Research Article Open Access

Enhancing wheat yield and nutritional quality through organo-mineral fertilizer application

Seryozha Yeritsyan[1], Lousine Yeritsyan1, Tatevik Jhangiryan[*1], Marina Barseghyan[1], Karen Grigoryan[2], Gayane Gasparyan[1]

[1]Hrant Petrosyan Scientific Center of Soil Science, Agrochemistry and Melioration, Branch of Armenian National Agrarian University (ANAU) Foundation, Armenia; [2]Institute of General and Inorganic Chemistry Named after Academician Manvelyan State Non-Profit Organization, National Academy of Sciences of the Republic of Armenia, Yerevan, Armenia

***Corresponding Authors:** Tatevik Jhangiryan-Hrant, Petrosyan Scientific Center of Soil Science, Agrochemistry and Melioration Branch of Armenian National Agrarian University (ANAU) Foundation, 24 Isakov Ave., Yerevan 0004, Armenia

Submission Date: April 1st, 2025; **Acceptance Date:** April 28th, 2025; **Publication Date:** May 2nd, 2025

Please cite this article as: Yeritsyan S., Yeritsyan L., Jhangiryan T., Barseghyan M., Grigoryan K, Gasparyan G. Enhancing wheat yield and nutritional quality through organo-mineral fertilizer applications. *Functional Food Science 2025*; 5(5): 146-159. DOI: https://doi.org/10.31989/ffs.v5i5.1604

ABSTRACT

Background: Wheat is a global staple vital to nutrition and the economy. Using organo-mineral fertilizers for crops such as wheat has enhanced soil microbial activity, improved plant nutrition, and activated bioactive components.

Objective: This study evaluates the effectiveness of the organo-mineral complex fertilizer "Complexon," developed by the "Hrant Petrosyan Scientific Center," in increasing winter wheat yield (variety: Vasa), improving grain quality, and enhancing flour output under irrigated meadow-grey soils.

Methods: Field experiments from 2021–2024 were conducted in the Arshaluys community, while commercial-scale trials took place in the Artik region between 2022-2024. Complexon contains macro- and microelements, amino acids, and complex-forming agents, which were all applied via seed soaking and foliar feeding. Parameters were evaluated, including grain yield, nutritional quality, flour output, and seed germination capacity.

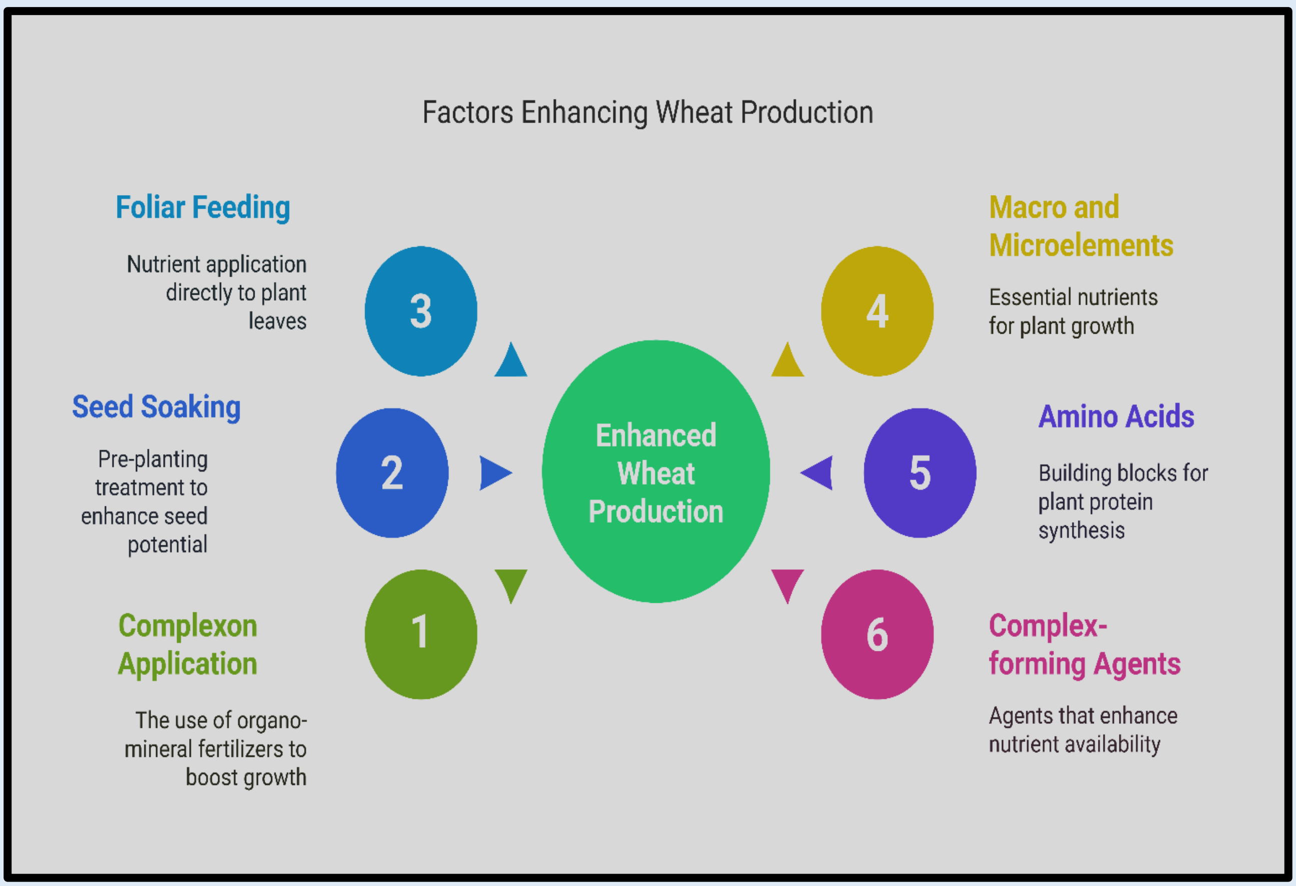
Results: Complexon increased wheat yields by 28.3–64.5% over three years compared to the control. This increase was 17.6–37.5%, compared to mineral fertilizers alone. Flour yields increased to 75–78% in commercial-scale trials, compared to 71–74% without Complexon use. Grain quality improved with a 2.0–2.2% rise in dry matter and a 151.7–157.9% reduction in cellulose content. Germination rates reached 96.9% under laboratory conditions, 93.9% in field trials, and

94.7% in vegetative trials. These results are significantly higher than the controls, as germination energy in laboratory, vegetative, and production trials were 86.1%, 83.5%, and 81.6%, respectively.

