Using the biologization elements in potato cultivation technology

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Abstract. The article analyzes experimental data on potato cultivation with the use of biologization elements in the conditions of the Ryazan region. Two-year experiments were conducted for studying the effect of straw and siderate on the yield and quality of potato tubers of the variety “Red Scarlett”, cultivated on dark gray forest soils. Sideral fertilizer was represented by white mustard, sown to a depth of 4 cm with a norm of 5.5 million germinating seeds per hectare. When studying the “straw+nitrogen” variant, ammonium nitrate was introduced manually. In the case of the siderate using the plants were 2.2–19.6% higher, the number of stems on the bush and the leaf area were larger 4.8–13.3% and 4.8–25.1%, respectively, compared to the control sample. When using white mustard as a fertilizer, the number of weeds was 33.3–43.4 % lower compared to the control variant. Planting straw with nitrogen fertilizer provided an increasing of the mass of tubers in comparison with control samples in both years of research: by 2.9% in 2019 and by 8.1% in 2020. The yield of potato tubers of the variety “Red Scarlett” was increased by 11.4% when planting siderate, and by 10.8% when plowing straw.

1. Introduction

As known, in agriculture the most important means of production are soil, which has fertility, and the cultivated plant, which assimilates the earthly factors of life only through the soil. Soil fertility is understood as its ability to serve as a habitat for cultivated plants, a source and intermediary in providing terrestrial sources of life [1-10].

To obtain high and stable yields of agricultural crops with the specified quality parameters, the farmer must act on the soil to improve its fertility and on the cultivated plant. Potato requirements for soil and its fertility are related to its biological characteristics – relatively underdeveloped root system and the formation of stolons and tubers in the soil. The most favorable for potato growing are loose soils with good air permeability, low moisture capacity and permeable subsurface horizons.

Increasing soil fertility with the use of various methods of biologization of agriculture is a very relevant method of increasing the yield of potato tubers. Such techniques include the introduction of bean cultures into crop rotations, intermediate crops for sideral fertilizer, and the incorporation of straw and other plant residues into the soil [2-4].

The aim of the research was to study the productivity of potato tubers depending on the level of soil fertility by replacing manure with other types of organic fertilizers in the conditions of the Ryazan region [5-8].
2. Materials and methods
The research was conducted on dark gray forest soils of the Ryazan region in 2019–2020. The field experiment scheme included the following variants:

- Var 1 (control) – natural fertility, without fertilizer application;
- Var 2 (straw + nitrogen) – manual application of the ammonium nitrate (10 kg of nitrogen per 1 ton of straw);
- Var 3 (sideral fertilizer) – sowing of the white mustard to a depth of 4 cm (5.5 million germinating seeds per hectare).

The predecessor of potato in the experiment was winter wheat with a grain yield of 2.0 tn per hectare in 2019, 2.8 tn per hectare in 2020, and straw – 4.0–5.6 tn per hectare. In the plots of the control variant (Var 1) and variants with the cultivation of an intermediate crop for green fertilizer (Var 3) was used introduced manually crushed straw. In the plots of Var 2 (straw+nitrogen) ammonium nitrate was introduced manually (10 kg of nitrogen per 1 ton of straw), after that, the soil was treated with disc harrows “BDT-3” to a depth of 8–10 and 10–12 cm. The cutting of the plot for the intermediate crop (white mustard) was carried out by ring-spur rollers.

White mustard was used as a sideral fertilizer. Mustard was sown to a depth of 4 cm with a norm of million germinating seeds per hectare (weight norm 20 kg per hectare). Plowing to a depth of 23–25 cm was carried out on the control after the appearance of mass shoots of weeds (after 2–3 weeks), for the rest variants – in mid-October. The yield of green mass of white mustard in 2020 was 8.2 tn per hectare.

In spring the experimental plot was loosened with a heavy tooth harrow “BZTS-1,0” to cover moisture when the soil was physically ripe. Before planting potato tubers introduced complex mineral fertilizers using the seeder “SZT-3,6” at the rate of 0.3 tn per hectare and cultivated the soil to a depth of 12–14 cm.

