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Economic efficiency of balanced fertilisation systems for table potatoes with macro- and meso-elements on dark grey podzolic soil using liquid phosphorus fertilisers

Abstract. Today's market conditions require producers to minimise the cost of technological processes for growing crops to maximise profits. One of the important conditions for the selection and application of certain agrotechnical measures in potato growing technology is to obtain high yields, maximum net profit and a high level of profitability. Among the technological methods for growing table potatoes, the use of fertilisers is one of the most expensive items. Therefore, the use of liquid phosphate fertilisers and balancing fertilisation systems with meso-elements is one of the most promising measures in this regard. The purpose of the research was to determine the

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economic efficiency of systems of balanced nutrient supply of table potatoes with macro- and meso-elements on dark grey podzolic soil in the conditions of the Left-Bank Forest-Steppe of Ukraine using liquid phosphorus fertilisers. The research was conducted in the field experiment of the O.I. Dushechkin Department of Agrochemistry and Quality of Crop Production of the National University of Life Sciences of Ukraine at Biotech LTD (Boryspil district, Kyiv oblast) during 2015-2017. The area of the registered plot was 40 m², and the repetition rate of the experiment is 3 times. The placement of variants is systematic. The research showed that the use of liquid phosphorous fertilizers in the rate of P₁₀₅ on the background of N₁₂₀K₁₈₀ showed high economic efficiency in the cultivation of table potatoes and allowed to obtain a conditional net profit of 54.4 thousand UAH/ha and a profitability level of 59%. The introduction of the starter fertiliser Ca₂₁Mg₁₅B_{1.5} into the scheme provoked a rise in economic indicators relative to the control, but a decrease compared to similar variants without these elements. The reason for this is the introduction of phosphorus and calcium into one layer of dark grey podzolic soil, which provoked their interaction and the formation of tri-substituted phosphates, which, in turn, led to a decrease in yield. The multi-depth application of nutrients in the technologies of growing table potatoes is a promising area for further study

Keywords: fertilisers, LCF 11-37, calcium, magnesium, boron, operating profit, profitability, fertiliser costs, yield, start fertiliser, profit

RELEVANCE

Current market conditions require producers to reduce the costs of growing crops in order to maximise profits (Lavrov, 2007). However, modern potato production must still be based on the latest scientific and technical achievements: varieties of intensive type, the use of high-quality seeds (Ostapenko *et al.*, 2020; Bordyuzha, 2019), advanced cultivation techniques, an effective system of fertilisers and plant protection products, and a high level of logistics. These techniques and elements of technology should be adapted to individual soil and climatic zones (Bordyuzha, 2019).

One of the important conditions for the selection and application of certain agrotechnical measures in potato cultivation technology is to obtain high yields, maximum net profit and a high level of profitability. The main task that remains to be solved is achieving the highest quantity of products of appropriate quality per unit area at the lowest labour

and money costs (Khodakovsky *et al.*, 2006; Shchitkin, 2004). Among the agrotechnical methods for growing table potatoes, the use of fertilisers is one of the most expensive items (Holubev, 1991). That is why the use of liquid phosphate fertilisers is one of the most practical measures in this regard. They are characterized by better mobilisation properties and availability of nutrients for plants, which allow for obtaining better results than other forms of fertilisers (Zinchenko *et al.*, 2001).

However, apart from the form of fertiliser, achieving balanced nutrition of potatoes not only with macronutrients but also with meso-nutrients is also essential in today's climate instability, which is the reason for the low yields of this crop in Ukraine in recent decades. Therefore, technological solutions that include the possibility of its initial provision with macro- and meso-elements are relevant (Bordyuzha, 2019), therefore becoming the basis of this research.

ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The key to growing profits from potato farming is high yields of high quality at reduced costs. At the same time, according to R.O. Myalkovsky (2017), A.I. Fateev and M.A. Zakharova (2005). At the same time, according to R. Rozhnyatovsky (2019), the main criterion for managing yield and product quality is an optimisation of plant nutrition, which is based on the principle of nutritional comfort, i.e., the creation of conditions that eliminate stress caused by lack of nutrients, ensure positional availability of their root system, etc. Therefore, according to scientists (Koval & Ilchuk, 2019; Hamayunova *et al.*, 2018), the high share of mineral fertilisers in the structure of potato production costs (19-21%) requires a constant search for new ways to reduce the cost of production. This question was studied by the following scientists: A.V. Bykin & I.P. Bordyuzha (2018), V.M. Hamayunova *et al.* (2018), Fr.V. Ostapenko *et al.* (2020), R.O. Myalkovsky (2017) and others. Among the possible solutions to this issue, they consider local fertilisation, foliar fertilisation with microelements, irrigation, etc. However, the issue of selecting the optimal physical form of fertiliser, as well as the possibility of balancing fertilisation systems with meso-elements, remains unaddressed, which is what this study aimed to investigate.

The purpose of the study is to establish the economic efficiency of balanced nutrition plans for table potatoes with macro- and meso-elements on dark grey podzolic soil in the conditions of the Left-Bank Forest-Steppe of Ukraine using liquid phosphorus fertilisers.

MATERIALS AND METHODS

The research was conducted in the field experiment of the O.I. Dushechkin Department of Agrochemistry and Quality of Crop Production of the National University of Life Sciences of

Ukraine at Biotech LTD (Boryspil district, Kyiv oblast) during 2015-2017.

The area of the registered plot was 40 m², the repetition rate of the experiment is 3 times. The placement of variants is systematic. The medium-late variety Mozart (originator HZPC Holland, the Netherlands) was chosen for the research.

The soil of the experimental plot is dark grey podzolic coarse-dusted light loamy on loess. It was characterised by a slightly acidic reaction of the soil solution (5.20), low mineral nitrogen content (13.4 mg/kg), a high degree of provision of mobile phosphorus (168 mg/kg) and potassium (174 mg/kg) and an average – exchangeable calcium (742 mg equivalent/100 g of soil) and magnesium (1.64 mg equivalent/100 g of soil).

The experimental design included the following fertilisation schemes:

1. No fertilisers (control);
2. N₁₂₀P₃₅K₁₈₀ (Rlcf);
3. N₁₂₀P₇₀K₁₈₀ (Rlcf);
4. N₁₂₀P₁₀₅K₁₈₀ (Rlcf);
5. N₁₂₀Rlcf₃₅K₁₈₀Ca₂₁Mg₁₅B_{1.5} (p.Ca, Mg);
6. N₁₂₀Rlcf₇₀K₁₈₀Ca₂₁Mg₁₅B_{1.5} (p.Ca, Mg);
7. N₁₂₀Rlcf₁₀₅K₁₈₀Ca₂₁Mg₁₅B_{1.5} (p.Ca, Mg);

The following fertilisers were used in the experiment: ammonium nitrate (DSTU 7370:2013), LCF 11-37 (TU – 2186-627-00209438-01), potassium sulfate (GOST 4145-74), magnesium sulphate, Bospholyar Boron (B-21%). The cost-effectiveness was determined at the prices of 2015-2017.

RESULTS AND DISCUSSION

Applying liquid forms of phosphorous fertilisers is a cost-effective measure. This study revealed that the use of liquid phosphate fertilisers at the rate of P₃₅ had a positive impact on economic efficiency (Figures 1 and 2). Operating profit at

this rate of phosphorus reached 18.2 thousand UAH/ha with a profitability level of 20.2%. As the rate of phosphorus fertilisers increased, production costs also increased (Fig. 3), but the effectiveness of these fertilisers resulted in higher yields of table potatoes, which in turn contributed to high profits. With the use of LCF 11-37 in the rate of P_{75} , the conditional net income amounted to 30.1 thousand UAH/ha

(33.0% profitability). The highest performance indicators were shown by the variant with the application of LCF 11-37 in the rate of P_{105} in combination with $N_{120}K_{180}$, where the operating profit was 54.4 thousand UAH/ha and the profitability level is 59%. In the control, the cost of cultivating potatoes exceeded the value of the harvest by 19.7 thousand UAH (Fig. 3), so there was no profit in this variant.

