Agroeconomic efficiency of chemical ameliorants new forms for potato cultivation

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Abstract. Applying granulated AgroMag to the soil in doses of 100-200 kg/ha annually and foliar treatment with AgroMag AktiMax during the growing season in combination with NPK-fertilizers with a predominance of potassium (N:P:K = 1:1-1.3:1.3-1.5) provides a significant increase in potato yields, a decrease in tuber morbidity common scab, improving the quality of products and increasing the fertility of acidic sod-podzolic soils.

1. Relevance
According to the agrochemical survey, the total arable land requiring priority liming is > 35.0 million hectares. Acidic soils (pH <5.5) have unfavorable biological and physicochemical properties. On soils with excess acidity, the yield and product quality of most agricultural crops, as well as the efficiency of mineral fertilizers, decrease by more than 30% [1].

From 2019 to 2024, within the framework of the program "Development of the reclamation complex of Russia", the Ministry of Agriculture of the Russian Federation developed proposals for the provision of subsidies to the budgets of the constituent entities to compensate for part of the costs incurred by agricultural producers for measures for liming acidic soils: the development of design estimates based on agrochemical data survey of fields with indicators of soil fertility in the coordinate system of the land plot; purchase of ameliorants for liming acidic soils, permitted for use on the territory of the Russian Federation; transportation costs for the delivery of ameliorants to the place of soil liming and technological work for the application of lime fertilizers. The basis for the development of such proposals was the need to stimulate agricultural producers to carry out work on the chemical reclamation of arable soils in order to increase their productivity. Until 2025, it is planned to produce 4.1 million hectares of acidic soils [2]. To assess the effectiveness of chemical reclamation, the following indicators have been used: a) an increase in the volume of crop production in terms of grain units (thousand tons); b) the area of arable land on which measures for liming acidic soils have been implemented, (thousand hectares).

Long-term domestic and foreign researches have shown that the acidic reaction of the soil is one of the main reasons for low crop yields, mass losses in grains and perennial grasses during overwintering, low protein content in grain and feed, insufficient efficiency of mineral fertilizers [3-5]. Optimization of the soil acidity level determines the decision of the country's food security based on a highly
efficient farming system, the main link of which is the expanded reproduction of soil fertility through the use of fertilizers [6].

Without liming, it is impossible to solve the problems of magnesium in agriculture. At present, this is an urgent task, since results of magnesium starvation are observed almost everywhere on plants, especially on soils of light texture: sandy and sandy loam, the area of which is more than 7 million hectares. The use of magnesium-containing lime materials: dolomite, dolomitized, magnesian floor and some types of metallurgical (for example, open-hearth) slags, could solve for a long period the problem of creating magnesium compounds available for plants in the soil [7-8].

At present, the problem of magnesium is aggravated, since as a result of flowing from the root layer with infiltration waters and removal of plants with crops, the annual loss of this element is 0.7-1.0 mg per 100 g of soil. With an average content of about 8 mg/100 g of soil, this reserve is enough for 8-11 years. And this is precisely the period when magnesium practically ceased to enter the soil with fertilizers, and it is basically impossible to mobilize it from gross forms in the soil. Therefore, in the coming years, it is necessary to use of magnesium and magnesium-containing lime fertilizers, especially on soils with light granulometric composition, which, moreover, as a rule, need to eliminate excess acidity [9-10].

2. Methods and Materials

The current research (2019-2021) on sod-podzolic sandy loam soil for examining the agrobiological efficiency of applying various doses of AgroMag granular magnesium fertilizer (> 62% MgO) and foliar feeding with AgroMag AktiMax suspension (4% N, 1% Ca, > 21% Mg), obtained from the natural mineral brucite, on the productivity of early potato varieties Zhukovsky and soil fertility, was carried out in the Moscow region at the agropoligon of the Russian Potato Research Center named after A.G. Lorkha. The experiment scheme consisted of 9 options. The soil is acidic (pH

\[ \text{KCl} = 4.5-4.7 \],

Hg = 2.9-3.3 meq/100 g of soil, S = 2.10-2.57 meq/100 g of soil, V = 50-60%; the content of mobile phosphorus is 243-350 m/ kg, the content of exchangeable potassium is 115-130 mg/kg. Background \((N_{116}P_{116}K_{152})\) was calculated by the balance method for a yield of 40 tons of tubers per hectare (according to M.K. Kayumov, 1989).

Potatoes were cultivated after vetch-oats. Agrochemical parameters of the soil were determined by conventional methods: \(\text{P}_2\text{O}_5\) and \(\text{K}_2\text{O}\) - according to Kirsanov (GOST (Russian State Standart) R 54650-2011); \(\text{pH}_{\text{KCl}}\) - according to GOST 26483–85; hydrolytic acidity according to Kappen (GOST 26212–91); the sum of absorbed bases - according to Kappen-Gilkovits (GOST 27821–88); the degree of soil saturation with bases \(V\), % - by calculation method; exchangeable Ca and Mg in accordance with GOST 26487-85; humus - according to GOST 26213–91. Statistical analysis of experimental data was carried out according to Dospekhov (1985).