Novelty: This study introduces a fertilizer tailored to Armenian soil and crop needs, demonstrating a potential intervention strategy for sustainable agriculture. Since Complexon was found to boost crop yield and enhance wheat's functional and nutritional quality, this study may align with beneficial effects for producing functional foods.

Conclusion: The application of Complexon offers a sustainable approach to wheat cultivation. While Complexon improves yield, grain quality, and flour output, it also reduces seed material requirements, which provides sustainable and economic benefits for producing functional foods.

Keywords: wheat, organo-mineral fertilizers, food functionality, crop yield, grain quality



Graphical abstract: Effectiveness of the organo-mineral complex fertilizer "Complexon"

INTRODUCTION

As food security is a prominent global concern, this study aims to ensure food security and safety for all, without harming human health or the environment [1-6].

Bioactive compounds in food are currently being researched for health-promoting effects beyond basic nutritional value. These studies evaluate their safety, effectiveness, and measurable impact on the human body. As the global interest in preventive healthcare grows, functional food science is an increasingly important aspect of integrative medicine [7-10].

Food security, especially prominent for wheat, requires the production of safe, high-quality grains that provide essential nutrients without harmful residues [11]. This requires appropriate amounts of fertilizers and pesticides [12-14].

Complex organic-mineral fertilizers are widely used to cultivate crops such as wheat. These fertilizers are used because they combine the advantages of organic and mineral components that improve soil fertility and increase crop yields [15-19].

Combining fertilizers ensures high yields and contributes to the safe production of healthy food by reducing harmful chemical residues, which is crucial for health maintenance [20-25].

Although annual wheat production in Armenia varies, the country produces about 400,000-500,000 tons of wheat, with an average yield of about 2-3 tons per hectare (National Statistical Service, 2021) [26].

However, the amount of wheat produced does not meet the country's overall needs. Armenia now imports wheat from other countries, such as the Russian Federation, Ukraine, and Kazakhstan. Therefore, Armenia must develop a stronger local wheat production system to ensure food security for the population.

Since winter wheat is a staple food, this study was devoted to cultivation protocols, increasing yield, and improving the nutritional and seed qualities of the grain. Numerous studies have proven that fertilizer application increases the grain yield and improves grain quality [27-29].

The Republic of Armenia justifies this since soil fertility is low. For every 10 g of grain, depending on the region of cultivation and conditions present, the plant uses 35-37 kg of nitrogen (N), 12-13 g of phosphorus (P_2O_5), and 23-26 kg of potassium (K_2O). This study focuses on foliar plant nutrition and applying fertilizer via soaking before sowing or coating with fertilizer (granulation).

In addition to increasing yields, this strategy has improved the grain's nutritional and sowing qualities. These findings demonstrate that nutrients are available in the seed endosperm or soil during the early seed germination and development stages. However, this may not sufficiently meet the plant's nutritional needs as the root system cannot effectively absorb nutrients from the soil. [30-33].

Wheat (*Triticum aestivum L.*) is a heavily relied-upon food source due to its rich protein, carbohydrate, fiber, vitamin (B vitamins, vitamin E), microelement (zinc, manganese, iron), and phenolic compound content. These substances have several benefits for the human body. Wheat, vegetable proteins, and carbohydrates provide energy, while fiber improves the digestive system. This food source has also been shown to reduce cholesterol levels and promote gastrointestinal motility.

This article will discuss the impact of complex organic-mineral fertilizers on winter wheat yield, crop quality improvement, and food security. The potential for integration of this intervention in agricultural systems is also evaluated.

This study demonstrated the effect of different methods of applying Complexon on grain yield, grain quality indicators, chemical composition, and flour yield of winter wheat 34

Material and method: Characteristics of the Vassa wheat variety. Like other high-quality grains, Vassa wheat contains essential nutrients that promote health. It is particularly known for its high protein, carbohydrate, and fiber content, which support a proper and healthy diet. The Vassa variety is distinguished by its high yield, reaching 6-7 tons per hectare when necessary and correct agricultural technologies are maintained. The variety also has strong storage and portability properties.

The Vassa variety grows to medium height and develops a strong root system, which allows the plant to withstand dry conditions and respond to combined mineral and organic fertilizers [35].

Description of the applied organomineral fertilizer: Complexon is a complex fertilizer, with its composition determined by the fertility status of agricultural lands in the Republic of Armenia and nutrient requirements of crops, beginning at the seed germination stage.

The fertilizer is soluble in water, contains macroelements (nitrogen in the form of NH_2^- and NO_3^- ions, phosphorus, potassium, sulfur, iron), microelements (B, Zn, Mn, Mo, Cu, Co), amino acids, and complexing agents. The fertilizer is used as an aqueous solution with a 0.35-0.40% concentration. It is administered through foliar feeding and drip irrigation 2-3 times during the growing season. It can combine insecticides and fungicides that do not contain copper.