Planting of potato tubers of the variety “Red Scarlett” was carried out in the first decade of May with a potato planter “KSM-4” to a depth of 6–8 cm with a planting density of 50 thousand tubers per hectare. Before planting the ridges were cut with a cultivator-spud “KON-2,8”.

On potato plantings were carried out two pre-emergence treatments and one post-emergence treatment to control weeds and loosen the soil, as well as two hilling. Pre-emergence and post-emergence inter-row processing was carried out with a cultivator-hiller “KON-2.8” and rotary harrows “BRU-0.7”.

The experience is repeated three times. The experiment is set by the method of randomized repetitions. Placement of plots – in one tier. The total area of the plot – 108 sq.m.

Method of crop accounting – continuous, with the entire accounting area of the plot. The biological yield of potatoes and its structure were determined by the method of fractional accounting.

Statistical processing of yield data was carried out by the method of variance analysis according to B. A. Dospekhov (1985) [11-12].

The calculation of the humus balance in the soil under potatoes was carried out according to the method proposed by A. M. Lykov [9].

3. Results
In the experiment, the introduction of mineral and organic fertilizers into the soil affects not only agrochemical factors of fertility. Fertilizers, especially organic, significantly affect all soil regimes, changing the habitat of plants, which affects their growth and development, and ultimately – the yield of the crop.

The results of the conducted biometric accounting of potatoes shown in the figure 1.
Weeds have a significant impact on the growth and development of potato plants. Potato belong to cultivated plants with a weak competitive ability in relation to weeds, especially at the beginning of the growing season. In the phase of the beginning of flowering after closing the rows potato plants are good at suppressing newly emerging weeds, but if weeds make their way to the upper tier, they cause great damage to the crop, reducing its size and deteriorating quality. Therefore potato plantings should be free from weeds throughout the growing season (figure 2).

Studies have shown, that the inclusion of white mustard in the crop rotation as an intermediate crop, grown after harvesting winter wheat for green fertilizer, is an effective tool of reducing the number of weeds.

If we consider each variant of the experiment as a separate agrophytocenosis, then in different cases there were different conditions for the productivity formation of potato plants (table 1).
Table 1. Results of accounting of the biological yield of potatoes and its structure, average for 2019–2020.

| Variants of field experiment | Mass of tubers, g per bush | Number of tubers per bush, units including by fractions | 
|-------------------------------|-----------------------------|---------------------------------------------------------|
|                               | total                       | less 30 g | 30–50 g | 50–80 g | more than 80 g |
| Var 1 (control)              | 395.5                       | 9.4       | 2.9      | 2.6      | 1.3     | 1.8    |
| Var 2 (straw + nitrogen)     | 419.5                       | 9.8       | 2.7      | 2.5      | 2.1     | 2.1    |
| Var 3 (sideral fertilizer)   | 450                         | 10        | 2.6      | 2.4      | 2.3     | 2.5    |

Table 1 shows, that in the years of research the maximum productivity of potato tubers of the variety “Red Scarlett” is obtained from the plowing of green mass of white mustard for fertilizer (Var 3). For this variant the mass of tubers per bush in 2019 was 336 g, in 2020 – 564 g, which is respectively 6.6 and 18.5% more than in the control variant (Var 1).

A generalizing indicator of the effectiveness of a particular agronomic technique is the size of the crop yield. Harvesting of potato tubers, carried out by the method of continuous accounting, revealed a close relationship in the change in the variants of field experience by year (table 2).

Table 2. The yield of potato tubers, tn per hectare.

| Variants of field experiment | 2019 Yield, tn per hectare | 2020 Yield, tn per hectare | Average, compared to the control variant, % |
|-----------------------------|----------------------------|----------------------------|---------------------------------------------|
| Var 1 (control)             | 13.7                       | 20.7                       | 17.2                                        |
| Var 2 (straw + nitrogen)    | 14.1                       | 22.9                       | 18.5                                        |
| Var 3 (sideral fertilizer)  | 14.8                       | 24.5                       | 19.6                                        |
| LSD_{05}                     | 1.49                       | 2.13                       |                                             |

The considered variants of the field experiment differ in such indicators of crop quality as the starch content in tubers and their marketability (figure 3).
Figure 3 shows, that the studied indicators of potato tubers quality depend both on the weather conditions of the growing season and on the experience options. In favorable for potato conditions in 2020 the marketability of tubers was 19.0–29.1% higher than in 2019. According to the content of starch in tubers was revealed an inverse relationship. In 2019, with a low yield of potato tubers, the starch content in them was 1.6–2.0% higher than in 2020.