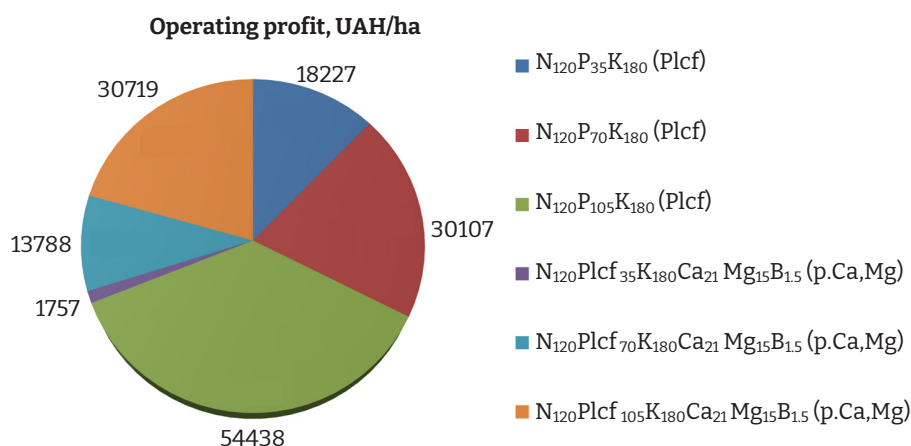


Figure 1. Operating profit generated by cultivating table potatoes of the Mozart variety using macro- and meso-elements in fertilisation systems, 2015-2017

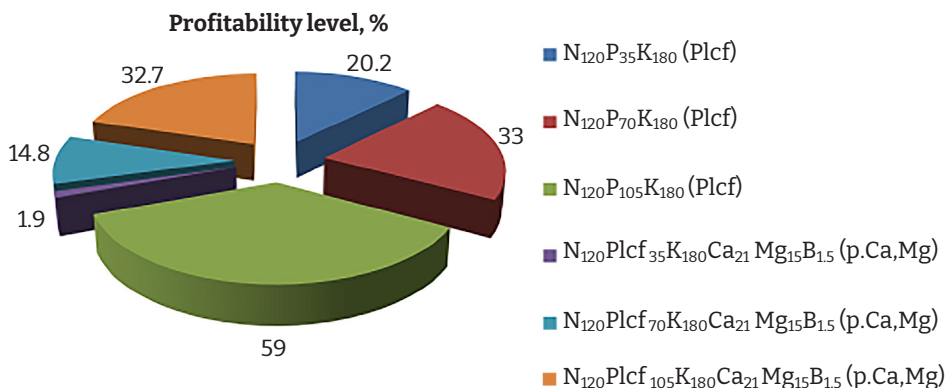


Figure 2. The level of profitability of the cultivation of the Mozart variety table potato using macro- and meso-elements in its fertilisation systems, 2015-2017