Experimental Design: Field experiments were conducted between 2021 and 2024 in the Arshaluys community of the Echmiadzin region on irrigated meadow gray soils. Four replications were completed, and the size of one experimental plot was 144 m^2 (5m x 7.2m) [36].

The experimental area is in the republic's semi-desert, natural soil zone. The altitude is 845 m above sea level, with an annual precipitation of 280-320 mm and an average annual air temperature of 11-12° C. The evaporation of water from the soil is 1000-1100 mm. The experimental plots were distributed in the field according to the Randomization principle. The research used a randomized complete block design (RCBD): T = 5, R = 4 [37]. For the experimental variants, see experiment 1, tables 3 and 4.

Complexon was applied according to the experimental scheme: the seeds were soaked in the fertilizer solution, and foliar nutrition was applied in the spring of the following year, during the plant's tillering stage. Field experiments studied the effect of Complexon on field germination and germination energy of winter wheat seeds, plant growth and yield, nutritional quality, and sowing quality indicators of the grain.

The effectiveness of Complexon was studied in vegetation and production crops. Production experiments were conducted in the black soils of the Artik region (in arid/ not irrigated conditions/) in 2022 and 2024, with an area of 50 and 70 hectares. The crops were fertilized with mineral fertilizers using $N_{110}P_{90}K_{65}$. Complexon was applied by soaking the seeds in the solution, with foliar nutrition during the plant's tillering stage. This crop's flour yield and wheat gluten/fibrin (henceforth - gluten) content were studied.

In laboratory conditions, experiments were performed in Petri dishes, each containing 100 seeds with two replicates. Germination was performed at 24.5°C in specially designed Plant Growth Chamber equipment. The duration of the experiments was between 8 and 10 days. In laboratory conditions, the experiments were set up in the following ways:

1. Soaking seeds with distilled water,
2. Soaking seeds with a 0.35% solution of mineral fertilizers,
3. Finally, soaking seeds with a 0.35% solution of Complexon.

Soaking the seeds with nutrient solutions was performed once, before sowing. Ammonium nitrate/saltpeter, calcium dihydrogen phosphate, and potassium chloride were used as mineral fertilizers. Seed germination was observed on the 3rd and 7th days of the experiment. Germination energy and germination capacity were recorded.

Vegetation experiments were conducted with four replications, pot capacity 6.5 kg, soil type irrigated meadow, and experimental variants—see experiment 2, table 5. In the vegetation experiment, the effect of Complexon on plant growth, yield, and grain quality indicators was studied.

Seed germination capacity, germination energy, plant growth, yield, and crop quality change during crop fertilization were also evaluated. Table 6 displays the experiment options/variants and results.

Research was conducted using soil research methods and field studies of soil and plant samples. For soil analysis, two soil pits up to 80 cm were placed. Soil samples were collected from the arable layer (0-52 cm). A Burkle Soil Sampling Kit was used to collect all soil samples. As soon as the samples arrived in the laboratory, the stones and plant remains were removed, and the samples were dried under room conditions (20-22°C). After drying, the samples were ground and passed through a 2 mm sieve. Phenological observation and biometric measurement were conducted during the growing season. The soil pH was estimated by dipping the pH electrode meter in the saturation paste (1:5, soil: water) [38].

EC was measured using an isometer, while carbonates were measured using a calcimeter, based on the volume of CO_2. Tiurin's method was used to determine organic carbon content (phenyl anthranilic acid titration), which displayed the humus substance content. A classical pipette method was used to determine and evaluate physical clay according to the N.A. Kachinsky classification scale. The nutrient content in the samples was extracted and determined: Available nutrients (nitrogen (N)-according to I. V. Tyurin and M. M. Kononova, phosphorus (P_2O_5)-according to B. M. Machigin, potassium (K_2O)-according to A. L. Maslova) [39] . The amounts of mobile Fe, B, and Zn were determined using a HACH LANGE DR 3900. To assess the nutritional quality of the yield (grain), crude protein was determined in the grain by the Kjeldahl method, starch was determined with the Bertrand method, and gluten and cellulose were found using the Henneberg-Stomann method [40-42]. The Kjeldahl apparatus determined total nitrogen within the grains by distillation, phosphorus was found by a colorimetric (photoelectrometric) photometer [40], and potassium was evaluated using a flame photometer (YENWAY PFPF Flame Photometer).

Numerous observations and measurements were made in the field experiments, which revealed the effect of Complexon on seed germination, plant growth, yield, nutritional quality, and sowing abilities of the grain. To determine the impact of Complexon on seed field germination capacity and germination energy, four 0.25 m^2 areas were separated in different sections of each experimental plot on the 3rd day of germination. These sections were separated with stakes (wedges), and the number of germinated seeds was counted. On the 7th day, the number of germinated seeds was counted. Based on the data of the sown seeds (500 germinated grains per 1 m^2), seed germination capacity and energy were calculated. Plants were removed from a one-square-meter area each to determine the structural elements of the crop yield on the eve of harvest. This occurred in 3 places of each repetition, and the number of seeded and non-seeded stems, grain and empty spikes, the weight of grains in the ear/spike, and the weight of a thousand grains were determined in the laboratory.

To assess the nutritional and sowing qualities of the grain, the specific gravity and vitreousness of the grain were determined. The specific gravity of the seeds was determined using the devices proposed by Sabinini-Kolosov (volumetric meter), according to the following formula:

$$d\ g/sm^3 = \frac{D}{V}$$

D is the specific gravity of wheat grains expressed in g/cm^3. This is the weight fraction taken for analysis, in grams, while V is the volume of water displaced equivalent to the volume of the grain, in mL (g) [38].

The vitreousness of the grain was determined using Diaphanoscope and Farinotome devices. Based on these data, the percentage of vitreousness was calculated. In field experiments, the yield was determined by harvesting and weighing the yield of each experimental plot.

