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ECONOMIC GROUNDING FOR ECOLOGICALLY SAFE STRATEGY OF MINERAL FERTILIZERS USE

The article analyzes both traditional approaches to the determination of optimal amounts for the mineral fertilizers use in crop production technologies and the new ones, based on the results of determination of biological processes activity in soil. Economic efficiency of environmentally safe strategy of mineral fertilizers use is grounded.

Keywords: *mineral fertilizers; microbial products; ecologically safe strategy.*

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ЕКОНОМІЧНЕ ОБҐРУНТУВАННЯ ЕКОЛОГІЧНО БЕЗПЕЧНОЇ СТРАТЕГІЇ ЗАСТОСУВАННЯ МІНЕРАЛЬНИХ ДОБРИВ

У статті проаналізовано традиційні підходи до визначення оптимальних норм застосування мінеральних добрив у технологіях вирощування сільськогосподарських культур та нові, що базуються на результатах визначення активності біологічних процесів у ґрунті. Обґрунтовано економічну доцільність екологічно безпечної стратегії використання мінеральних добрив.

Ключові слова: *мінеральні добрива; мікробні препарати; екобезпечна стратегія.*
Табл. 4. Літ. 18.

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ЭКОНОМИЧЕСКОЕ ОБОСНОВАНИЕ ЭКОЛОГИЧЕСКИ БЕЗОПАСНОЙ СТРАТЕГИИ ПРИМЕНЕНИЯ МИНЕРАЛЬНЫХ УДОБРЕНИЙ

В статье проанализированы традиционные подходы к определению оптимальных норм применения минеральных удобрений в технологиях выращивания сельскохозяйственных культур и новые, основанные на результатах определения активности биологических процессов в почве. Обоснована экономическая целесообразность экологически безопасной стратегии использования минеральных удобрений.

Ключевые слова: *минеральные удобрения; микробные препараты; экобезопасная стратегия.*

Problem setting. The development of agricultural production today is impossible without the use of mineral fertilizers, which allow increasing the level of soil nutrient regime and crop yields. According to FAO, Western Europe and the United States obtain the third part of their harvest due to mineral fertilizers. Calculations of M.M. Horodnii (2008) show that the share of fertilizers in crop formation is: in Europe – 45–50%, in the US – 40–45%, in Ukraine – 30–40%.

But along with positive importance of mineral fertilizers there are also negative consequences of their use. Real practice of management indicates the uncontrolled use of mineral fertilizers and other chemicals that may cause violation of the natural course of biological processes in the soils of agrocenoses and environmental pollution.

In relation to the above, the systems of crops fertilization should take into account environmental and economic feasibility criteria for their use. This becomes

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of great national importance. The Law of Ukraine "On the Fundamentals (Strategy) of State Environmental Policy of Ukraine till 2020" sets the guidelines of environmentally sustainable nature management as one of the priorities, which requires creating the grounds for wide introduction of environmentally oriented technologies in agriculture (Law of Ukraine, 21.12.2010, # 2818-VI).

Considering the above there is a need in development of new ecologically safe and cost-effective strategy of mineral fertilizers use.

Recent research and publications analysis. The study of the problems of efficient and ecologically safe use of mineral fertilizers has received considerable attention. Various aspects of it are displayed in the works of M.M. Horodnii et al. (2004), O.O. Yehorshyn et al. (2012), D.A. Korenkov (1990), V.I. Makarov et al. (2011) and others. O.A. Korchynska (2000), Y.A. Makhortov (2001) and others dedicated their works to grounding economic efficiency of mineral fertilizers use.