3. Results

The application of magnesium-containing AgroMag granular and foliar spraying of AgroMag AktiMax significantly increased the yield of potatoes - by 12.5-58.9%, its marketability - by 1.4-1.6% (6-8 options), starchiness of tubers - by 2, 0-3.7% (3 and 8 options) in comparison with the background option (Table 1). Note that in the best year for meteorological conditions in 2020, the potato yield was 30-40% higher than the average for two years. However, the observed correlations under different conditions of the growing season, were similar: the best option was Background + \(\text{Mg}_{200}\) AgroMag + AgroMag AktiMax 6 l/ha x 2 times \((8^{\text{th}}\) option). Reducing the dose of Agromag and AgroMag AktiMax by 2 times led to a decrease in the yield of tubers by 1.7 times. Application of one AgroMag at a dose of 100 kg/ha contributed to an increase in productivity in comparison with the second option by 17.5%, and a doubling of the dose of AgroMag - by 33.9%.

The addition of magnesium fertilizers to the potato fertilization system significantly reduced the nitrate content in tubers to 40-52 mg/kg instead of 73 mg/kg.

As a result of an increase in the yield of tubers, their quality in the options with the use of magnesium fertilizers, the yield of nutritionally valuable components increased, the maximum yield of
dry matter - 1.17 t/ha and starch - 0.84 t/ha was obtained in the option F + Mg<sub>500</sub>AgroMag + Aktimax 6 l/ha x 2 times (8<sup>th</sup> option), which is higher than the F option by 75 and 83%, respectively.

**Table 1.** Productivity depending on various forms and doses of magnesium-containing fertilizers (on average for 2019-2021).

| Option | Productivity, t/ha | Increase from Mg |
|--------|-------------------|-----------------|
| 1. Without fertilizers | 23.1 | - |
| 2. N<sub>116</sub>P<sub>116</sub>K<sub>152</sub> - background (F) | 28.0 | 4.9 |
| 3. F + Mg<sub>100</sub>AgroMag | 32.9 | 9.8 |
| 4. F + Mg<sub>100</sub>AgroMag + Aktimax 3 l/ha x 2 times (budding-flowering) | 38.0 | 14.9 |
| 5. F + Aktimax 3 l/ha x 2 times (budding-flowering) | 31.5 | 8.4 |
| 6. F + Mg<sub>100</sub>MgSO<sub>4</sub> | 33.2 | 10.1 |
| 7. F + Mg<sub>200</sub>AgroMag | 37.5 | 14.4 |
| 8. F + Mg<sub>200</sub>AgroMag + Aktimax 6 l/ha x 2 times (budding-flowering) | 44.5 | 21.4 |
| 9. F + Aktimax 6 l/ha x 2 times (budding-flowering) | 32.3 | 9.2 |
| LSD<sub>.05</sub> | 1.6 | |

**Table 2.** Potato quality depending on various forms and doses of magnesium-containing fertilizers (on average for 2019-2021).

| Variants | Marketability, % | Starch | Nitrates, mg/kg tubers |
|----------|-----------------|--------|------------------------|
| total | +/- to control | +/- from Mg | | |
| 1. Without fertilizers | 92.1 | - | 12.6 | 33 |
| 2. N<sub>116</sub>P<sub>116</sub>K<sub>152</sub> - background (F) | 93.5 | 1.4 | 11.6 | 73 |
| 3. F + Mg<sub>100</sub>AgroMag | 95.3 | 3.2 | 1.8 | 13.7 | 41 |
| 4. F + Mg<sub>100</sub>AgroMag + Aktimax 3 l/ha x 2 times | 95.3 | 3.2 | 1.8 | 11.8 | 52 |
| 5. F + Aktimax 3 l/ha x 2 times (budding-flowering) | 94.0 | 1.9 | 0.5 | 11.8 | 44 |
| 6. F + Mg<sub>100</sub>MgSO<sub>4</sub> | 94.6 | 2.5 | 1.1 | 11.9 | 40 |
| 7. F + Mg<sub>200</sub>AgroMag | 95.7 | 3.6 | 2.2 | 11.9 | 47 |
| 8. F + Mg<sub>200</sub>AgroMag + Aktimax 6 l/ha x 2 times | 96.2 | 4.1 | 2.8 | 13.1 | 52 |
| 9. F + Aktimax 6 l/ha x 2 times (budding-flowering) | 95.3 | 3.2 | 1.8 | 11.0 | 40 |
| LSD<sub>.05</sub> | 1.7 | | 0.9 | 21 |

The application of magnesium fertilizers led to an improvement in the physicochemical parameters of the soil of the arable layer (Table 3).

The introduction of various doses and forms of magnesium fertilizers against the background of complete mineral fertilizers led to changes in the physicochemical parameters of the soil.