Statistical analysis: The yield data were subjected to mathematical processing using the analysis of variance and dispersion. A significant difference was calculated between the variants (MSD0.95 / Significant at 0.95) and the experimental error (Sx%). The research was conducted in the Scientific Center of Soil Science, Agrochemistry and Melioration laboratory after Hrant Petrosyan" Branch of Armenian National Agrarian University (ANAU) Foundation.

Results and Discussion: The experiments were conducted in the republic's semi-desert zone on carbonate-irrigated meadow-gray soils, whose mechanical composition is medium clay-sandy. The reaction (pH) was faintly alkaline, and the absorption complex was saturated with calcium and magnesium. The soluble salts (EC) content was within permissible limits (Table 1).

According to the threshold data specified for mobile nutrient availability for RA soils, the soil of the experimental area is poorly supplied with mobile nitrogen and phosphorus. The soil is moderately supplied with potassium (Table 2). Furthermore, the experimental area lacks adequate iron, boron, and zinc.

Table 1. Agrochemical characteristics of the soil of the field (Experiment 1)

Sample Depth, cm	Humus, %	Mechanical Composition Physical Clay, % <0.01mm	pH	Carbonates $CaCO_3$, %	Cation Exchange Complex Ca+Mg, mg/eq 100g of soil	Ec, mS/cm
0-29	2,39	36,3	8,2	6,5	24,0+10,1	241,5
29-52	0,97	38,5	8,3	10,6	23,1+8,5	187,0

Each value is expressed as the mean ± standard deviation (SD) based on three independent replicates.

Table 2. The content of plant-available nutrients in the soil of the field (Experiment 1)

Sample Depth, cm	Available Nutrients for Plants, mg per 100g of soil			Available Nutrients for Plants, mg per 1kg of soil		
	N	P_2O_5	K_2O	Fe	B	Zn
0-29	3,5	1,85	21,6	4,8	0,38	0,94
29-52	2,1	0,78	15,8	3,6	0,27	0,65
Recommended Amounts	>10	>6	>36	>10	>1,2	>3,0

Each value is expressed as the mean ± standard deviation (SD) based on three independent replicates.

The results of our field and vegetation experiments conclude that the use of Complexon significantly contributed to an increased winter wheat grain yield. The highest results were obtained when Complexon was applied through soaking, and foliar nutrition was applied in the following year's spring. Moreover, this pattern has been maintained in the field for three years in vegetation and production experiments. Thus, according to the results of the field experiments, when Complexon was applied in two stages, the grain yield amounted to 42.9-52.7 c/ha, depending on the year. This average is 64.5% higher than controls, and 28.3% higher than mineral fertilizer use (Table 3).

Complexon's high efficiency is due to its composition, which is determined by the soil fertility level and the application timing.

It is assumed that increased seed germination capacity and germination energy under the influence of fertilizer are possible only if fertilizer activates enzymes that promote seed germination while the seed is still absorbing moisture.

Table 3. The effect of Complexon on the yield of winter wheat grain and the structure of crop/yield elements (Experiment 1)

Varieties	**Grains Yield by Years, c/ha**			**Average Grain Yield, c/ha**	**Variety**		**Weight of a thousand grains, g**	**Grains Bulk Density, g/cm³**	**Grains' vitreousness, %**
	2021	2022	2024		Grains Number, pieces	Grains Weight, g			
1	24,5	34,9	30,4	29,9	27,1	1,01	37,4	1,08	54,1
2	34,0	44,8	37,9	38,9	29,5	1,17	39,7	1,15	58,6
3	38,2	49,7	44,8	44,2	30,4	1,23	40,4	1,20	63,4
4	42,9	52,7	52,1	49,2	32,1	1,35	42,1	1,31	71,2
5	37,6	50,7	43,0	43,8	30,1	1,21	40,3	1,21	63,5
Sx %		2,1							
MSD $_{0.95}$ c/ha		2,70							
Total Error, Sx, c/ha		0,85							

Variants: 1. Control version (without fertilization), 2. $N_{110}P_{90}K_{60}$ inserting into the soil (background), 3. Background + Complexon with soaking the seeds, 4. Background + Complexon with soaking the seeds, then with foliar feeding in the following year's spring, 5. Background + Complexon with foliar feeding in the spring of the following year.

By beginning fertilizer application during seed germination, plants are provided with the necessary nutrients, which contribute to plant growth, increased yield, and improved nutritional qualities of the grain. Moreover, this pattern is maintained for three years during the experiment. The effectiveness of Complexon compared to the controls and the variants, which obtained only mineral fertilizers, is high even when applied by soaking or foliar feeding. However, Complexon is more effective when used by soaking the seeds.

The highest efficiency of Complexon is achieved when it is applied twice during the vegetation period: soaking the seeds before sowing and through foliar feeding during the tillering stage. The effectiveness of Complexon is noticeable on the qualitative indicators and chemical composition of the grain (Tables 3 and 4).

The data in Table 3 shows that Complexon improved the structure of crop elements. Namely, the number and weight of grains in the spike and the weight of a thousand grains were obtained when Complexon was applied through soaking. The use of Complexon improved the chemical composition of the grain, including the amount of dry matter in the grains, such as proteins, starch, and gluten. However, fiber content decreased. These alterations show the accumulation of more nutrients (proteins, carbohydrates, gluten, etc.) per unit volume. Therefore, the prime cost of the product decreases. The baking quality of flour increases as it becomes possible to reduce the need for baking quality supplementary products (Table 4).

