile, using foliar top dressing with Nanovit Cereals and Using urea-ammonia nitrate (UAN) contributes to yield formation in the Mavka IR variety at 5.9 to 6.6 t/ha. The yield of the Zira variety with the same treatments was 5.6 to 5.8 t/ha. Treatment with Vita Cereals before sowing and Nanovit Cereals micro fertiliser at the beginning of the booting stage gave the highest conditional net profit of 31280 UAH/ha (45.7 UAH per 1 euro). The profitability ranged from 113 to 121% on the control plots, while it was higher (150%) on the treated plots.

Keywords: wheat winter, environmental risk assessment, varieties, foliar fertilization, yield, grain quality, economic efficiency.

INTRODUCTION

Crops are an integral part of Ukraine's bioenergy resources. The ecological sustainability of varieties is becoming increasingly important for raising crop production efficiency by optimising anthropogenic environmental conditions. This should ensure appropriate genetic protection from negative environmental factors, pests and diseases. Forming a market economy in the agricultural sector requires the availability of different varieties in terms of commercial value.

Short-term breeding and the rapid introduction of new varieties can enhance the use of natural and technological resources. In most cases, only one variety is grown in agrophytocenoses, which are characterised by growth and development, the growing season, yield formation, and response to environmental factors. Varieties are integral components of a scientifically based farming system, and further progress in increasing winter wheat yield and quality is associated with improvements and the development of new breeding models and agrotechnologies (Karpenko et al., 2022; Butenko et al., 2025).

Root-zone fertilisation can be done by broadcasting and incorporating fertilisers in solid or liquid forms into the soil (Keivanrad et al., 2012; Zakharchenko et al., 2024). For cereals, fertilisers are applied during the spring season (beginning of the booting stage) by the seed drill with a discriminator in the root collar zone using the placement method. Foliar fertilisation is used during the intensive growing season to improve product quality. Crops are sprayed with a urea solution to increase winter wheat grains' protein and gluten content (Shelest et al., 2023; Sobko et al., 2023). Mineral fertilisers with microelements are also used to fertilise crops foliarly. Spraying is often combined with plant protection products (Novák et al., 2021; Hryhoriv et al., 2024).

Applying bulk blending fertilisers with microelements is highly effective for foliar feeding. This method of application, used as a preventive measure, does not alter the concentration of these micronutrients in the soil; however, it positively impacts the plant's state, almost eliminates physiological suppression, increases plant resistance to parasitic diseases, and significantly increases the adsorption of nitrogen, phosphorus and potassium from the soil. As a result, this approach increases yield quantity and quality (Nan et al., 2019; Litvinov et al., 2020; Verma & Singh, 2021). Farmers often use fertilisers with macro- and micronutrients because it is challenging to determine deficiencies in winter wheat plants in advance.
One of the most common fertilisers used to supply winter wheat with the necessary nutrients is a range of chelated fertilisers containing a unique substance that biodegrades within 28 days (Kvitko et al., 2021; Radchenko et al., 2021). For instance, Nanovit Cereals 36 Extra and Nanovit Cereals are applied as foliar feeds at a rate of 3-6 l/ha from the tillering stage through to the onset of the booting stage, in conjunction with plant protective measures (Karpenko et al., 2020; Eduardo et al., 2021).

The Ministry of Ecology and Natural Resources of Ukraine registers 196 plant growth regulators and lists them as approved for use in agricultural production. Of these, 13 are registered by the Institute of Bioorganic Chemistry and Petrochemistry. According to the Cherkasy Institute, the well-known plant growth stimulant Agrostimulin has increased winter wheat yields by an average of 17% over in six years. Additionally, growth stimulants Violan and Radostim have yield increases ranging from 18 to 24%. Winter wheat is Ukraine' main grain crop, accounting for over half of the grain production. Its significance for domestic agriculture and the overall economy cannot be overstated, especially in today's realities. However, despite the unique soil and climate conditions suitable for cultivating this crop, the real production levels in Ukraine are not commensurate with the country's potential (Datsko et al., 2025). Foliar feeding enhances the adaptive capacity of plants to specific growing conditions and reduces the impact of stress factors. Overall, the genetic potential of winter wheat, which is developed through natural processes and selective breeding, is more effectively utilised with the application of biostimulants. A new trend has emerged in foliar fertilisation because synthetic biologically active growth stimulants may provide positive outcomes. Still, they can also introduce undesirable side effects that may compromise plant health. Consequently, it is recommended that environmentally safe natural stimulants be utilised to optimise photosynthesis (Lamandé & Schjønning, 2017; Rieznik et al., 2023). Applying root and foliar fertilisers can help achieve a consistently high yield of excellent winter wheat. Even one nutrient or compound deficiency can adversely affect the plant's growth and development (Tanchyk et al., 2021; Radchenko et al., 2021).