The most important indicator of soil fertility is the content of humus in it and its composition. The calculation of humus for potato plants, based on nitrogen, carried out during the field experiment, is presented in table 3:

| Variants of field experiment | Nitrogen removal by crop, kg per hectare | Mineralization of humus, centner per hectare | The formation of humus, centner per hectare | The balance of humus, centner per hectare, +/- |
|-----------------------------|------------------------------------------|---------------------------------------------|---------------------------------------------|---------------------------------------------|
| Var 1 (control)             | 103.5                                    | 20.7                                        | 1.2                                         | -12.3                                       |
| Var 2 (straw + nitrogen)    | 114.5                                    | 19.6                                        | 13.7                                        | -0.8                                        |
| Var 3 (sideral fertilizer)  | 122.5                                    | 22.0                                        | 21.8                                        | +6.4                                        |

For calculating humus balance were used recommended norms, coefficients and the following parameters: winter wheat grain yield – 30 centner per hectare, straw yield – 60 centner per hectare, green mass yield of white mustard – 120 centner per hectare, nitrogen removal from 1 tn of potato tubers – 5 kg.

4. Discussion
The results of biometric accounting of potato plantings shows, that such indicators as the height of plants, the number of stems in the bush, the area of the leaf surface, changed depending on the experience options: in 2019 they were significantly lower than in 2020. The number of stems per bush and the area of leaves were more in 2020 than in 2019 by 0.9–1.1 and by 8.0–2.3 thousand sq.m. per hectare, respectively.

On average, experiments with the siderate (Var 3) contributed to a slightly better growth and development of potato plants compared to the control (Var 1) and “straw + nitrogen” variants (Var 2). Potato plants were much taller, better leafy and had a greater stem density. The variant with the siderate (Var 3) had an undoubted advantage over other variants of field experiment. Compared with the control (Var 1), these plants were higher by 2.2–19.6%, the number of stems per bush and the area of leaves, respectively, by 4.8–13.3% and 4.8–25.1% more than the control plants.

Monitoring of potato infestation showed, that as a result of sufficiently careful care of plantings, the level of infestation in both years of research is quite low (herbicides were not used). Before harvesting in 2020 the number of weeds for each of the conducted variants of the field experiment increased by 2.5–3.0 times compared to the phase of the beginning of flowering, mainly due to a sharp increase in plants of star woodlice (Stellaria media). In potato plantings also predominated young spring weeds: mar white (Chenopodium album), wild radish (Rafanus rafanistrum), obhbwf запрокинутая (Amaranthus retroflexus), chicken millet (Ehinochloa crus gallii). Less often on the experimental plot met: odorless chamomile (Matricaria perforata), yakutka field (Thaspi arvensis). Of the perennial weeds the most common were: field bindweed (Convolvulus arvense) and sow-thistle field (Sonshus arvensis).

The introduction of straw against the background of fertilizing the soil with compensating doses of nitrogen led to a certain increase in the infestation of potato plantings.

Growing crop mustard white on green fertilizer was an effective tool in the suppression of weeds. For this variant (Var 3) the number of weeds is 33.3–43.4% lower compared to the control variant (Var 1).
For the variant with straw embedding (Var 2) the mass of potato tubers in comparison with the control (Var 1) increased in both years of research: by 2.9% in 2019 and by 8.1% in 2020.

Evaluation of the number of potato tubers per bush showed a strong dependence on the weather conditions in the growing season. In the favorable weather conditions in 2020 the number of potato tubers according to the experience variants was 11.8–12.2 per bush. In a less favorable 2019 fewer tubers were formed – 7.1–7.9 per bush.