Table 4. Effect of Complexon on the chemical composition of winter wheat grain (Experiment 1)

Varieties	Content, %							
	Dry Matter	Crude Protein	Starch	Gluten	Vitreousness, %	N	P_2O_5	K_2O
1	86,1	10,19	68,69	2,94	18,51	1,63	0,47	0,65
2	86,3	10,75	69,88	2,87	20,42	1,72	0,58	0,68
3	87,1	11,13	70,17	2,36	23,51	1,78	0,61	0,69
4	88,3	12,50	71,54	1,14	26,40	2,00	0,76	0,71
5	87,1	11,25	70,06	2,38	23,19	1,80	0,63	0,68

Each value is expressed as the mean ± standard deviation (SD) based on three independent replicates.

Variants: 1. Control version (without fertilization), 2. $N_{110}P_{90}K_{60}$ (background), 3. Background + Complexon with soaking the seeds, 4. Background + Complexon with soaking the seeds + foliar nutrition during the plant's tillering stage in the spring of the following year, 5. Background + Complexon during the plant's tillering stage.

Results of vegetation experiments: The effectiveness of Complexon was studied under vegetation experiment conditions. The results indicate that Complexon provided incomparably higher effectiveness in vegetation experiments than a mixture of ammonium nitrate/saltpeter, double superphosphate, and potassium chloride.

Plant growth, yield, and other indicators are lower when fertilizer is applied. Plant growth and yield are lower when a mixture of basic mineral fertilizers (NPK) is used for soaking or foliar feeding (Table 5).

The application of minerals had a weak effect on the chemical composition of the grain. Meanwhile, the application of Complexon, regardless of the application method, provided noticeable effectiveness. This was expressed through increased plant growth, chemical composition of the grain, thousand-grain weight, and specific weight. The chemical composition of the grain also improved: the content of dry matter, crude protein, gluten, phosphorus, and potassium increased, while the fiber content decreased.

Suppose the data is separated into the content of dry matter, crude protein, and gluten from the data presented in Table 5. In that case, Complexon concludes that nutrient levels increase even though fiber content decreased. Therefore, it can be concluded that Complexon leads to significant qualitative changes in the grain, contributing to increased nutritional value, increased flour yield, and improved baking quality.

Table 5. Effect of Complexon on growth, yield, and grain chemical composition of winter wheat (variety Vassa) (vegetation experiments, without creating a background of fertilization with basic mineral fertilizers)- Experiment 2

Varieties	Plant Height, cm	Grains Yield, g/seed	Variety		Thousand Grains Weight, g	Grains Bulk Density, g/cm³	Content, %						
			Grains Number, pieces	Grains Weight, g			Dry Matter	Vitreousness, %	Crude Protein	Gluten	Phosphorus, P_2O_5	Potassium, K_2O
1	46,4	14,4	27,08	0,94	35,02	1,01	84,80	19,42	10,69	2,71	0,51	0,55
2	47,1	15,5	28,40	1,01	35,24	1,03	84,83	20,95	10,51	2,80	0,60	0,54
3	47,5	16,1	30,05	1,06	35,27	1,04	84,84	24,05	10,78	2,80	0,63	0,57
4	49,6	17,3	31,16	1,17	37,21	1,19	85,92	25,94	11,05	1,92	0,72	0,59
5	50,3	19,2	32,59	1,28	39,35	1,28	86,77	27,76	11,31	1,44	0,77	0,60
6	50,1	17,1	31,02	1,15	37,01	1,12	85,30	25,01	11,10	1,96	0,68	0,54
Sx, %		1,6										
Average Weight, g/seed		0,84										
Total Error, Sx, g/seed		0,27										

Variants: 1. Control version (soaking seeds with water), 2. Soaking seeds with a 0.4% solution of mineral fertilizers (NPK), 3. Soaking seeds with a 0.4% solution of mineral fertilizers (NPK), then foliar feeding at the plant tillering stage, 4. Soaking seeds with a Complexon solution, 5. Soaking seeds with a 0.4% concentration of Complexon, then foliar feeding during the plant's tillering stage, 6. Foliar feeding with a Complexon solution during the plant's tillering stage.

The effect of Complexon application on the sowing quality and yield of winter wheat seed. To improve the sowing quality of seeds, specifically germination capacity and germination energy, and subsequently enhance crop yield and quality, we recommend treating seeds with Complexon. This is a complex organic-mineral fertilizer, which can be used before sowing. This treatment significantly increases germination capacity and energy, promoting stronger plant growth, higher yields, and improved crop nutritional and sowing characteristics. Vegetation and field experiments between 2022 and 2024 showed that soaking winter wheat seeds with a Complexon solution significantly increased their germination capacity and energy. This amounted to 96.9 and 86.1%. In the vegetation experiment, this increase was 94.7 and 83.5%, with field experiments noticing 93.9 and 81.6%. The control treatment and mineral fertilizer solution-soaked versions experienced lower germination capacity and energy. Capacity in laboratory experiments was found to be 91.7 and 91.8%, in vegetation experiments of 89.4 and 89.5%, and field experiments of 86.4-87.0%. Germination energy was 74.9 and 75.2%, 71.6 and 71.8%, 69.8 and 70.3%, respectively (experiment 3). Thus, a positive result regarding seed germination capacity energy was obtained only when Complexon was applied. This makes it possible to reduce the number of seeds required per unit area by significant amounts. The use of Complexon also improves plant growth, increases yield, contributes to stronger nutritional and sowing qualities, and increases the yield of flour from the grain.

It is also essential to determine their effect on the seed qualities of the resulting crop, which is necessary to ensure a greater yield and quality of seed material. In this regard, the use of winter wheat crop grown in different fertilization backgrounds was evaluated through seed material that affects the sowing quality (germination capacity, germination energy) of the resulting seed material. Plant growth, yield, and quality indicators of the crop were recorded (experiment 4, table 6). The results of the experiments revealed that the sowing quality of seeds obtained from mineral fertilizers and Complexon (the seed material was obtained by soaking the seeds with $N_{110}P_{90}K_{60}$ (background) + Complexon + foliar feeding during the plant's tillering stage) was higher. In this variant, the laboratory germination capacity of seeds was 97.1%, the field germination capacity was 93.8%, and the germination energy was 93.7% and 85.2%, respectively. Meanwhile, in the control treatment, the laboratory germination capacity of seeds was 78.5% on average, with field experiments showing 77.2%, and the germination energy was 61.8% and 55.3%, respectively.