MATERIAL AND METHODS

The study aimed to comprehensively examine the effectiveness of seed treatment and foliar feeding when growing different winter wheat varieties. The research was conducted during 2023-2024 at the LLC "Organic-D" field in Hnivan city, Vinnytsia region. The soil of the experimental plot is classified as a light loamy grey forest soil on loess deposits with a profile depth of 100-120 cm. The humus content is 4.2-4.4%, phosphorus and potassium are 0.15-0.10% and 2.1-2.2%, respectively, and the pH of the arable soil layer is 6.9-7.0. Soil has good water permeability, aeration, and high water-holding capacity. In a 0-150 cm layer, they can hold up to 500 mm of water, the annual precipitation supply. Such soils have high potential fertility (Voytovyk et al., 2024).

The climate of the Vinnytsia region is moderately continental, characterised by distinctly pronounced arid-dry phenomena. It is shaped by a considerable amount of solar radiation and the prevalence of continental air from temperate latitudes. The region experiences hot summers with drought and moderately cold winters with unstable snow cover. The temperature varies significantly throughout the year, characterised by substantial fluctuations. The change of seasons is gradual, without sharp drops. The duration of the frost-free period is 150-170 days. Long-term research indicates that the maximum air temperature has not exceeded +38 °C, while the minimum has not dropped below -35 °C. January is typically the coldest month, while July is the warmest. The average long-term temperature in January is -3.8 °C, and in July it is + 22.4 °C. Two registered winter wheat varieties were involved in the experiment. One was developed (Zira) at the Institute of Grain Crops of NAAS in cooperation with the Synelnykove Breeding and Research Station of the Institute of Grain Crops, Ukraine. Seeds of the other variety, Mavka IR, were obtained from the Yuriev Plant Production Institute of NAAS, Ukraine. Before sowing, the seeds were treated with Vita Cereals at a rate of 2.5 l/t. Foliar fertilisation was applied twice during the tillering stage and the beginning of the booting stage (BBCH 25-30) with Vita Cereals 2 l/ha, Nanovit Cereals 1.5 l/ha, Using urea-ammonia nitrate (UAN) on frozen-thawed soil 150 kg/ha and during the tillering phase 150 kg/ha. Four repetitions for each treatment were established. The area of the experimental plot is 25 m^2.

RESULTS AND DISCUSSION

The application of the Vita Cereals growth stimulator and Nanovit Cereals foliar fertiliser significantly influenced the formation of crop productivity. With the application of Nanovit Cereals fertiliser, the Zira variety produced 470 productive culms/m^2 while the Mavka IR variety yielded 473 culms/m^2 (Table 1). The number of productive culms for the Zira variety increased to 474/m^2, and the weight of 1000 grains reached 40.0 g. The weight of 1000 grains was the highest with the application of UAN for the Mavka IR variety.

Table 1. Winter wheat plants' productivity under study, 2023-2024.

Variety	Treatment	Number of productive culms, pcs./m^2	Grain number per ear, pcs.	1000 grains weight, g
Mavka IR	Control	456	48	39.1
	Vita Cereals	467	50	39.5
	Nanovit Cereals	473	51	40.4
	UAN	475	52	40.7
Zira	Control	456	45	37.3
	Vita Cereals	465	47	37.7
	Nanovit Cereals	470	48	39.0
	UAN	474	50	40.0

The productivity of winter wheat formation depended on the number of grains per ear, which also depended on climatic conditions and the growth background. On average, after over two years of research, the number of grains per ear was significantly higher on the treated plots than on the control plots without fertilisers.

Using the complex, concentrated liquid microfertiliser Vita Cereals to treat winter wheat seeds before sowing and apply it during the growing season contributed to better growth and development of winter wheat, resulting in more grains per ear than the control variant. The best results were obtained on plots of the Mavka IR variety, where the number of grains per ear increased to 52 when UAN was applied. The findings indicated that applying the fertiliser influenced both the plants' height and the length of the ears. When treated with the Vita Cereals growth stimulator, the height of the winter wheat plants for the studied varieties ranged from 93 to 98 cm, and the ear length ranged from 11.0 to 11.3 cm (Table 2).

Table 2. Biometric indicators of winter wheat plants depending on treatments (for the average 2023-2024).

Variety	Treatment	Plant height, cm	Ear length, cm
Mavka IR	Control	98	10.8
	Vita Cereals	98	11.3
	Nanovit Cereals	99	11.1
	UAN	102	11.3
Zira	Control	92	10.5
	Vita Cereals	93	11.0
	Nanovit Cereals	95	11.1
	UAN	97	11.2

Thus, the biometric indicators of winter wheat plant varieties depended on the pre-sowing treatment of winter wheat seeds Vita Cereals (2 l/ha) and the foliar application of micronutrient-rich fertilisers.