Despite the considerable number of scientific papers on the use of mineral fertilizers, it should be noted there are no reliable methods for determining the optimal dose of nitrogen fertilizers for crops. Most calculations are made for the planned yield based on the results of the previous diagnostics of soils and coefficients of using an active ingredient of fertilizers by plants (Volkohon, 2013). There are various versions of the method, but their essence is assessing the removal of elements with the planned harvest (Horodnii et al., 2004; Sozinov et al., 1996; Hofman et al., 2004). These methodological approaches would be perfect provided the complete use of applied fertilizers by cultivated plants. However, the extent of absorption of nutrients from fertilizers is low: nitrogen – 35–50%, phosphorus – no more than 20%, potassium – within 25–60% depending on soil and climatic characteristics (Korenkov, 1990). Accordingly, the use of these methods leads to planning the most of estimated doses of environmental pollution. Obviously, this is also impractical from the economic point of view. Especially, the specified regards to nitrogen fertilizers because they are the biggest polluters of the environment. In addition, the largest share of funds in agricultural production is spent for production, packaging, transportation, storage and use of these fertilizers. In Europe the figure is equal to 38% on average, reaching 42% in the USA (Posgate, 1978). Given the degree of assimilation of nitrogen from fertilizers by plants, the appropriateness of traditional approaches in their use becomes questionable.

Based on the logic of mineral nutrition of plants, the optimum nitrogen nutrition standards are those that supply structural needs of plants and, at the same time, do not pollute the environment. However, until recently it has been impossible to determine them. Problem solution appeared in the late 20th – early 21st centuries, and is associated with the emergence of a new trend in soil microbiology – associative nitrogen fixation. Thus, in determining the effect of different doses of mineral nitrogen on the process of associative nitrogen fixation it was shown that there are amounts of fertilizers which stimulate the activity of biological nitrogen fixation from the atmosphere by bacteria that spatially and functionally are closely connected with plants roots. Such amounts of fertilizers are defined as a physiologically optimal for plant-bacterial associations (Ladha et al., 1986; Umarov et al., 1985). Typically, these are low doses, the use of which is not able to ensure the fulfilment of crop yield potential. However, this prompted us to search not only the amounts of mineral nitrogen

that stimulate nitrogen fixation, but also those that at least do not reduce the level of activity compared to the figures of the variant without the use of fertilizers (a kind of environmental criteria). Such doses may be considered environmentally appropriate.

An additional test for the reasonability of nitrogen fertilizers doses defined in such a way is to study the peculiarities of the course of the process of biological denitrification in the root zone of plants. The use of phosphate and potash fertilizers at this can be done in a balanced manner to the amount of mineral nitrogen. Subject to these methodological approaches the ratios of active ingredient absorption from fertilizers increase.

A significant increase in the degree of nutrients use by crops and, in particular, from mineral fertilizers, is also achieved through the use of microbial preparations. In our view, the lack of attention to microbiological factor of transformation of compounds of main elements of plant nutrition largely led to low efficiency of fertilizers use and environmental pollution. Traditionally, the matters of mineral nutrition of plants were considered only as a problem for agrochemistry and plant physiology. Today, their solution should be approached as a complex and necessarily considering the developments in soil microbiology with the relevant economic justification.

The research objectives. Economic grounding for the use of physiologically (environmentally) appropriate doses of mineral nitrogen for taking corresponding managerial decisions in the development of modern systems of crops fertilizing.

Key research findings. The main parameters in determining the economic efficiency of mineral fertilizer use are crop yield, cost parameters – spending per 1 ha, unit cost, income, profitability. At the same time in Ukraine, according to O.A. Korchynska (2000), most methods of determining the optimal doses of mineral fertilizers are focused on obtaining target yield or maximization of yield growth per 1 ha. Meanwhile, the level of target yield or maximum yield per area unit may occur disadvantageous from the economic point of view.

Under current market conditions the environmental component of mineral fertilizers use, we believe, is limited to environmentally threshold doses of mineral fertilizers, i.e. those doses that do not pollute the environment. The criterion of economic efficiency in the determination of optimal doses of mineral fertilizers, in our opinion, should be the income and profitability level.