If the field germination capacity and germination energy data are compared with the application of Complexon, soaking in a Complexon solution is more expedient than foliar feeding with the same solution for sowing the crop (seed material) (Experiment 4, Table 6).

Table 6. Effect of Seed Quality (from Complexon Application) on Structural Elements, Grain Quality, and Yield of Winter Wheat (Without Basic Fertilizer Background, Experiment 4, 2022–2024 Average)

Varieties	Number of plants before harvest, Plants/m²	Of which stemmed, plants/m²	Per ear		Thousand grains weight, g	Grains bulk density, g/cm³	Grains yield, c/ha	Vitreousness, %
			Number of grains, pieces	Weight of grains, g				
1	288	277	24,1	0,91	37,4	1,08	25,1	18,02
2	301	284	25,2	0,95	37,7	1,12	27,0	18,27
3	338	288	26,9	1,04	38,6	1,19	29,9	18,72
4	372	294	27,5	1,08	39,3	1,22	31,7	19,61
5	329	283	27,1	1,04	38,3	1,15	29,5	18,65
Sx %	1,8							
$MSD_{0.95}$ c/ha	1,5							

Variants: 1. seed material was obtained without applying fertilizer, 2. seed material was obtained in the $n_{110}p_{90}k_{60}$ fertilized variant (background), 3. seed material was obtained by soaking the seeds – background + complexon, 4. seed material was obtained by soaking the seeds – background + complexon + foliar feeding during the tillering stage, 5. Seed material was obtained - background + complexon at the tillering stage.

The improvement in seed material quality achieved through the application of Complexon led to increased levels of dry matter, protein, gluten, and NPK content in the resulting crop, even though fiber content decreased. This means that increased dry matter and reduced fiber content in the grain directly contribute to increased flour yield. Flour yield calculations based on 12 tons harvested from production fields covering 50 and 70 hectares, respectively, support this outcome.

Scientific Innovation and Practical Implications: This study introduces a novel organo-mineral fertilizer, Complexon, that was specifically formulated for Armenian meadow-grey soils. This marks a significant innovation in agricultural practices. Its unique composition, including macro- and microelements, amino acids, and complex-forming agents, demonstrates a synergistic effect that significantly enhances wheat yield and nutritional quality. This approach surpasses traditional mineral fertilization and aligns with the growing demand for sustainable agriculture and functional food production. The substantial increases in wheat yield (28.3–64.5% compared to the control), improved flour output (75–78%), and enhanced grain quality (increased dry matter, reduced cellulose) highlight the practical efficacy of Complexon.

The practical implications of this research are profound. Improving seed germination capacity and energy allows for reduced seed material usage, contributing to cost-effectiveness and resource efficiency. Furthermore, the enhanced nutritional profile of the wheat grain directly supports the production of functional foods, offering consumers nutritionally enriched products. This study provides a compelling case for adopting Complexon in wheat cultivation, demonstrating the potential to address agricultural productivity, food quality, and sustainability. The successful commercial-scale trials validate Complexon's viability for widespread application, promising to bolster food security and promote favorable dietary options.

Functional foods provide benefits beyond their fundamental nutritional value. These products offer specific health benefits contributing to health maintenance and disease prevention. Complexon not only improves the quantity and quality of the crop yield but also supports the production of functional foods by providing nutritionally enriched products to the public. This innovative approach in food production enables the development of foods that possess bioactive properties and strong antioxidant activities that support human health. Functional foods can serve as sources of high-quality proteins, vitamins, and other biotechnological components, directly contributing to overall health by reducing the risk of various chronic diseases. Wheat cultivated with Complexon has the potential to become a key ingredient in functional foods that meet nutritional needs and have a beneficial impact on overall health.

CONCLUSIONS

The proposed organic-mineral fertilizer (Complexon) increases wheat yield and maximizes crop nutritional value. This offers the potential for a functional food that can actively improve health.

Complexon fertilizer improves wheat seed germination capacity, germination energy, plant growth, yield, and grain quality indicators. Laboratory, vegetative, and field experiments have shown that the use of Complexon significantly increases seed germination capacity and germination energy, which allows less seed material to be used per unit area. Using Complexon also increases crop yield by 17.6-37.5% on average. In addition, Complexon significantly improves the nutritional qualities of the grain as the content of dry matter, proteins, starch, and gluten increases, even though fiber content decreases. The increased flour yield confirms the positive effect of Complexon, where the flour yield obtained was 75-78%, which is higher than that of the controls that received mineral fertilizers. The crop used as seed material showed high germination capacity and germination energy, positively affecting seed quality and yield stability.

Therefore, the use of Complexon increases wheat yield and ensures an improvement in the qualitative properties of the resulting crop. These improvements increase the benefits of functional food production, which contributes to overall human health.

Recommendations: Organomineral fertilizers are recommended to improve the yield, nutritional value, and functionality of wheat, an essential raw material for ensuring food security.

Abbreviations: RCBD: randomized complete block design.

Contributions: -All authors contributed to this study

Competing interests: The authors declare no conflict of interest.

Acknowledgement and funding: The authors would like to thank the administration of the «Scientific Center of Soil Science, Agrochemistry and Melioration after Hrant Petrosyan» Branch of Armenian National Agrarian University (ANAU) Foundation for their cooperation and support. They are also grateful to the local farmers for permission to conduct experiments and collect samples during the field surveys. The Science Committee of MESCS RA supported the work within the base funding program of scientific and technical activities.