The Vinnytsia region is one of Ukraine's leading grain-producing regions. The main competitive advantages of the region's products in external grain markets are high quality, low prices, and relatively stable production. The region has sufficient natural and climatic conditions and labour resources to increase grain production significantly. The grain market in the region is characterised by high volatility, which is associated with the peculiarities of demand and supply for grain. For normal plant development, not only are nitrogen, phosphorus and potassium necessary, but also micronutrients such as iron, copper, molybdenum, manganese, cobalt, zinc, boron and sulphur. These elements participate in all physiological processes of plant development, increase plant growth efficiency, enhance the efficiency of many enzymes in the plant body and improve the absorption of nutrients from the soil. Most trace elements are active catalysts that facilitate and influence the direction of biochemical reactions. Nutrient deficiency negatively affects the growth and development of plants. Therefore, other substances cannot replace micronutrients. Achieving maximum yields of the proper quality, as genetically determined in seeds, requires the balanced use of fertilisers that contain micronutrients. When the soil lacks these micronutrients, the process crucial for plant development slows down, ultimately leading to crop yield loss and decline in the plant’s organic characteristics.

Scientists have proven that foliar feeding is most effective on sufficiently fertilised soils during intensive cultivation, where the deficiency of macro- and microelements can be a limiting factor for increasing yields. Winter wheat varieties exhibit unique genetic traits related to enzyme systems, absorption structures, and photosynthesis. They also vary in their responses to fertiliser form and amounts, soil acidity, salinity, and other physicochemical attributes. Therefore, understanding and properly utilising the nutritional characteristics of each specific variety is one of the most effective ways to enhance the effectiveness of mineral fertilisers and environmental factors. Fertilizers increase yield, improve quality and disease resistance, promote rapid growth and development, and improve water use efficiency.

The data presented in Table 3 indicate that winter wheat yield directly depends on fertilisation and varietal characteristics. The grain yield of the Mavka IR variety was 5.8 t/ha on plots with the application of foliar top dressing with the Vita Cereals. The Zira variety yielded slightly less, at 5.4 t/ha, with the same treatment. Applying fertiliser Nanovit Cereals resulted in a 5.6 t/ha winter wheat yield for the Zira variety and 5.9 t/ha for the Mavka variety.

Table 3. Impact of seed treatment and foliar feeding on the productivity of winter wheat varieties, 2023-2024.

Variety	Treatment	1 plant grain weight, g	Grain weight,g/m²	Yield, t/ha
Mavka IR	Control	1.18	515	5.1
	Vita Cereals	1.24	539	5.8
	Nanovit Cereals	1.27	543	5.9
	UAN	1.31	545	6.6
Zira	Control	1.04	489	4.8
	Vita Cereals	1.15	513	5.4
	Nanovit Cereals	1.19	528	5.6
	UAN	1.24	530	5.8
LSD_{05}				*0.11*

The Mavka variety yielded the highest amount, ranging from 5.1 to 6.6 t/ha. This variety demonstrated a strong responsiveness to foliar feeding and seed treatment, and high adaptability to local conditions (Table 4). The protein content in the grain of the Zira and Mavka varieties on the control plots was 13.6% and 13.7%, with gluten content of 28.3% and 28.9%, respectively. Following foliar feeding, the highest protein (14%) and gluten (29.5%) in Zira variety grains were observed. This corresponded to a 0.3% increase in protein content and a 0.6% increase in gluten content compared to the untreated control plot.

The best quality indicators were observed in plots with seed treatment by Vita Cereals l/ha and the application of Nanovit fertiliser during the tillering stage and the beginning of the booting stage (BBCH 25-30). The result indicated that the Mavka variety grains contained 14.1% protein and 29.0% crude gluten, while the Zira variety grains had quality indicators of 14.2% protein and 30% crude gluten.

Several studies have demonstrated that foliar fertilization can significantly enhance crop yields and quality (Viecelli et al. 2019, Sobko et al. 2023). For instance, research conducted by the Faculty of Agrochemistry and Crop Product Quality of the National University of Life Resources and Environmental Sciences found that applying a Urea Kristalon (1 kg per 200 l of water) to winter wheat plants during the earing phase increased protein content by 0.8% to 1.4% and gluten content by 2.2% to 2.7%.

Table 4. Winter wheat varieties' grain quality indicators under study (for the average 2023-2024).