Given the complexity of economic evaluation (in terms of specific farms), the determination of the impact of certain factors, including the use of mineral fertilizers, we carried out the calculations of technological and expenditure sides of flow process charts on the methodical basis (Sabluk et al., 2008) taking into account the specific characteristics of the amounts of mineral fertilizers dressing, that are studied, and the use of microbial preparations.

Economic evaluation was conducted upon the following indicators of production efficiency: yield, expenses (total cost) on 1 ha of cultivated area and 1 ton of products basis, revenue on 1 ha of cultivated area basis, income on 1 ha of cultivated area and 1 ton of products basis, the profitability level of production.

Prices for resources and agricultural products are taken as of 02.01.2015. Under current conditions of swift price dynamics cost parameters may change in near future, but trends for the comparison of the efficiency of the studied variants defined by the comparative analysis will be saved.

Economic evaluation was carried out upon the efficiency of winter wheat grain, potatoes, spring barley grain, maize green mass. Environmentally appropriate doses of mineral fertilizers were determined previously at the Institute of Agricultural Microbiology and Agricultural Production of NAAS (Volkohon, 2013; Hrynyk et al., 2010).

The results of economic efficiency calculations of the use of different doses of mineral fertilizers in growing winter wheat are given in Table 1.

Table 1. **Economic efficiency of winter wheat grain production at different levels of mineral fertilization,** *calculated by the authors using the data* (Volkohon, 2013: 92)

Indicators	Variant 1	Variant 2	Variant 3
Yield t / ha	5.17	4.99	5.65
Costs per 1 ha, UAH	7341.23	8546.15	8678.65
incl. the cost of mineral fertilizers, UAH	2106.56	3162.40	3162.40
The cost of 1 ton, UAH	1419.97	1712.66	1536.04
Sales price of 1 ton, UAH	3300.00	3300.00	3300.00
Revenues per 1 ha, UAH	17061.00	16467.00	18645.00
Income per 1 ton, UAH	1880.03	1587.34	1763.96
Income at 1 ha, UAH	9719.77	7920.85	9966.35
The level of profitability, %	132.4	92.7	114.8

Notes: variant 1 – application of physiologically appropriate doses of mineral fertilizers ($N_{60}K_{40}$) and inoculation with Polimiksobakteryn; variant 2 – application of high doses of mineral fertilizers ($N_{90}K_{60}$) without inoculation; variant 3 – application of high doses of mineral fertilizers ($N_{90}K_{60}$) and inoculation with Polimiksobakteryn.

While using physiologically (environmentally) appropriate amounts of mineral fertilizers – $N_{60}K_{40}$ (phosphoric ones were not used due to high content of mobile phosphates in the soil) and making preplant bacterization with Polimiksobakteryn and getting grain yield of 5.17 t/ha, the cost of 1 ton of product will be 1419.97 UAH, and the level of profitability – 132.4%. By increasing the agricultural background to $N_{90}K_{60}$ (without inoculation) and getting the yield of 4.99 t/ha, the cost will increase to 1712.66 UAH/t and profitability will decrease to 92.7%. The use of Polimiksobakteryn at the same level of mineral fertilization will promote increasing the yield to 5.65 t/ha, reducing the cost to 1536.04 UAH/t and increasing the profitability to 114.8% as compared to the second variant. Consequently, the use of physiologically (environmentally) appropriate amounts of mineral fertilizers (variant 1) provides the highest level of income and profitability of winter wheat grain production, despite the fact that the yield is lower by 0.48 t/ha as compared to the variant of application of higher doses of fertilizers with Polimiksobakteryn inoculation (variant 3).

Based on the investigated features of the processes of biological nitrogen fixation and denitrification in the root area of winter wheat at growing on meadow black soil under the influence of different doses of mineral nitrogen introduced in two stages, environmentally appropriate doses of mineral nitrogen were determined as those that do not exceed 60 kg/ha. Application of 90 kg of mineral nitrogen per 1 ha of crops is a compromise from the environmental point of view (Volkohon, 2013).

Economic grounding for the use of different doses of mineral fertilizers at growing potatoes is given in Table 2.