Exchangeable acidity in variants with application of AgroMag granulated at a dose of 100 kg/ha (3<sup>rd</sup> and 4<sup>th</sup> options) stabilized at a pH level of 4.9, hydrolytic acidity (Hg) decreased to 3.3-3.4 meq/100 g, the sum of exchangeable bases (S) increased to 3.2 meq/100 g, the degree of saturation with bases (V) - up to 48.5-49.0%, compared with the option without fertilizers and the background
option. An increase in the dose of AgroMag to 200 kg/ha (7th option) contributed to a further increase in the pH value to 5.2 and 5.7 units, a decrease in hydrolytic acidity - to 2.63 meq/100 g, an increase in the amount of exchangeable bases up to 5.2 meq/100 g, the degree of saturation with bases - up to 66.4%. A similar effect on the agrochemical properties of sod-podzolic soil was observed with the addition of magnesium sulfate.

### Table 3. Change in agrochemical indicators of soil fertility, 2021.

| Experimental option | pH KCL | Ng meq/100 g soil | S | V,% | P2O5 mg/kg soil (according to Kirsanov) | K2O mg/kg soil | Ca mg/kg soil | Mg mg/kg soil |
|---------------------|-------|------------------|---|-----|----------------------------------------|---------------|---------------|---------------|
| 1                   | 4.5   | 3.15             | 2.7 | 46.1 | 386                                    | 160           | 403           | 110           |
| 2                   | 4.5   | 3.68             | 3.0 | 44.9 | 403                                    | 180           | 453           | 125           |
| 3                   | 4.7   | 3.40             | 3.3 | 49.3 | 402                                    | 179           | 455           | 175           |
| 4                   | 4.7   | 3.33             | 3.2 | 49.0 | 427                                    | 202           | 489           | 163           |
| 5                   | 4.5   | 3.46             | 3.0 | 46.4 | 421                                    | 210           | 443           | 123           |
| 6                   | 4.7   | 2.63             | 5.7 | 68.4 | 417                                    | 217           | 471           | 162           |
| 7                   | 4.9   | 2.63             | 5.2 | 66.4 | 429                                    | 214           | 447           | 173           |
| eight               | 5.0   | 3.15             | 5.2 | 62.3 | 417                                    | 204           | 473           | 182           |
| nine                | 4.7   | 3.43             | 3.1 | 47.5 | 425                                    | 210           | 450           | 134           |
| LSD05               | 0.2   | 0.27             | 0.2 | 4.8  | 35                                     | 38            | 33            | 19            |

The application of AgroMag granulated at a dose of 100 kg/ha (3rd and 4th options) caused an increase in the content of exchangeable calcium by 29-33 mg/kg, magnesium - by 10-17 mg/kg, relative to the background variant; an increased dose of AgroMag 200 kg/ha (7th option) increased the content of calcium and magnesium by 51 and 108 mg/kg, respectively, which is higher than the effect of MgSO4 (6th option).

The best indicators were determined in the option NPK + Mg200AgroMag (7 options) and NPK + Mg200AgroMag + Aktimax 6 l/ha (8 option): pH - 4.9-5.2 units, Ng - 2.63-3, 15 meq/100 g, the amount of absorbed bases - 5.2 meq/100 g, saturation degree - 62.3-66.4%, exchangeable calcium content 700 mg/kg, magnesium 193-206 mg/kg soil.

The calculation of economic efficiency based on the results of field experience showed that the use of magnesium-containing fertilizers was beneficial in all combinations and doses. Conditional income in variants with the use of magnesium fertilizers from additional production ranged from 80.6 to 197.4 thousand rubles/ha, the cost of production decreased to 3.18-4.02 rubles/kg, the payback was 1.9-6.0 rubles/expenses, with an increase in production profitability from 248% to 371%. The best economic indicators associated with the maximum yield of tubers were obtained in the F + AgroMag option 200 kg/ha + AgroMag Aktimax leaf treatment at a dose of 6 l/ha x 2 times: conditional income 263.8 thousand rubles/ha, profitability of production 371% and return on costs 6.0, in combination with low production cost of 3.18 rubles/kg.

Thus, high values of economically valuable properties (yield, structure, product quality) were obtained in the variant with the complex application of Agromag granulated at a dose of 200 kg/ha for and double spraying of AgroMag AktiMax at a dose of 6 l/ha: yield on average for two years 44.5 t/ha (increase to the background 16.5 t/ha or 58.9%), marketability 96.2%, maximum yield of dry substances (1.17 t/ha) and starch (0.84 t/ha); low concentration of nitrates - 52 mg/kg tubers. The results in the collection of nutrients from this option are record-breaking, which allows to recommend the use of AgroMag granulated at a dose of 200 kg/ha in combination with two-fold foliar dressing AgroMag AktiMax at a dose of 6 l/ha for use in the practice of growing crops for potato processing enterprises.

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