Potato nutrition management using manure fertilizer

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Abstract. The studies developed agrochemical regulatory parameters for the use of organic fertilizer based on litterless chicken manure for managing potato nutrition on meadow-chernozem soil in the forest-steppe of Western Siberia. The place of research was the experimental field and the department of agrochemistry and soil science of the FSBEI HE Omsk State Agrarian University in 2012-2014. The studied objects included potato plants of the Alaya Zarya variety and meadow-chernozem medium-thick medium-humus medium-loamy soil. Potatoes formed a yield of 22.9 t / ha without fertilizers and 26.0-33.2 t / ha with fertilizers. The use of 12 t / ha was the most effective because the yield increases in 10.3 tons or 45.0%, the payback of 1 ton of manure was 0.86 tons of tubers. 1 ton of litterless manure increases the concentration of N-NO₃ by 2.06 mg/kg, P₂O₅ - 2.73 and K₂O - 1.28. The authors established quantitative characteristics of the action intensity of 1 ton of manure on potato yields (1.14 t/ha) and proposed a formula of calculating doses for a planned increase in yield based on this study. They identified a normative indicator (coefficient b₂) of the action intensity of 1 t/ha of manure on the nitrate-nitrogen content, mobile phosphorus and potassium. It allows to predict their accumulation in the soil and to determine the dose of fertilizers considering the optimal and actual content of the nutrient element in the soil.

1. Introduction

Studies conducted in the southern part of Western Siberia have proved the high efficiency of organic fertilizers that increase soil fertility and crop productivity [1]. Modern farming systems need to consider soil and plant as a single whole. At the same time, one of the main tasks of applying fertilizers is managing soil fertility and plant nutrition, which requires the development of regulatory parameters [2, 3]. Manure of birds used in agriculture as fertilizer is an important source of nutrients for cultivated plants [4-6]. For rotted litterless manure, there are no agrochemical standards for managing the nutrition of potato plants in Western Siberia. The purpose of the research was to develop agrochemical regulatory parameters for the use of organic fertilizer based on litterless chicken manure for managing potato nutrition on meadow-chernozem soil in the forest-steppe of Western Siberia.

2. Conditions, materials and methods

The place of research was the experimental field and the department of agrochemistry and soil science of the FSBEI HE Omsk State Agrarian University in 2012-2014. The studied objects included potato
plants of the Alaya Zarya variety and meadow-chernozem medium-thick medium-humus medium-loamy soil. In the soil before planting the content of N-NO$_3$ is 6.1-10.4, P$_2$O$_5$ is 111-124, K$_2$O is 256-274 mg/kg.

The location of the plots in the experimental plot was systematic. The repetition of the options was threefold. Plot area was 20 m$^2$; accounting area was 16m$^2$. Agricultural technology was common for the zone. 1 ton of organic fertilizer based on litterless chicken manure gives 20 kg of nitrogen, 17 kg of phosphorus and 6 kg of potassium introduced into the soil.

In soil samples, the researchers determined the nitrate-nitrogen content according to Grandval-Lyazh; the content of mobile phosphorus and potassium according to Chirikov.

### 3. Results and discussion

Field studies in 2012-2014 found that the use of organic fertilizer based on litterless chicken manure, mineral fertilizers, as well as their joint application had a positive effect on potato productivity (Table 1). For three years of research in the control, potatoes on average formed a tuber yield of 22.9 t/ha, and 26.0-33.2 t/ha with the use of fertilizers.

| Variety          | Productivity, t/ha | Increase t/ha | Fertilizer payback by yield increase t/t |
|------------------|--------------------|---------------|----------------------------------------|
|                  | 2012  | 2013  | 2014  | average | t/ha | %         |                                          |
| Control variety  | 18.6  | 24.8  | 25.2  | 22.9    | –    | –         |                                          |
| 4 t / ha         | 23.4  | 27.2  | 27.5  | 26.0    | 3.1  | 13.5      | 0.78                                    |
| 8 t / ha         | 31.2  | 29.3  | 30.2  | 30.2    | 7.3  | 31.9      | 0.91                                    |
| 12 t / ha        | 36.4  | 31.0  | 32.3  | 33.2    | 10.3 | 45.0      | 0.86                                    |
| 16 t / ha        | 36.6  | 29.2  | 33.2  | 33.0    | 10.1 | 44.1      | 0.63                                    |
| LSD$_{05}$       | 3.11  | 2.04  | 2.54  | 2.91    | –    | –         | –                                       |

The option with a rotted organic fertilizer in an amount of 12 t/ha - 33.2 t/ha gave the highest yield of potato tubers, which is 10.3 t/ha (45%) higher than in the control. The introduction of organic fertilizer at a dose of 16 t/ha of fertilizer did not increase the yield of potato tubers (Fig. 1).