Table 2. **Economic efficiency of potato production at different levels of mineral fertilization,** *calculated by the authors using the data* (Hrynyk et al., 2010: 15)

Indicators	Variant 1	Variant 2	Variant 3
Yield t / ha	27.1	23.2	25.1
Costs per 1 ha, UAH	37849.92	38256.01	39013.48
incl. the cost of mineral fertilizers, UAH	7471.27	8695.77	8695.77
The cost of 1 ton, UAH	1396.68	1648.97	1554.32
Sales price of 1 ton, UAH	3200.00	3200.00	3200.00
Revenues per 1 ha, UAH	86720.00	74240.00	80320.00
Income per 1 ton, UAH	1803.32	1551.03	1645.68
Income at 1 ha, UAH	48870.08	35983.99	41306.52
The level of profitability, %	129.1	94.1	105.9

Notes: variant 1 – application of physiologically appropriate doses of mineral fertilizers ($N_{90}P_{90}K_{120}$) and inoculation with Biogran; variant 2 – application of high doses of mineral fertilizers ($N_{120}P_{90}K_{150}$) without inoculation; variant 3 – application of high doses of mineral fertilizers ($N_{120}P_{90}K_{150}$) and inoculation with Biogran.

For Svitanok Kyivskyi potato variety physiologically (environmentally) appropriate amount of mineral fertilizers are $N_{90}P_{90}K_{120}$ accompanied with planting material treatment with Biogran microbial preparation. The Yields thus reached 27.1 t/ha. According to our calculations (Table 2) in such conditions the cost of 1 ton of potato will be 1396.68 UAH, and the level of profitability – 129.1%. By increasing the application rate of fertilizer to $N_{120}P_{90}K_{150}$ without bacterization the yield will be 23.2 t/ha, with profitability rate of 94.1%. The use of Biogran on this agricultural background increases the yield to 25.1 t/ha and profitability – to 105.9%. To sum it up, it should be noted that physiologically (environmentally) appropriate amounts of mineral fertilizers (variant 1) provide the highest yield, efficiency and profitability of potato production.

Investigations of the processes of biological nitrogen fixation and denitrification in the root area of potato plants show that among the investigated doses of fertilizers environmentally acceptable are those that do not exceed (by nitrogen) 90 kg/ha (Hrynyk et al., 2010).

While using physiologically appropriate amounts of mineral in growing spring barley ($N_{60}K_{25}$) and making preplant bacterization with Mikrogumin microbial preparation and getting the grain yield of 3,77 t/ha, the cost of 1 ton of product will be 1716.19 UAH, and the level of profitability – 78 9% (Table 3).

By increasing the agricultural background to $N_{120}K_{50}$ (without inoculation) and getting the yield of 3.58 t/ha, the cost will increase to 2409.59 UAH/t and the profitability will decrease to 27.4%. The use of Mikrogumin at the same level of mineral fertilization will decrease the cost to 2097.74 UAH/t increasing the yield to 4.19 t/ha and profitability – to 46.3% as compared to variant 2. Thus, the use of physiologically (environmentally) appropriate amounts of mineral fertilizers provides the highest income and the level of profitability of spring barley grain production despite the fact

that the yield is lower by 0.42 t/ha as compared to the variant of application of high doses of fertilizers with the inoculation with Mikrogumin (variant 3).

Table 3. **Economic efficiency of spring barley grain production at different levels of mineral fertilization,** *calculated by the authors using the data* (Hrynyk et al., 2010: 11)

Indicators	Variant 1	Variant 2	Variant 3
Yield t / ha	3.77	3.58	4.19
Costs per 1 ha, UAH	6470.05	8626.32	8789.54
incl. the cost of mineral fertilizers, UAH	1851.01	3707.14	3707.14
The cost of 1 ton, UAH	1716.19	2409.59	2097.74
Sales price of 1 ton, UAH	3070.00	3070.00	3070.00
Revenues per 1 ha, UAH	11573.9	10990.60	12863.30
Income per 1 ton, UAH	1353.81	660.41	972.26
Income at 1 ha, UAH	5103.85	2364.28	4073.76
The level of profitability, %	78.9	27.4	46.3

