ISSN 1068-3674, Russian Agricultural Sciences, 2019, Vol. 45, No. 1, pp. 16–20. © Allerton Press, Inc., 2019.
Russian Text © V.I. Titova, A.A. Chudokvasoff, 2018, published in Rossiiskaya Sel'skokhozyaistvennaya Nauka, 2018, No. 6, pp. 9–12.

CROP PRODUCTION

The Influence of Fertilizers and a Complex of Protection Measures on Crop Capacity and Quality of Potato Tubers of Different Varieties

V. I. Titova[a], * and A. A. Chudokvasoff[a]

[a]*Nizhny Novgorod State Agricultural Academy, Nizhny Novgorod, 603107 Russia*

**e-mail: titovavi@yandex.ru*

Received April 25, 2018

Abstract—The influence of mineral fertilizers used in combination with other intensive plant-protection measures (Selest Top insectofungicide, Zenkor Ultra herbicide, Concerto, Acrobat, Revus Top and Zummer fungicides, and Reglon Forte dessicant) was researched during a 3-year field experiment. Three potato varieties were examined: Vineta (standard) and Labella early ripening varieties and middle-late Granada variety. The experiment was carried out in the Nizhny Novgorod oblast in podzolized chernozem in 2015–2017 in three replications. The basic mineral fertilizers were applied in spring at a dose of $N_{120}P_{156}K_{176}$ (diammophoska, N_{aa}) while performing ridge tillage. The experimented group was fertilized with $N_{120}P_{156}K_{176} + K_{120}$ and with K_{cl} in autumn. Planting was performed with applying the Extrasol microbial drug, and the Isabion and Agris Phosphor organomineral fertilizers were used in a tank mixture with pesticides. It has been established that the Labella variety is the most high-yielding (38.0–47.9 t per hectare) and stable according to observations in different years, and the Granada variety gives the largest yield of starch (87.1 c/ha).

Keywords: potato varieties, fertilizers, plant protectors, crop capacity, starch

DOI: 10.3103/S1068367419010166

The potato crop is known to be of great importance in providing the population with food [1], and the achievement of the world level of its yield in Russia requires that the application of mineral fertilizers and agrochemicals become an indispensable element of modern agricultural technologies [2]. In addition, this crop allows solving a number of agrotechnical tasks in plant growing, namely: struggle against weeds and accumulation of pathogenic biota not only directly in the potato agrocenosis but also in crop rotation in general [3–7]. Thus, in order to obtain high yields of intensive potato varieties, modern potato production should be organized everywhere based on a combination of the fertilizer system and plant protection system [8–12], which is especially important for farms that have a narrow specialization in crop production [13].

The purpose of this study is to assess the responsiveness of table potato varieties to traditional mineral fertilizers in case of their being grown using modern biological drugs and agrochemicals against the background of a set of measures aimed at protecting crops from pests, diseases, and weeds.

METHODS

The objects of study were potatoes and fertilizers. The Vineta potato variety, which was created by the Europlant Pflanzenzucht GMBH German Company, was studied as a standard for the experiment. This table variety is early ripening (the vegetation period is 75–80 days), has a creamy yellow pulp, the yield is 16–23.8 t/ha, and the starch content is 12.9–15.2%. The variety is resistant to mechanical damage, nematodes, and droughts and has a very good taste. The Labella potato variety, which was created by the Solana GmbH & Co. KG (Germany), was also studied. This table variety is early ripening (the growing season is 70–80 days) and has a high intensity of growth, the peel color is red, the pulp color is yellow, the yield is 17–34 t/ha, and the starch content is 12.0–14.8%. The variety is highly resistant to leaf twisting virus, to golden potato cyst nematode, various types of mold and potato cancer pathogen, and elevated temperatures during the growing season and it has high taste qualities. The Granada potato variety, which was created by the Solana GmbH & Co. KG, was also studied. This table variety is middle-late (the growing season is 90–110 days), its yield is up to 60 t/ha, and starch content is up to 17%; the variety has high taste qualities.