The important indicator of effectiveness is the payback of one fertilizer unit by increasing productivity. We got a maximum payback from 1 unit at 8 t/ha - 0.91 t/t and 12 t/ha - 0.86 t/t.

Thus, in studies on meadow chernozem soil, all the options for using mineral and organic fertilizers, both separately and jointly, made it possible to obtain a significant increase in the yield of potato tubers. The most effective was the introduction of 12 t/ha of organic fertilizers.

The results of the field experiment showed the high responsiveness of potatoes to the application of organic fertilizers based on litterless chicken manure on meadow chernozem soil. The high functional dependent yield of potatoes (Y, t/ha) from doses of organic fertilizers (X, t/ha) to 12 t/ha also confirmed this, since after 12 t/h, the yield does not increase (equation 1):

$$y = 0.88x + 22.81, \quad r = 0.81. \quad (1)$$

From equation (1) it follows that the coefficient of the intensity of action ($b_1$) 1 t/ha of organic fertilizer based on litterless chicken manure on the formation of the potato crop is 0.88 t/ha (Fig. 2).
Figure 1. The dependence of the yield of potato tubers on the doses of organic fertilizers based on litterless chicken manure when cultivated on meadow chernozem soil (average 2012-2014)

\[ y = 0.013x^2 + 1.96x + 129.8 \]
\[ R = 0.91 \]

Figure 2. The dependence of the yield of potato tubers on the doses of organic fertilizers based on litterless chicken manure when cultivated on meadow chernozem soil (average 2012-2014)

The obtained norm of efficiency of organic fertilizers based on litterless chicken manure makes it possible to determine the possible increase in the yield of potato tubers on the studied soil types in the conditions of agricultural production. Considering that obtaining an additional 1 t/ha of potato tubers requires 1.14 t of manure (1 t/ha: 0.88 t/ha = 1.14), the yield increase can be calculated by the formula (2):

\[ y = 0.876x + 22.81 \]
\[ R = 0.81 \]
\[ P = \frac{D}{1.14}, \quad (2) \]

where \( P \) is the planned increase in yield of potato tubers, t / ha; \( D \) is the dose of litterless chicken manure, t / ha; 1.14 is the amount of litterless chicken manure introduced to obtain 1 ton of potato tubers, t / ha.

Data on the planned increase in potato productivity \((P, \text{t} / \text{ha})\) and the coefficient of the intensity of the studied organic fertilizers \( (b_1 = 0.88 \text{t} / \text{ha of potato tubers}) \) makes it possible to calculate the dose of litterless manure \((t / \text{ha}, \text{formula } 3)\):

\[ D = \frac{P}{b_1}. \quad (3) \]

Thus, the obtained experimental data allow determining the necessary dose of organic fertilizer to obtain a planned increase in potato yield.

The content of nutrients in the soil depends on the doses of fertilizers [7-10]. In our research (Table 2), the introduction of organic fertilizers increased the content of nitrate-nitrogen in the soil (0-20 cm) under the potato in the seedling phase of plants from low (8.9 mg/kg soil) content, before applying fertilizers, to the high content (17.7-47.0 mg/kg soil). We found that the use of 1 ton of organic fertilizer based on litterless chicken manure increases the content of nitrate-nitrogen by 2.06 mg/kg of soil (equation 4):

\[ F = 2.06x + 9.34, \quad r = 0.79. \quad (4) \]

| Variety         | N-NO\(_3\) | P\(_2\)O\(_5\) | K\(_2\)O | N-NO\(_3\) | P\(_2\)O\(_5\) | K\(_2\)O |
|-----------------|-----------|----------------|---------|-----------|----------------|---------|
| Control variety | 9.0       | 115            | 264     | 4.3       | 112            | 262     |
| 4 t / ha        | 17.7      | 125            | 273     | 6.7       | 114            | 266     |
| 8 t / ha        | 26.5      | 135            | 278     | 7.8       | 116            | 268     |
| 12 t / ha       | 33.7      | 144            | 282     | 9.3       | 119            | 267     |
| 16 t / ha       | 42.2      | 160            | 285     | 10.2      | 121            | 265     |

The fertilizers also positively influenced the content of mobile phosphorus in the soil during the potato entry phase, increasing its content from 115 mg/kg in the control to 125-173 mg/kg in variants with fertilizers. The one ton of litterless chicken manure increases the content of mobile phosphorus in the soil by 2.73 mg/kg (equation 5).

\[ F = 2.73x + 114, \quad r = 0.78. \quad (A) \]

Despite the very high content of mobile potassium in general, during the potato sprouting phase, its amount in the soil also increased from 264 mg/kg of soil in the control to 273-294 mg/kg in soil with fertilizers.