Notes: variant 1 – application of physiologically appropriate doses of mineral fertilizers ($N_{60}K_{25}$) and inoculation with Mikrogumin; variant 2 – application of high doses of mineral fertilizers ($N_{120}K_{50}$) without inoculation; variant 3 – application of high doses of mineral fertilizers ($N_{120}K_{50}$) and inoculation with Mikrogumin.

Based on the investigated features of processes of biological nitrogen fixation and denitrification in the root area of spring barley plants, environmentally appropriate doses of mineral nitrogen are those that do not exceed 60 kg/ha (Hrynyk et al., 2010).

Table 4. **Economic efficiency of green corn production at different levels of mineral fertilization,** *calculated by the authors using the data* (Hrynyk et al., 2010: 5)

Indicators	Variant 1	Variant 2	Variant 3
Yield t / ha	45.2	44.9	47.4
Costs per 1 ha, UAH	8870.75	11357.80	11446.18
incl. the cost of mineral fertilizers, UAH	4381.37	6566.08	6566.08
The cost of 1 ton, UAH	196.26	252.96	241.48
Conditional sales price of 1 ton, UAH[1)]	450.00	450.00	450.00
Conditional revenues per 1 ha, UAH	20340.00	20205.00	21330.00
Conditional income per 1 ton, UAH	253.74	197.04	208.52
Conditional income at 1 ha, UAH	11469.25	8847	9883.82
Conditional level of profitability, %	129.3	77.9	86.4

Notes: variant 1 – application of physiologically appropriate doses of mineral fertilizers ($N_{80}P_{36}K_{68}$) and inoculation with Biogran; variant 2 – application of high doses of mineral fertilizers ($N_{120}P_{54}K_{102}$) without inoculation; variant 3 – application of high doses of mineral fertilizers (N120P54K102) and inoculation with Biogran; [1)] sales price is determined based on the level of prices for oat grain and content of feed units in oat grain and green corn.

When growing green corn physiologically appropriate amounts of mineral fertilizers are $N_{80}P_{36}K_{68}$, that in combination with preplant bacterization with Biogran provides the yield at the rate of 45.2 t/ha (Table 4). We calculated that in such a case the cost of 1 ton of product will be 196.26 UAH, and the conditional level of profitability – 129.3%. Using higher amount of mineral fertilizers ($N_{120}P_{54}K_{102}$) without seed bacterization the cost will be 252.96 UAH/t, at the yield rate of 44.9 t/ha and

conditional profitability of 77.9%. Provided the use of Biogran in addition to this dose of fertilizers the yield increases to 47.4 t/ha, the cost decreases to 241.48 UAH/t and profitability increases to 86.4%. Summing it up, it should be noted that physiologically (environmentally) appropriate amounts of mineral fertilizers (variant 1) provide the highest income and the level of green corn production profitability, though the yield is lower by 2.2 t/ha as compared to the variant of application of high doses of fertilizers with Biogran inoculation (variant 3).

The investigations of the processes of biological nitrogen fixation and denitrification in the root area of corn plants allowed defining environmentally appropriate doses of mineral nitrogen at the level of 80 kg/ha (Hrynyk et al., 2010).

Conclusions and development prospects. The use of physiologically (environmentally) appropriate amounts of mineral fertilizers in combination with the use of microbial preparations provides the most complete implementation of their fertilizing capacity, and thus, achieving the highest economic results. This gives reasons to state that the mentioned doses of fertilizers are the most cost effective at the same time. Consequently, the current strategy of mineral fertilizers application should be based on the use of physiologically (environmentally) appropriate amounts of mineral fertilizers combined with microbial preparations that will allow agricultural producers not only significantly save on fertilizers, but also have better economic performance without polluting the environment.

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