Economic and agri-environmental efficiency of applying fertilizers and growth regulators in broccoli cultivation

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Abstract. The highest yield (18.6 t/ha) and the best economic effect (320 thousand rubles/ha) with good product quality was obtained on alluvial soils of the Moscow Region with the complex use of the Maraton F₁, hybrid, mineral fertilizers N₁₂₀P₆₀K₁₅₀ for broccoli in combination with top dressing humic fertilizer “gumistar” (3 l/ha) and microfertilizer “tensocktail” (0.5 kg/ha). The developed plant nutrition system provides an increase in the content of dry matter, sugars, and vitamins in products with a slight increase in nitrates.

1. Introduction

Broccoli cabbage is one of the most valuable vegetable crops due to its excellent nutritional and healing properties, high-quality vegetable protein, ascorbic acid, a complex of other vitamins and mineral salts [1, 2].

However, in our country, the technology of cultivation of broccoli is not developed enough, the yield level of this crop rarely reaches 10-12 t/ha, and broccoli tops often crumble, which reduces the commodity properties of products [3, 4]. According to H. Michalik [5], the level of nitrates in broccoli heads ranges from 540 to 3430 mg/kg, which exceeds permissible levels. According to other data [6, 7], these fluctuations do not exceed 200-500 mg/kg NO₃. There are actually no experimental data on this issue in Russia.

2. Material and Methodology

Research on the use of fertilizers and growth regulators for broccoli cabbage hybrid Maraton F₁, which is zoned in Russia since 2006, conducted in 2012-2014. Studies were carried out on alluvial meadow soils of the floodplain of the Moscow River, containing 3.4–3.8% of humus, with a humus horizon thickness of 40–60 cm, and a soil reaction close to neutral (pH 5.5–6.1). The soil is sufficiently supplied with movable P₂O₅ according to Chirikov (176–191 mg/kg) and has an average supply of exchangeable K₂O according to Maslova (128–148 mg/kg), which is generally characteristic of the soil conditions of vegetable farms of the Moscow region.

The scheme of experiments included options with the following fertilizers: nitrogen-phosphorus, nitrogen-potassium, and phosphorus-potassium fertilizers in the form of urea (46% N), double superphosphate (43% P₂O₅) and potassium chloride (56% K₂O), a microelement fertilizer “tensocktail” of the “Hydro-Agro Rotterdam” company (B-0.52%, Ca-2.57%, Fe-3.84%, Mg-2.57%, Mo-0.13%, Zn-0.53%, Cu-0.53), a biocompost “Bioud-compost” from the “Eco-Agti” LLC; with the
content of organic matter > 30% used in a dose of 5 t / ha, a biohumus called “Gumistar” of the “Green-Peak” company is obtained using Californian worms and used in a dose of 3 l / ha; a zeolitic fertilizer from the Khotynetsky deposit of the Oryol region is used at a dose of 100 kg / ha, as well as a natural plant growth regulator “Zircon” is used at a dose of 250 ml / ha.

Agrotechnical cultivation of broccoli was generally accepted for the Central region of the non-chernozem zone. Broccoli seedlings were grown in film greenhouses for 30 days, the seedlings were transplanted in early June according to a 70 x 40 cm pattern. Mineral, organic fertilizers, zeolite were applied before planting seedlings, and the growth regulators Gumistar and Zircon, as well as the tensococktail, were used 7-10 days after planting by manual spraying of plants. The area of the experimental plot was 16.8 m², the repetition was 3-4 times. Broccoli harvesting was done selectively as the heads mature.

3. Research Results
The results of the calculation of the yield of broccoli (Table 1) revealed a rather high efficiency of mineral fertilizers in a dose of N₁₂₀P₀K₁₅₀. For 3 years, the yield increase was 56%, and nitrogen fertilizers increased plant productivity by 21%, phosphate fertilizers – by 25%, and potash fertilizers – by 29%. The biocompost increased the yield of broccoli by 51%, which was slightly lower than when using the estimated dose of mineral fertilizers.