Fractional analysis showed that potato tubers, weighing more than 80 g, in 2020 were significantly more than in 2019. In the variant with siderate (Var 3) large tubers were almost up to two times more than in the control (Var 1). In the variant with straw (Var 2) the data is closer to the control (Var 1), both in 2019 and in 2020.

The statistical processing of yield data allows to conclude, that the influence of the studied variants on the yield of potato tubers is significant. In 2019 no reliable increase in potato yield was obtained for all the conducted variants. In 2020, according to the studied variants, a reliable increase in the yield was obtained.

Assessing the effect of the studied variants in average for two years, it should be recognized, that from plowing straw (Var 2) and planting siderate (Var 3) potato tubers yield increased by 10.8 and 11.4%, respectively.

Var 2 (straw + nitrogen) and Var 3 (siderate) provided high marketability of potato tubers, which turned out to be directly dependent on the level of yield.

The calculations shows, that the humus balance in the control variant is negative: minus 12.0 centner per hectare. For Var 2 (straw + nitrogen) the humus balance deficit is reduced to minus 2.0 centner per hectare with a higher level of potato tubers yield compared to the control. For Var 3 (siderate) there is a positive balance of humus: plus 0.4 centner per hectare.

5. Conclusion

Planting in the soil of green mass of white mustard, grown after harvesting winter wheat, contributes to better growth and development of potato plants, weed suppression, increasing of the yield of potato tubers by 11.4% and improve their quality.

The introduction of compensating doses of nitrogen on the Var 2 provides an increasing of potato tubers yield by 10.8%.

A reliable increase in potato tubers yield in both years of research was obtained only from the use of siderate (Var 3).

Planting straw in the soil with the introduction of nitrogen fertilizers (Var 2) increased the level of profitability by 2.8%. Planting in the soil of green mass of white mustard (Var 3) decreased the level of profitability by 7.7%.

References

[1] Shchur A V, Vinogradov D V and Valckho V P 2016 Effect of different levels agroecological loads on biochemical characteristics of soil. South of Russia: ecology, development 11(4) 139-148
[2] Barnes G, 1984 The use of plant growth regulator. Chem. Ind. 799 805
[3] Vasileva V 2015 Aboveground to root biomass ratios in pea and vetch after treatment with organic fertilizer. Global Journal of Environmental Science and Management 1 (2) 71-74
[4] Kostin A E, Avdeev Yu M and Titov D V 2017 Modeling the ecological state of phytocenoses. Advances in modern science and education 8(4) 188-192
[5] Nakayeva A A and Okazova Z P 2017 On the competitiveness of field crops. Successes of modern science 2(12) 191-195
[6] Vasileva V, Kertikov T 2007 Effect of Humustim treatment on the sowing qualities and grain yield of spring pea SoilScience, AgrochemistryandEcology 40 (4) 55-60
[7] Antipova L K and Vasileva V 2017 Forming the productivity of a mixture of corn and soya for green fodder, depending on the method of sowing and weather conditions. Bulletin of
Agrarian Science in the Black Sea Region 4(96) 72-80

[8] Vasileva V, Kertikov T and Ilieva A 2017 Dry mass yield and amount of fixed nitrogen in some forage legume crops after treatment with organic fertilizer Humustim. *Bulgarian Journal of Agricultural Sciences* 23(5) 816-819

[9] Vasileva V 2015 Aboveground to root biomass ratios in pea and vetch after treatment with organic fertilizer. *Global Journal of Environmental Science and Management* 1(2) 71-74

[10] Devi A R, Kotoky R, Pandey P and Sharma G D 2016 Application of Bacillus spp. for Sustainable Cultivation of Potato (Solanum tuberosum L.) and the Benefits, Bacilli and Agrobiotechnology. *Cham: Springer International Publishing AG* 185 212

[11] Vinogradov D V, Terekhina O N, Byshov N V, Kryuchkov M M, Morozova N I, Zakharova O A 2018 Features of applying biological preparations in the technology of potato growing on gray forest soils. *International Journal of Engineering and Technology* 4.36 242-246

[12] Zhichkin K, Nosov V, Zhichkina L, Zhenzhebir V and Rubtsova S 2020 The agricultural crops production profitability in modern conditions. *E3S Web of Conferences* 175 13008