The relationship between the doses of bedding chicken manure and the content of mobile potassium in the soil shows that the concentration of this element increases by 1.28 mg/kg of soil with one ton of fertilizer (equation 6).

\[ F = 1.28x + 266.2, \quad r = 0.75. \quad (6) \]

By harvesting, the content of available elements in the soil decreased significantly compared to the content in the seedling phase.
Production can apply the formula (7) for assessing changes in the concentration of available elements in the soil \((C, \text{mg/kg})\) when using organic fertilizers based on litterless chicken manure:

\[
C = C_1 + D \cdot b_2, \tag{7}
\]

where \(C_1\) is the content of the element in the soil before planting, \(\text{mg/kg}\); \(D\) is a dose of organic fertilizers based on litterless chicken manure, \(\text{t/ha}\); \(b_2\) is the coefficient of the action intensity of 1 ton of organic fertilizers based on litterless chicken manure on the content of the available element in the soil, \(\text{mg/kg}\).

The calculations showed that increasing the nitrate-nitrogen content by 1 mg/kg in the soil under potatoes requires 0.49 t/ha of litterless chicken manure \((1 \text{ mg/kg} \div 2.06 \text{ mg/kg} = 0.49)\). From this it follows that we can determine the doses of organic fertilizers \(\text{(t/ha)}\) according to formula (8) based on information on the optimal level of nitrate-nitrogen in the soil for potatoes:

\[
D_N = (N_0 - N_I) \cdot 0.49, \tag{8}
\]

where \(N_0\) is the optimal content of nitrate-nitrogen in the soil, \(\text{mg/kg}\); \(N_I\) is actual nitrate nitrogen content in the soil, \(\text{mg/kg}\); 0.49 is the dose of organic fertilizers based on litterless chicken manure to increase the content of N-NO\(_3\) by 1 mg/kg in the soil layer of 0-20 cm, t/ha.

Calculation of doses of organic fertilizers \(\text{(t/ha)}\) according to formulas (9, 10) based on information on the optimal level of mobile phosphorus and potassium in the soil for potatoes:

\[
D_P = (P_0 - P_I) \cdot 0.37; \tag{9}
\]

\[
D_K = (K_0 - K_I) \cdot 0.78, \tag{10}
\]

where \(P_0, K_0\) is the optimal content of the element in the soil, \(\text{mg/kg}\); \(P_I, K_I\) is actual element content in the soil, \(\text{mg/kg}\); 0.37 is the dose of organic fertilizers based on litterless chicken manure to increase the content of \(P_2O_5\) by 1 mg/kg in the soil layer 0-20 cm, t/ha; 0.78 is the dose of organic fertilizers based on litterless chicken manure to increase the content of \(K_2O\) by 1 mg/kg in the soil layer 0-20 cm, t/ha.

In this case, it is necessary to consider which element is at a larger relative minimum and to calculate the dose of manure according to it.

We can use the optimal levels of elements in the soil when calculating the doses of fertilizers according to the general formula (11):

\[
D = (E_0 - E_f) \cdot b_2. \tag{11}
\]

where \(E_0\) and \(E_f\) are the optimal and actual content of the element in the soil, \(\text{mg/kg}\); \(b_2\) is the coefficient of the action intensity of a unit of fertilizer applied to the chemical composition of the soil, \(\text{mg/kg}\).

4. Conclusion

When using organic fertilizers based on litterless chicken manure, the most effective was the use of 12 t/ha because the yield increase was 10.3 tons or 45.0%, the payback of 1 ton of manure was 0.86 tons of tubers. The introduction of manure increased the level of N-NO\(_3\), mobile \(P_2O_5, K_2O\) in the soil. 1 ton of litterless manure increases the concentration of N-NO\(_3\) by 2.06 mg/kg, \(P_2O_5\) - 2.73 and \(K_2O\) - 1.28. We determined the quantitative characteristics of the intensity of the action of 1 ton of manure on the yield of potatoes and based on this we proposed a formula for calculating doses for a planned increase in yield. They identified a normative indicator of the intensity of the action of 1 t/ha of manure on the nitrate-nitrogen content, mobile phosphorus and potassium that allows determining the dose of fertilizers considering the optimal and actual content of the nutrient element in the soil. The
agrochemical standards established in the experiment make it possible to control the nutrition of the culture based on the calculation of manure doses.

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