The effectiveness of applying mineral fertilizers in the cultivation of green bean for seeds

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Abstract. Growing beans is one of the main ways to increase the production of vegetable protein. The problem of implementing high seed productivity of vegetable bean varieties while maintaining the high quality of the produced seeds is relevant. Increasing the yield of seeds and improving their quality is possible due to the scientifically based use of mineral fertilizers in the cultivation of beans. Optimal rates and the ratio of nitrogen, phosphorous and potash fertilizers allow getting a significant increase in the yield of high-quality seeds. On sod-podzol medium-loamy soils, the optimal rate of mineral fertilizers for green beans and Cinderella varieties was N30P45K45. There was an increase in the total protein content under the influence of mineral fertilizers by 0.2–2.0% in the Cinderella variety and by 0.5–1.8% in the Lika variety. The use of optimal mineral fertilizers in the cultivation of green beans provided a net income for the Lika variety 122.2 thousand rubles/ha and the Cinderella variety – 117.4 thousand rubles/ha.

1. Introduction
Green beans (*Phaseolus vulgaris* L.) are strategic crops in terms of nutritional value and are among the top ten most useful vegetables. The amino acid and protein composition of beans is close to the proteins of meat and fish and can replace them in extreme conditions. The protein of beans is absorbed by the body by 75%, being a building and energy material for it. Therefore, growing beans is one of the main ways to increase the production of vegetable protein [1, 2, 3]. In this regard, the study of the optimal combination of technological methods for growing common beans, which will ensure the formation of a high yield and quality, is relevant and timely. Fertilizers that allow the most complete realization of genetic possibilities are of great importance in improving the quality of bean seeds. Research that helps to decipher the patterns of crop formation under the influence of mineral fertilizers in specific soil and climate conditions is of considerable interest for the theory and practice of fertilizer application [3, 4]. In Western Siberia, when growing haricot, a positive reaction was detected to the use of nitrogen fertilizers at a dose of 30 kga.s./ha against the background of phosphorus and potassium (R60K60), which contributed to the formation of yields up to 9.4 t/ha, and the increase in yield relative to the control was 147% [5].

In the Kurgan region, when using N32P32K32, the yield of bean seeds increased by 0.27-0.61 t/ha, or by 18-20%, in comparison with the non-fertilized variant [6]. On cultivated sod-podzol sandy loam soil of the Republic of Belarus the use of mineral fertilizers in the cultivation of green beans varieties Second, Rachel and Magura to ensure that the net income in the phase of technological ripeness 43.3–
89.5 $/ha with a margin of 19 to 28%, in the phase of full ripeness – 117.9–231.7 $/ha with profitability 117-162% with the best performance in the variants with pre-sowing introduction N$_{50}$, 70P$_{40}$K$_{40}$ [7].

Bean plants are capable of accumulating a significant amount of symbiotic nitrogen, but the application of nitrogen fertilizers on most types of soil increases the yield of beans, as the use of nitrogen accumulated by bacteria begins only with the seed formation phase. Therefore, it is effective to apply 20-40 kg/ha of nitrogen fertilizers before sowing in the spring period [8].

The aim of the research was to determine the optimal rates and ratios of mineral fertilizers for obtaining a yield of high-quality green bean seeds.

2. Materials and methods

The experiments were carried out in 2013-2014 at the site of the experimental production Department of FSBSI FSCVG (Moscow region). The soil of the site is sod-podzol medium loamy. Agrochemical characteristics of the arable (0-20 cm) soil layer before sowing of seeds: the content of humus by Tyurin is 1.82 %, the reaction medium pH$_{H2O}$ 6.1, hydrolytic acidity 1.32 mEq/100 g soil, the amount of absorbed bases 19.2 mEq/100 g of soil, degree of saturation with bases 93.6%, the content of mobile phosphorus at average of 472 mg/kg of soil, exchangeable potassium 167 mg/kg soil, mineral nitrogen 9 mg/kg.