The use of zeolite on NPK background allowed to increase the yield of broccoli by 9%, tensococktail – by 34%, humistar – by 38%; a higher efficiency was observed with using the growth regulator Zircon (by 45%). The combined use of the estimated dose of mineral fertilizers N₁₂₀P₀K₁₅₀ for spring cultivation in combination with using the growth regulator humistar and complex microfertilizer tensococktail ensured the best result in the experience and the greatest yield of broccoli. For 3 years, the average yield on this variant was 18.6 t / ha, or an increase of the broccoli yield in 216%.

Table 1. Productivity and quality of broccoli depending on the use of fertilizers and growth regulators.

| Options                              | Productivity of broccoli heads (t / ha) | Quality broccoli heads |
|--------------------------------------|----------------------------------------|------------------------|
|                                      | t / ha | %       | Dry matter, % | Amount of sugars, % | Vitamin C mg % | Nitrates (NO₃), mg / kg |
| No fertilizer                        | 8.6    | 100     | 11.2          | 1.8                | 74.8           | 138                    |
| N₁₂₀P₀K₀                             | 10.9   | 127     | 12.5          | 2.3                | 75.5           | 261                    |
| N₁₂₀K₁₅₀                            | 11.3   | 131     | 11.8          | 2.4                | 87.0           | 270                    |
| P₀K₁₅₀                               | 11.6   | 135     | 12.8          | 2.6                | 81.8           | 203                    |
| N₁₂₀P₀K₀                            | 13.4   | 156     | 13.0          | 2.4                | 81.6           | 172                    |
| Biocompost (5t / ha)                 | 13.0   | 151     | 12.4          | 2.2                | 90.7           | 166                    |
| NPK+ biocompost                      | 14.8   | 172     | 12.5          | 2.2                | 83.8           | 200                    |
| NPK+ gumistar                        | 16.7   | 194     | 13.1          | 2.4                | 82.8           | 191                    |
| NPK+ zircon                          | 17.3   | 201     | 13.0          | 2.4                | 87.4           | 193                    |
| NPK+ zeolite                         | 14.2   | 165     | 13.0          | 2.4                | 78.8           | 242                    |
| NPK+ tensococktail                   | 16.3   | 190     | 13.0          | 2.6                | 79.8           | 199                    |
| NPK+ gumistar + tensococktail        | 18.6   | 216     | 13.6          | 2.4                | 89.5           | 204                    |

HCP₀₅t/ha 1.26-2.28 S₅₀%=2.8-3.3

Broccoli is a diet product; therefore, product quality is very important. It should be noted that fertilizers and plant growth regulators generally improved the biochemical quality of broccoli heads. The dry matter content in broccoli from 11.2 to 13.6%, the amount of sugars from 1.8% to 2.6%, and the vitamin C from 74.8 to 90.7 mg% were noted. Top yield options for experience provided a significant improvement in product quality.

The nitrate content in broccoli heads was slightly increased under the influence of fertilizers and plant growth regulators, but only slightly. The highest NO₃ concentration is noted in variant N₁₂₀K₁₅₀.
(270 mg/kg), which is far from the MPC for cabbage vegetables (900 mg/kg for early production and 500 mg/kg NO₃ for late production). Therefore, ecologically, the developed system of application of fertilizers and growth regulators is absolutely safe and can be used in the production of broccoli.

Table 2. Economic efficiency of using the fertilizer, zeolite, and growth regulators for broccoli (2013-2015).