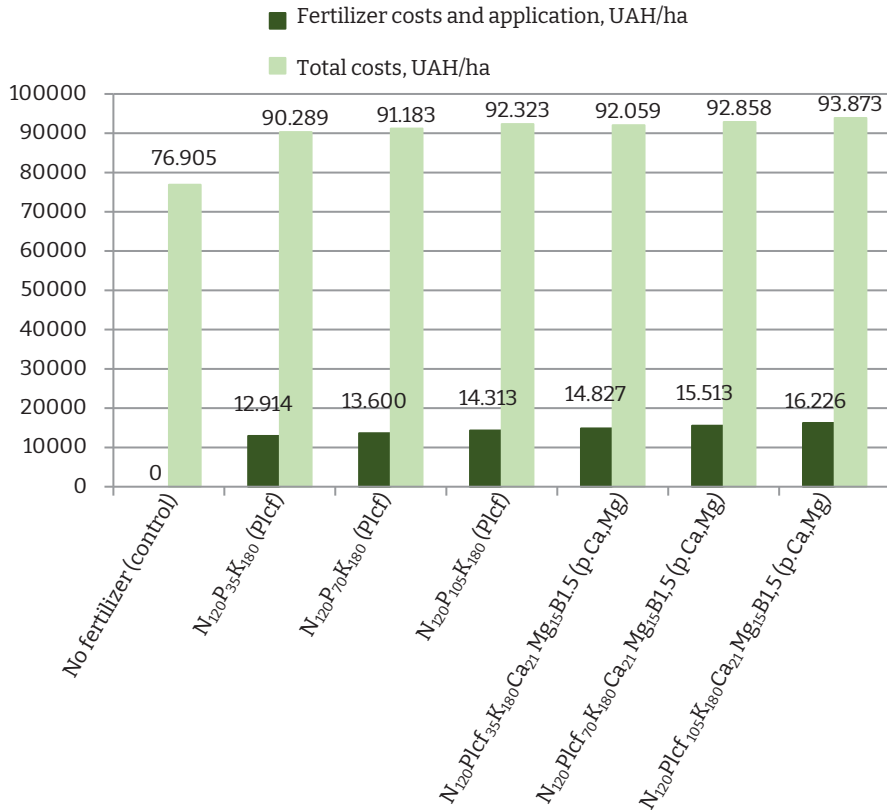


Figure 3. Production costs related to the cultivation of table potatoes of the Mozart variety using macro- and meso-elements in its fertilisation systems, 2015-2017

The introduction of fertilisers with calcium, magnesium and boron into the fertiliser system resulted in an increase in production costs by an average of 16,025 UAH/ha (Fig. 3) and an increase in profitability as compared to the control. At the rate of P_{35} with $Ca_{21}Mg_{15}B_{1.5}$, this economic indicator was 1.9%, at the rate of P_{70} and P_{105} – 14.8% and 32.7%, respectively. However, due to lower yields (Fig. 4), which were caused by a decrease in the amount of available phosphorus in the soil, as phosphorus and calcium were applied

in one layer, along with higher production costs, these options were less profitable than those using only NPK. Thus, when using $N_{120}Rlcf_{35}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg) yield decreased by 2.9 t/ha (fig. 4) compared to the same variant without meso-elements with an increase in production costs by 1,770 UAH/ha (fig. 3), when $N_{120}Rlcf_{70}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg) was applied: -4.8 t/ha of potato tubers and +1675 UAH/ha of costs, $N_{120}Rlcf_{105}K_{180}Ca_{21}Mg_{15}B_{1.5}$ (p.Ca, Mg): -7.3 t/ha of tubers and +1550 UAH/ha of expenses.