REFERENCE:

1. Gasparyan G., Eloyan A., Jhangiryan T., Markosyan A., Beglaryan I., Barseghyan M. Wheat production management in saline soils through the use of vinasse. Functional Food Science. 2025; 5(1): 20-29. DOI: https://doi.org/10.31989/ffs.v5i1.1539
2. Jhangiryan T., Hunanyan S., Markosyan A., Yeritsyan S., Eloyan A., Barseghyan M., Gasparyan G. Assessing the effect of joint application of mineral fertilizers and biohumus on potato yield quality indicators. Functional Food Science. 2024; 4(12): 508-520. DOI: https://doi.org/10.31989/ffs.v4i12.1528
3. Beglaryan I., Eloyan A., Daveyan S., Jhangiryan T., Yeritsyan S., Gasparyan G. Effectiveness of pumpkin cultivation in crop rotation on forest brown soil. Bioactive Compounds in Health and Disease. 2025; 8(1): 1-10. DOI: https://doi.org/10.31989/bchd.8i1.1548
4. Jhangiryan T., Markosyan A., Yeritsyan H., Valeeva J., Petrosyan M., Valeeva G. Biohumus "Sis" for the ecologically pure agricultural production. BIO Web of Conferences. 2022; 52: 5. DOI: https://doi.org/10.1051/bioconf/2022520006
5. Sukiasyan A., Jhangiryan T., Ledashcheva T., Hunanyan S., Kirakosyan A. Environmental aspects of the application of mineral fertilizers. E3S Web of Conferences. 2024; 555: 03012.DOI: https://doi.org/10.1051/e3sconf/202455503012
6. Larionov M. V., Sargsyan K. S., Sayadyan H. Y., Margaryan V. G., Hunanyan S. A., Yeritsyan S. K., et al. The Influence of Cultivation, Storage, and Processing Technology on the Nitrate Content in Potato Tubers and Vegetable Crops as an Example of Ecologically and Hygienically Oriented Organic Agricultural Nature Management. Journal of Ecohumanism. 2024; 3(8): 292-302. DOI: https://doi.org/10.62754/joe.v3i8.4731
7. Martirosyan D.M., Lampert T., Lee M. A comprehensive review on the role of food bioactive compounds in functional food science. Functional Food Science. 2022; 3(2): 64-79. DOI: https://doi.org/10.31989/ffs.v2i3.906 1
8. Williams K., Oo T., Martirosyan D. M. Exploring the effectiveness of Lactobacillus probiotics in weight management: A literature review. Functional Food Science. 2023; 3(5): 42-54. DOI: https://doi.org/10.31989/ffs.v3i5.1115
9. Martirosyan D. M., Stratton S. Quantum and tempus theories of functional food science in practice. Functional Food Science. 2023; 3(5): 55-62. DOI: https://doi.org/10.31989/ffs.v3i5.1122
10. Elgadir M. A., Mariod A. A. Effect of Selected Food Additives on Quality of Meat and Meat Products, Recent Advances: Mini review. Agriculture and Food Bioactive Compounds. 2025; 2(4): 76-85. DOI: https://doi.org/10.31989/RDFFP.v2i4.1578
11. Agbodjato, N. A., and Babalola, O. O. Promoting sustainable agriculture by exploiting plant growth-promoting rhizobacteria (PGPR) to improve maize and cowpea crops. *PeerJ*, *12*, 2024, e16836. DOI: https://doi.org/10.7717/peerj.16836
12. Martirosyan D.M., Lampert T., Lee M. A comprehensive review on the role of food bioactive compounds in functional

food science. Functional Food Science. 2022; 3(2): 64-79. DOI: https://doi.org/10.31989/ffs.v2i3.906