Field experience scheme: 1 - without fertilizer (control), 2 – N$_{30}$P$_{30}$K$_{30}$, 3 – N$_{30}$P$_{45}$K$_{45}$, 4 – N$_{45}$P$_{45}$K$_{45}$, 5 – N$_{45}$P$_{60}$K$_{60}$, 6 – N$_{45}$P$_{90}$K$_{90}$, 7 – N$_{60}$P$_{90}$K$_{90}$. Fertilizers were applied to the soil once, in the spring for pre-sowing cultivation. Ammonium nitrate (a.s. 34%), double superphosphate (a.s. 46%) and potassium sulfate (a.s. 58%) were used as fertilizers. The profitability indicators were considered based on the cost of green bean seeds 200 rubles/kg and the following cost of fertilizers: ammonium nitrate –15300 rubles/t, double superphosphate –18,000 rubles/t, potassium chloride – 20500 rubles/t.

Two zoned varieties of green beans were grown - early-matured Cinderella and medium-matured Lika. The experiment was laid in four-fold repetition; the placement of plots is randomized. The area of the accounting plot is 20 m$^2$.

3. Results

In order to identify the relationship in the “fertilizer-crop” system and determine the optimal norms of mineral fertilizers, the variants of experiments with different norms and combinations of fertilizers were analyzed. It was found that the studied techniques had a different effect on the yield of green bean varieties. Thus, when using N$_{30}$P$_{45}$K$_{45}$, the yield of the early-maturing variety Cinderella increased by 0.71 t/ha, or 32.3%, and the medium-matured Lika only by 24.5% (table 1).

| Variants  | Lika variety | Cinderella variety |
|-----------|--------------|--------------------|
|           | t/ha | % to control | t/ha | % to control |
| 1 - without fertilizer (control) | 2.69±0.17 | 100 | 2.20±0.08 | 100 |
| 2 – N$_{30}$P$_{30}$K$_{30}$ | 3.18±0.17 | 118.2 | 2.64±0.12 | 120.0 |
| 3 – N$_{30}$P$_{45}$K$_{45}$ | 3.35±0.16 | 124.5 | 2.91±0.04 | 132.3 |
| 4 – N$_{45}$P$_{45}$K$_{45}$ | 3.45±0.39 | 128.3 | 2.48±0.18 | 112.7 |
| 5 – N$_{45}$P$_{60}$K$_{60}$ | 3.32±0.18 | 123.4 | 2.52±0.15 | 114.5 |
| 6 – N$_{45}$P$_{90}$K$_{90}$ | 3.36±0.23 | 124.9 | 2.63±0.13 | 119.5 |
| 7 – N$_{60}$P$_{90}$K$_{90}$ | 3.24±0.15 | 120.4 | 2.45±0.25 | 111.4 |
| HCP$_{65}$ | 0.21 | - | 0.23 | - |

Beans, due to nodule bacteria on the roots, can enrich the soil with nitrogen, improving its structure, so it can be used as green manure. High rates of nitrogen fertilizers when growing beans are not appropriate, as for good growth and development of plants, only the “starting” amount of available...
nitrogen in the soil is needed. In our study, it was found that the use of nitrogen fertilizers in the norm of more than 30 kg/ha did not have a positive effect on the yield of beans of both studied varieties.

When increasing the norms of phosphoric and potash fertilizers to 60-90 kg/ha, there is a tendency to increase the yield by 23-25% for the Lika variety. For the Cinderella variety, the effective dose of mineral fertilizers was detected when using N<sub>30</sub>P<sub>45</sub>K<sub>45</sub>, further increase in the amount of applied fertilizers caused an inhibiting effect on the yield of seeds.

To achieve a higher profit associated with growing bean seeds, it is important to obtain a high-quality product [3]. Due to the fact that bean seeds are a valuable food product, we conducted a biochemical analysis of the seeds obtained in the experiment for a number of indicators (table 2).