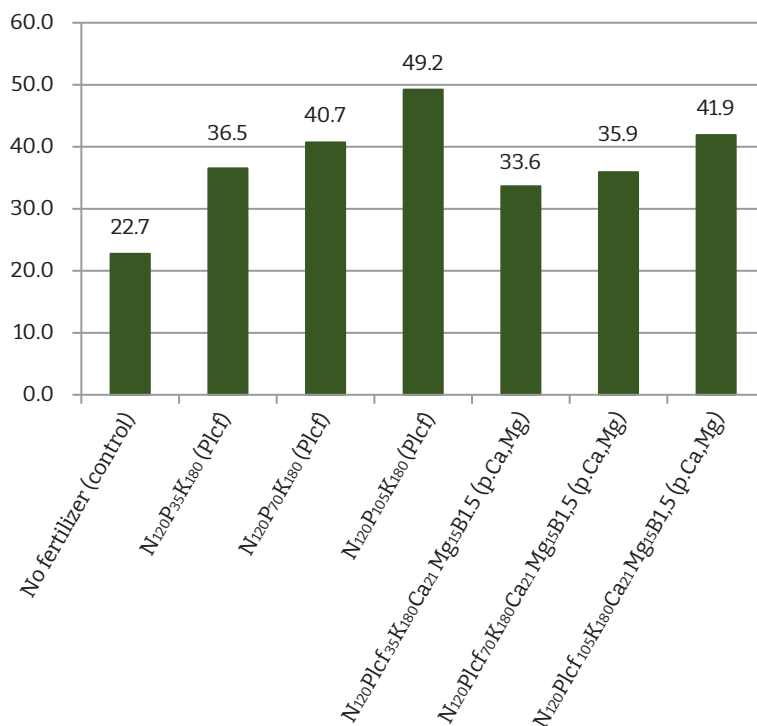


Figure 4. The yield of table potatoes of the Mozart variety when cultivated on dark grey podzolic soil, 2015-2017

CONCLUSIONS

The application of liquid phosphorus fertilisers in the rate of P_{105} in combination with $N_{120}K_{180}$ showed high economic efficiency in the cultivation of table potatoes and allowed to obtain an operating profit of 54.4 thousand UAH/ha and a profitability level of 59%. The introduction of the starter fertiliser $Ca_{21}Mg_{15}B_{1.5}$ into the scheme provoked a rise in economic indicators relative to the control, but a decrease compared

to similar variants without these elements. The reason for this is the introduction of phosphorus and calcium into one layer of dark grey podzolic soil, which triggered their interaction and the formation of tri-substituted phosphates, which, in turn, led to a decrease in the yield of potato tubers. The multi-depth application of nutrients in the technologies of growing table potatoes is a promising area for further study.

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Економічна ефективність збалансованих систем удобрення картоплі столової макро- і мезоелементами на темно-сірому опідзоленому ґрунті з використанням рідких фосфорних добрив

Анотація. Сучасні ринкові умови вимагають від виробників мінімізації витрат на технологічні процеси вирощування сільськогосподарських культур для отримання максимального прибутку. Однією з важливих умов вибору та застосування тих чи інших агротехнічних заходів у технології вирощування картоплі є отримання високих врожаїв, максимального чистого прибутку та високого рівня рентабельності. Серед технологічних прийомів вирощування столової картоплі застосування добрив є однією з найдорожчих статей. Тому застосування рідких фосфорних добрив та балансування систем удобрення мезоелементами є одним із найперспективніших заходів у цьому плані. Метою досліджень було визначення економічної ефективності систем збалансованого живлення картоплі столової макро- та

мезоелементами на темно-сірому опідзоленому ґрунті в умовах Лівобережного Лісостепу України з використанням рідких фосфорних добрив. Дослідження проводили в польовому досліді кафедри агрохімії та якості продукції рослинництва ім. О.І. Душечкіна Національного університету біоресурсів і природокористування України на базі ТОВ «Біотех» (Бориспільський район, Київська область) протягом 2015-2017 років. Площа облікової ділянки становила 40 м², повторність дослідів – 3-кратна. Розміщення варіантів – систематичне. Дослідження показали, що застосування рідких фосфорних добрив у нормі P_{105} на фоні $N_{120}K_{180}$ показало високу економічну ефективність при вирощуванні картоплі столової та дозволило отримати умовний чистий прибуток 54,4 тис. грн/га та рівень рентабельності 59%. Внесення в схему стартового добрива $Ca_{21}Mg_{15}B_{1,5}$ спричинило зростання економічних показників відносно контролю, але зниження порівняно з аналогічними варіантами без цих елементів. Причиною цього є внесення фосфору та кальцію в один шар темно-сірого опідзоленого ґрунту, що спровокувало їх взаємодію та утворення тризаміщених фосфатів, які, в свою чергу, призвели до зниження врожайності. Перспективним напрямом подальших досліджень є різноглибинне внесення поживних речовин у технологіях вирощування картоплі столової

Ключові слова: добрива, LCF 11-37, кальцій, магній, бор, операційний прибуток, рентабельність, витрати на добрива, урожайність, стартове добриво, прибуток