The field experiment was conducted in the production conditions in 2015–2017 in the podzolized medium-loam chernozem area in the Arzamas district of the Nizhny Novgorod oblast, which is among the top ten large potato-growing regions of Russia [14]. Over the years of studies, the agrochemical characteristics of the soil depending on the location of potatoes in accordance with the alternation of crops in space were as follows: the content of phosphorus and potassium mobile compounds was 200–250 and 110–140 mg/kg, respectively; pH of salt extract was 5.45; the humus content was 3.8–4.1%. The experiment was made in three replications. The total area of the plot was 0.97 ha (38.7 × 250), and the harvesting area was 0.81 ha (32.4 × 250). Soil analyzes were performed using the methods recommended by Pryanishnikov All-Russia Research Institute of Agrochemistry [15]: the content of phosphorus and potassium was determined according to GOST R 54650-2011, the content of organic matter was determined according to GOST 26213-91, pH was measured according to GOST 26483-85, and the starch content in potato tubers was determined by the Evers polarimetric method (GOST 7194-81).

Potatoes were cultivated with a full cycle of measures for the protection of plants and introduction of mineral fertilizers without applying organic fertilizers. The winter wheat was planted before potatoes. All agrotechnical operations were performed using special equipment: John Deere 8335 R, 6130 D, or 6130 tractors; RAUCH fertilizer spreader; Grimme GF 600 ridge-forming cutter; Grimme GL 36T potato planter; John Deere 4730 self-propelled sprayer for applying soil herbicides; Amazone Pantera 4502 self-propelled sprayer for foliar cultivation; Grimme KS 5400 topper; Grimme Varitron 470; Grimme SE 150 or Grimme SF 170-60 self-propelled potato harvesters.

Mineral fertilizers were applied at a dose of $N_{120}P_{156}K_{156}$ kg/ha (the options without applying potassium chloride in autumn) and $N_{120}P_{156}K_{276}$ kg/ha (with applying potassium chloride before autumn plowing). According to the recommendations [8, 9, 11, 16], potassium chloride was introduced in autumn before plowing, and diammophoska and ammonium nitrate were introduced in spring during ridge tillage. Plantation was performed with applying the Extrasol liquid microbiological fertilizer with a complex of rhizosphere bacteria of the strain *Bacillus subtilis* Ch-13 (at a dose of 4.5 L/t of tubers in the soil with planting using the Grimme GL 36T planting machine) [17–19]. The Isabion liquid complex organomineral fertilizer was used at a dose of 2.5 L/ha (in the budding stage, 20–25 days after germination), and the Agris Phosphor liquid nitrogen-phosphorus fertilizer on the organic basis was used at a dose of 4 L/ha (foliar spraying in the phase of the maximum growth of tubers before the beginning of withering of leafy tops, 70–75 days after planting). The potato protection system included the use of the Selest Top insecticofungicide (0.4 L/ha), Zenkor Ultra soil herbicide (1 L/ha), three or four consecutive treatments with fungicides Consento (2 L/ha), Acrobat (2 kg/ha), Revus Top (0.6 L/ha), and Zummer (0.4 L/ha) as well as Reglon Super desiccant (2 L/ha).

The terms of potato planting and harvesting varied depending on weather conditions, but the potatoes were planted on May 5–10 and harvesting took place on August 20–28 on average over the years of research.

RESULTS AND DISCUSSION

The potato yield varied over a very wide range in different years (Table 1). The calculation of the average yield for the analyzed years made it possible to assess the effect of the fertilizers. Thus, from amongst the early ripening varieties, Labella was the most high-yielding: the increase in its yield in comparison with the Vineta variety turned out to be significant both on average over the years of studies and in each year against both backgrounds (with or without applying potassium chloride). The yield of the Granada middle-late variety was significantly higher than that of the standard (the Vineta variety). The difference in yield between the Granada and Labella varieties was higher than the smallest significant difference only in 2017. Thus, if there were equal agrochemical backgrounds and protective measures in a farm with certain climatic conditions, the middle-late Granada variety was inferior in yield stability to the early ripening Labella variety. This may be caused by some irregularities in the time of harvesting potatoes of the Granada variety (the start of harvesting may have been postponed to an earlier date based on the forecast of weather conditions). Meanwhile, it is known that, if early-ripening and middle-late potato varieties are harvested at one time and with the same nitrogen dose, the late varieties must be harvested at least 2–3 weeks after the start of harvesting early-ripening potato varieties [20].