13. Martirosyan D., Kanya H., Nadalet C. Can functional foods reduce the risk of disease? Advancement of functional food definition and steps to create functional food products. Functional Foods in Health and Disease. 2021; 11(5): 213-221. DOI: https://doi.org/10.31989/ffhd.v11i5.788
14. Martirosyan D., Stratton S. Advancing functional food regulation. Bioactive Compounds in Health and Disease. 2023; 6: 166. DOI: https://doi.org/10.31989/bchd.v6i7.1178
15. Thomas C. L., Acquah G., Whitmore A. P., McGrath S. P., Haefele S. M. The Effect of Different Organic Fertilizers on Yield and Soil and Crop Nutrient Concentrations. Agronomy. 2019; 9(12): 776. DOI: https://doi.org/10.3390/agronomy9120776
16. Toprak S., Seferoğlu S. The Use Efficiency of Phosphorus in Organomineral Fertilization Systems. Communications in Soil Science and Plant Analysis. 2024; 55(22): 3307-3316. DOI: https://doi.org/10.1080/00103624.2024.2391989
17. Ranva S., Singh Y., Jain N., Bana R., Aseri G., Madar R., Shokralla S., Mahmoud E., El-Sabrout A., Elansary H. Impact of Safe Rock Minerals, Mineral Fertilizers, and Manure on the Quantity and Quality of the Wheat Yield in the Rice-Wheat Cropping System. Plants. 2022; 11(2): 183. DOI: https://doi.org/10.3390/plants11020183
18. Markad A. Role of Nitrogen in Wheat Production System and Nitrogen for Improving Wheat Yield and Quality: A Review. Journal of Experimental Agriculture International. 2024; 46(7): 599-609. DOI: https://doi.org/10.9734/jeai/2024/v46i72613
19. Trukhachev V. I., Belopukhov S. L., Grigoryeva M., Dmitrevskaya I. I. Study of the Sustainability of Ecological and Chemical Indicators of Soils in Organic Farming. Sustainability. 2024; 16: 665. DOI: https://doi.org/10.3390/su16020665
20. Varalakshmi V., Bhagyalakshmi T., Shivakumar. Exploring Potential of Organo-Mineral Fertilizers in Augmenting Crop Yield and Quality - A Review. Advances in Research. 2025; 6 (December 7, 2024): 297-308.
21. Kafil Uddin Md., Biplob Saha K., Vanessa Wong N. L., Antonio Patti F. Organo-mineral fertilizer to sustain soil health and crop yield for reducing environmental impact: A comprehensive review. European Journal of Agronomy. 2025; 162: 127433. DOI: https://doi.org/10.1016/j.eja.2024.127433
22. Aguilar A. S., Cardoso A. F., Lima L. C., Luz J. M. Q., Rodrigues T., Lana R. M. Q. Influence of organomineral fertilization in the development of the potato crop cv. Cupid. Biosci J. 2019; 35: 199-210. DOI: https://doi.org/10.14393/BJ-v35n1a2019-41740
23. Almeida V. R., Vieira J., Almeida R. R., Carneiro G., Teixeira I. R., Vieira J., Mozena W., Almeida R. R. Use of organomineral at fertilization of beans in the Midwest region of Brazil. Res. Sq. 2019; 1-20. DOI: https://doi.org/10.21203/rs.3.rs451294/v1
24. Atere C. T., Olayinka A. Effect of organo-mineral fertilizer on soil chemical properties, growth, and yield of soybean. African Journal of Agricultural Research. 2012; 7: 5208-5216. DOI: https://doi.org/10.5897/ajar11.1378
25. Barbarick K., Ippolito J. Nitrogen fertilizer equivalency of sewage biosolids applied to dryland winter wheat. Journal of Environmental Quality. 2000; 29(4): 1345-1351. DOI: https://doi.org/10.2134/jeq2000.00472425002900040043x
26. Statistical Yearbook of Armenia, 2021, 2022. Available from: https://armstat.am/am/?id=12 (Accessed January 2025)
27. Antille D. L., Godwin R. J., Sakrabani R., Seneweera S., Tyrrel S. F., Johnston A. E. Field-scale evaluation of biosolids-derived organomineral fertilizers applied to winter wheat in England. Agronomy Journal. 2017; 109: 654-674. DOI: https://doi.org/10.2134/agronj2016.09.0495
28. Saltali K., Tuğrul C., Atici I., Bilir B. The effect of chemical and organomineral fertilizer treatments on the yield and some yield parameters of wheat plants. International Anatolian Agriculture, Food, Environment and Biology Congress. 2024; 624-631.
29. Marecek S., Martirosyan D. An assessment of clinical trials used in functional food science. Functional Foods in Health and Disease. 2023; 13(2): 22-35. DOI: https://doi.org/10.31989/ffhd.v13i2.1077
30. Gasparyan G. H., Yeritsyan L. S., Ayvazyan S. A., Sahakyan A. J. The efficiency of mineral and water-soluble complex fertilizers in potato fields. Agronomy and Agroecology. 2023; 2(82): 145-149. DOI: https://doi.org/10.52276/25792822-2023.2-145
31. Yeritsyan S., Gasparyan G., Yeritsyan L., Martirosyan G. Increasing the efficiency of chili pepper cultivation through an effective fertilization system. International Scientific Journal, Agriscience and Technology. Armenian National Agrarian University. 2022; 2(78): 154-158. DOI: https://doi.org/10.52276/25792822-2022
32. Yeritsyan S., Gasparyan G., Avagyan G., Grigoryan K. Struggling against bunt and smut diseases of wheat and barley by applying new complex fertilizers in organic agriculture.

Armenian National Agrarian University, Agriscience and Technology. 2020; 4(72): 55-61.

33. Yeritsyan S., Gasparyan G., Grigoryan K., Khachatryan A. Research on the efficiency of complex fertilizer produced from the new serpentine-based ingredient. Agriscience and Technology. Armenian National Agrarian University. 2024; 2: 130-137. DOI: https://doi.org/10.52276/25792822-2024.2-130
34. Kowalska I., Soluch A., Mołdoch J., Jończyk K. The effect of farming systems and cultivars on the qualitative and quantitative composition of bioactive compounds in winter wheat (Triticum aestivum L.). Molecules. 2025; 30: 902. DOI: https://doi.org/10.3390/molecules30040902
35. Glyazunova N. N., Khomutova A. V., Bezgina Yu. A. Monitoring of phytophagous pest populations in the crops of different winter wheat varieties. Agrarian Bulletin of the North Caucasus. 2023; 2(50): 58-64. DOI: https://doi.org/10.31279/2949-4796-2023-2-50-58-63
36. Dospekhov B. A. Methodology of field experiment. "Kolos", Moscow; 1973. p. 423. (in Russian)
37. Bush J. R., Baisley J., Harding S. V., Alfa M. J. Consumption of Solnul™ resistant potato starch produces a prebiotic effect in a randomized, placebo-controlled clinical trial. Nutrients. 2023; 15: 1582. DOI: https://doi.org/10.3390/nu15071582
38. ISO 10390:200. Soil quality - determination of pH, Edition 2. Technical Committee: ISO/TC 190/SC 3 Chemical and physical characterization.
39. Arinuskina E. V. Manual for soils chemistry analysis. Moscow State University; 1962. 491 pages. (in Russian)
40. Yagodin B. A., Deryugin I. P., Zhukov Yu. P., Ed. Yagodin B. A. Practical Course in Agrochemistry: Textbook for University Students. Moscow; 1987. 511 pages. (in Russian)
41. Paloheimo L., Herkola E., Kero M. A method for cellulose determination. Agricultural and Food Science. 1962; 34(1): 57-65. DOI: https://doi.org/10.23986/afsci.71590
42. GOST 27839-2013. Wheat flour. Methods for determining the quantity and quality of gluten. Put into effect by the Order of Rosstandart No. 294-st dated June 28, 2013.