| Options                     | Productivity of heads, t/ha | The cost of production, thousand rubles/ha | Net income, thousand rubles/ha | Profitability level, % | The cost of 1 ton of products thousand rubles |
|-----------------------------|-----------------------------|-------------------------------------------|-------------------------------|------------------------|---------------------------------------------|
| No fertilizer               | 8.6                         | 256.9                                     | 18.3                          | 7                      | 29.9                                        |
| N₁₂₀P₆₀                  | 10.9                        | 271.7                                     | 77.1                          | 28                     | 24.9                                        |
| N₁₂₀K₁₅₀                 | 11.3                        | 269.1                                     | 92.5                          | 34                     | 23.8                                        |
| P₆₀K₁₅₀                  | 11.6                        | 266.7                                     | 104.5                         | 39                     | 23.0                                        |
| N₁₂₀P₆₀K₁₅₀             | 13.4                        | 272.6                                     | 156.2                         | 57                     | 20.3                                        |
| Biocompost (5t/ha)        | 13.0                        | 285.9                                     | 130.1                         | 45                     | 22.0                                        |
| NPK+biocompost            | 14.8                        | 301.0                                     | 172.6                         | 57                     | 20.3                                        |
| NPK+ gumistar             | 16.7                        | 273.9                                     | 260.5                         | 95                     | 16.4                                        |
| NPK+ zircon               | 17.3                        | 277.3                                     | 276.3                         | 100                    | 16.0                                        |
| NPK+ zeolite              | 14.2                        | 280.0                                     | 174.3                         | 62                     | 19.7                                        |
| NPK+ tenso-cocktail       | 16.3                        | 274.1                                     | 247.5                         | 90                     | 16.8                                        |
| NPK+ gumistar+tenso-cocktail | 18.6                   | 275.2                                     | 320.0                         | 116                    | 14.8                                        |

The economic efficiency of using fertilizers and plant growth regulators under broccoli cabbage (Table 2) showed that the cost of producing broccoli products slightly increased (from 257 to 301 thousand rubles/ha). However, they are more than compensated by an increase in net income, an increase in the level of profitability of production (from 7 to 116%), a decrease in the cost of 1 ton of broccoli cabbage heads (from 29.9 thousand rubles to 14.8 thousand rubles), which is 2 times actually. This demonstrates a high economic efficiency of the developed fertilizer system.

4. Conclusions
When growing broccoli cabbage on the alluvial meadow soils of the Central Non-chernozem Zone of the Russian Federation, mineral fertilizers in a dose of N₁₂₀P₆₀K₁₅₀ provided an increase in yield of 56%, while potash fertilizers, then phosphorus and nitrogen fertilizers were in the first minimum. The efficiency of the biocompost at a dose of 5 t/ha was close to the NPK level.

Plant nutrition with growth regulators (gumistar, zircon) and microelements (tenso-cocktail) during the growing season made it possible to increase the yield of broccoli by 34-45%.

A complex application of NPK with a gumistar and tenso-cocktail allowed to obtain the highest yield increase (116%, non-fertilized control). Fertilizers and growth regulators increased the content of dry matter, sugars, and vitamin C in broccoli, and the nitrate content was 2-3 times lower than the MPC.

Calculating economic efficiency of using fertilizers and growth regulators in the cultivation of broccoli revealed a twofold decrease in the cost of production and an increase in net income from the developed system of fertilizers from 18.3 to 320 thousand rubles/ha and an increase in the profitability of production from 7 to 116%.

References
[1] Pivovarov V F 2006 Russian vegetables (Moscow, Russia: VNIISSOK)
[2] Rabinovich A M, and Borisov V A 2008 The healing properties of vegetable and spicy aromatic plants of Russia (Moscow, Russia: “Arnebiya” LLC)
[3] Borisov V A, Litvinov S S, and Romanova A V 2003 The quality and storage of vegetables (Moscow, Russia: All-Russian Research Institute of Vegetable Growing)
[4] Soldatenko A V, Pivovarov V F, Razin A F, Meshcheryakova R A, Shatilov M V, Ivanova M I,
Taktarova S V, ... Razin O A 2018 The economy of vegetable growing: the state and the present Russian Vegetables 5(43) pp 63-68
[5] Michalik H 1989 Azotany w warzywach Biul. Warz. 1 pp 115-119
[6] Terbe I A, Zsoldos L, and Patocs I 1987 Zöldségnövények nitráttartalma. In Korteszeti es elelmiszeripari egyetem kiadvanyai (vol. 1) (pp. 125-13) (Budapest, Hungary)
[7] Santamaria P 2006 Nitrate in vegetables: toxicity content, intake and EC regulation J. Food Agric 86 pp 10-17