Variety	Treatment	Protein, %	+/- to control	Gluten, %	+/- control
Zira	Control	13.7	-	28.9	-
	Vita Cereals	13.9	0.2	29.1	0.2
	Nanovit Cereals	14.0	0.3	29.5	0.6
	UAN	14.2	0.5	30.0	1.1
Mavka IP	Control	13.6	-	28.3	-
	Vita Cereals	13.7	0.1	28.6	0.3
	Nanovit Cereals	13.8	0.2	28.8	0.5
	UAN	14.1	0.5	29.0	0.7

The formation of grain quality indicators in winter wheat varieties was achieved by applying UAN to the thawed-frozen soil at 150 kg/ha and in the BBCH growth stage 26 at a rate of 150 kg/ha. The protein content in the Zira variety was measured at 14.2%, while the grains of the Mavka IR variety had a protein content of 14.1%. Therefore, foliar fertilisation of winter wheat with UAN stimulates growth and development, increasing grain yield and quality. Economic efficiency of production reflects the action of objective economic laws that manifest themselves in the production process.

Production efficiency is the final benefit of using the means of production, labour, and the totality of their costs. The ratio of the result to the costs of the means of production and labour determines production efficiency. The growth of this ratio contributes to the increase in agricultural profits, which is the basis for increasing and improving production, raising wages and improving the cultural and living conditions of industrial workers. The essence of the problem is to significantly increase the production of products necessary to meet society's material and cultural needs for each unit of cost - material, labour and financial (Butenko et al. 2025).

The competitiveness of agricultural products depends on many factors, including their quality and cost. Producing such agricultural products in Ukraine is a key prerequisite for developing the agrarian sector of the economy. Production cost is determined by production efficiency, which domestic and foreign scientists refer to as technical efficiency. Increasing the economic efficiency of agricultural production contributes to an increase in agricultural income, which is the basis for expanding and improving production.

Calculations of the economic efficiency of foliar fertilisation showed that the increase in winter wheat grain yield was from 0.6 to 1.5 t/ha compared to the control without fertilisers (Table 5). The highest conditional net profit of 31280 UAH/ha was observed in plots where UAN was applied before sowing winter wheat and during the growing season, specifically at the beginning of the booting stage.

The level of profitability was 155%, compared to 113-121% in the control plots without foliar fertilisation.

Table 5. Economic efficiency of winter wheat varieties cultivation under study (average for 2023-2024).

Parameters	Treatments							
	Mavka IR variety				Zira variety			
	Control	Vita Cereals	Nanovit Cereals	UAN	Control	Vita Cereals	Nanovit Cereals	UAN
Yield, t/ha	5.1	5.8	5.9	6.6	4.8	5.4	5.6	5.8
Yield grain, t/ha	-	0.7	0.8	1.5	-	0.6	0.8	1.0
Gross output value, UAH/ha	39780	45240	46020	51480	37440	42120	43680	45240
Cost of wheat production, UAH/ha	18000	19500	19700	20200	17600	18700	18900	19000
Prime cost 1 t of seeds, UAH/ha	3529	3362	3339	3061	3667	3463	3375	3276
Conditional net profit, UAH/ha	21780	25740	26320	31280	19840	23420	24780	26240
Profitability level, %	121	132	134	155	113	125	131	138

**Euro exchange rate as of 01.05.2025 – 45.7 UAH per 1 euro.*

CONCLUSIONS

- When using Nanonit fertiliser, the Zira variety produced 470 culms/m^2, and the Mavka IR variety had 473 culms/m^2. The application of foliar feeding, followed by Nanovit Cereals fertiliser, increased the number of culms to 474 pcs/m^2 and the weight of 1000 grains to 40 g for the Zira variety. In plots where winter wheat seeds were treated and foliar top dressing with Vita Cereals was applied, the average number of grains per ear was 47-50 pcs. The weight of 1000 grains in the studied varieties was 37.7-39.5 g.
- The yield of the winter wheat variety is directly influenced by the application of foliar fertiliser and the varietal characteristics of wheat. Treatment of seed and foliar feeding by Vita Cereals contributed to the yield formation of the varieties from 5.4 to 5.8 t/ha.
- Applying foliar top dressing with Nanovit Cereals and UAN contributed to the yield formation of the Mavka IR variety grains, ranging from 6.6 to 5.9 t/ha.
- The Zira variety also benefited from these treatments, producing 5.6-5.6 t/ha yields. The highest quality indicators were observed in plots with seed treatment by the growth stimulator Vita Cereals and the application of Nanovit Cereals fertiliser during the tillering period of winter wheat.
- The results indicated that the seeds of the Mavka IR variety contained 14.1% protein and 29.0 % crude gluten. The quality indicators of the Zira variety grains showed 14.2% protein and 30.0 % crude gluten. The highest conditional net profit of 31280UAH/ha was obtained in the plots where winter wheat seeds were treated with Vita Cereals, and Nanovit Cereals was applied at the beginning of the booting stage.
- The profitability of the applied treatments was 155% compared to 112-121% in the control plots without foliar feeding.

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