### Table 2. Biochemical characteristics of bean seeds, 2014.

| Variants         | Dry matter, % | Monosaccharides, % | Total protein content, % |
|------------------|---------------|--------------------|--------------------------|
| Cinderella variety |               |                    |                          |
| 1 – without fertilizer (control) | 7.23         | 1.55              | 16.1                     |
| 2 - N<sub>30</sub>P<sub>30</sub>K<sub>30</sub> | 7.42         | 1.54              | 16.3                     |
| 3 - N<sub>30</sub>P<sub>45</sub>K<sub>45</sub> | 7.26         | 1.42              | 16.7                     |
| 4 - N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> | 7.04         | 1.49              | 18.1                     |
| 5 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 7.27         | 1.58              | 17.6                     |
| 6 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 7.43         | 1.61              | 17.8                     |
| 7 - N<sub>60</sub>P<sub>60</sub>K<sub>60</sub> | 7.16         | 1.66              | 18.1                     |
| Lika variety |               |                    |                          |
| 1 – without fertilizer (control) | 6.92         | 1.42              | 19.4                     |
| 2 - N<sub>30</sub>P<sub>30</sub>K<sub>30</sub> | 7.11         | 1.48              | 19.9                     |
| 3 - N<sub>30</sub>P<sub>45</sub>K<sub>45</sub> | 7.23         | 1.51              | 19.8                     |
| 4 - N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> | 7.03         | 1.55              | 20.3                     |
| 5 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 7.12         | 1.47              | 20.3                     |
| 6 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 7.21         | 1.49              | 20.2                     |
| 7 - N<sub>60</sub>P<sub>60</sub>K<sub>60</sub> | 6.98         | 1.49              | 21.2                     |

It was found that under the influence of mineral fertilizers, the total protein content increases by 0.2-2.0% in the Cinderella variety and by 0.5-1.8% in the Lika variety; moreover, the increase in the protein content in seeds is directly proportional to the increase in the fertilizer rate in the experiment. At the same time, the use of high standards does not significantly affect the content of dry matter and monosaccharides.

### Table 3. Economic efficiency of using mineral fertilizers for growing green beans for seeds, 2013-2014.

| Variants         | Yield, t/ha | Cost of additional products thousand rubles/ha | Costs, thousand rubles/ha | Conditionally net income, thousand rubles | Profitability level, % |
|------------------|-------------|-----------------------------------------------|---------------------------|-------------------------------------------|------------------------|
| Cinderella variety |             |                                               |                           |                                           |                        |
| 1. Control (N<sub>0</sub>P<sub>0</sub>K<sub>0</sub>) | 2.69        | -                                             | -                          | -                          | -                      |
| 2 - N<sub>30</sub>P<sub>30</sub>K<sub>30</sub> | 3.18        | 98.0                                          | 18.7                      | 90.6                        | 424.1                  |
| 3 - N<sub>30</sub>P<sub>45</sub>K<sub>45</sub> | 3.35        | 132.0                                         | 24.6                      | 122.2                       | 436.6                  |
| 4 - N<sub>45</sub>P<sub>45</sub>K<sub>45</sub> | 3.45        | 152.0                                         | 28.4                      | 140.6                       | 435.2                  |
| 5 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 3.32        | 126.0                                         | 35.3                      | 111.8                       | 256.9                  |
| 6 - N<sub>45</sub>P<sub>60</sub>K<sub>60</sub> | 3.36        | 134.0                                         | 44.9                      | 116.0                       | 198.4                  |
| 7 - N<sub>60</sub>P<sub>60</sub>K<sub>60</sub> | 3.24        | 110.0                                         | 48.9                      | 90.4                        | 124.9                  |
| HCP<sub>05</sub> | 0.21        | -                                             | -                          | -                          | -                      |
Calculated showed that the level of profitability of both the Cinderella variety and the Lika variety was the highest in variant 3 (N_{30}P_{45}K_{45}) of fertilizer application. This rate of application of fertilizers is optimal for the studied varieties of green beans both in terms of increasing productivity and economic efficiency of the use of fertilizers. Further increase in the rates of nitrogen, phosphorus, and potassium fertilizers led to a decrease in the level of profitability, this was especially evident in the Cinderella variety. This is primarily due to the biology of the variety (early maturity), the influence of abiotic factors and, as a result, a certain decrease in yield.

4. Summary
The data obtained in the experiment indicate a high efficiency of using nitrogen, phosphorus, and potassium fertilizers when growing green beans for seeds. By experimental and statistical methods, effective norms of mineral fertilizers for the Lika variety (N_{30}P_{45}K_{45}) and the Cinderella variety (N_{30}P_{45}K_{45}) have been established, which allow obtaining the greatest increase in the yield of high-quality seeds and the highest profitability.

5. References
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