The potato protection system included the use of a wide range of drugs with protective action. Therefore, as recommended by potato growers [21], potatoes were planted using the Selest Top insecticofungicide, which contains contact and locally systemic fungicides fludioxonil and difenoconazole (the class of triazoles and phenylpyrroles; it stimulated the development of the root system of plants, especially for the early-ripening Vineta and Labella varieties. At the same stage, potatoes were planted using the Extrasol microbiological drug, and the strains of its rhizosphere bacteria, settling on the roots of plants, strengthened the immunity of the young plants and their resistance to stress, especially to lowering of temperature in spring and early summer.

Good shoots against the background of applying the Zenkor Ultra soil herbicide of systemic action as a protective screen (the manifestation of herbicidal properties was observed in case of its being introduced into the wet soil) that is intended to combat annual dicotyledonous and herb weeds additionally activated the growth of the aboveground crop phytomass. It was important to maintain the optimal planting density and prevent the growth of weed plant phytomass, which could become an ideal medium for the development of pathogenic microflora.

Table 1. Yield of potato tubers

Option	Variety	Yield, t/ha			On average for 2015–2017		
		2015	2016	2017	yield, t/ha	+, – with respect to the standard	
						t/ha	%
NPK	Vineta standard	34.2	24.0	25.8	28.0	–	–
	Labella	40.4	33.2	40.3	38.0	10.0	35.7
	Granada	41.5	33.8	50.7	42.0	14.0	50.0
NPK + K_{cl}	Vineta standard	38.7	28.4	33.0	33.4	–	–
	Labella	48.5	41.7	53.6	47.9	14.5	43.4
	Granada	44.4	36.7	56.9	46.0	12.6	37.7
	LSD_{05}	4.9	5.4	6.2		5.1	

Therefore, the next step was the successive use of a complex of fungicides. First, the following fungicides were introduced with preventive purposes: the Consento fungicide with systemic translaminar action (the active agent is propamocarb hydrochloride of the carbamate class and fenamidone of the imidazolinone class) that blocked the growth of fungi mycelium and the Acrobat locally systemic fungicide (the active agent is mancozeb of the dithiocarbamate class and dimethomorph of the class of cinnamic acid amides) that damages a fungus both by direct contact and during penetration into the vascular system of the plant, cleaning it from inside, which ensured the protection of cultivated plants from mixed-type infections. As potato leaf mass grew, it was time to use the Revus Top systemic translaminar fungicide (the active agent is mandipropamid and difenoconazole, which are able to be adsorbed by the waxy leaf layer, due to which the drug is not washed off with water and precipitation) and Zummer contact fungicide (the active agent is fluazinam of the pyrimidinamine class), which ensured the protection of potatoes from late blight and other pathogens of a fungal nature.

It should be noted that, during the vegetation of potatoes, 3–4 weeks after the appearance of shoots, plant protection drugs came to be used with modern agrochemicals—primarily Isabion that is a liquid organic (60%) fertilizer, including 10% of free amino acids. This fertilizer enhanced the action of systemic fungicides and insecticides, ensuring their penetration into plants and, when being used in the beginning phase of leafy tops' thickening, it helped optimize the nutrition of potatoes due to the additional amount of minerals (11% of total nitrogen, calcium, sodium, sulfates, and chlorides).

During the period of tuberization, the fertilizer system was supplemented with the Agris Phosphorus organomineral fertilizer that has a high phosphorus content (100 g/L), contains nitrogen (12 g/L), a number of trace elements on the chelate basis (S, Mg, Zn, Cu, Fe, Mn, Mo, B, Co), and a complex of amino acids, humic and organic acids, which increased the stress resistance of plants and accelerated the outflow of substances from leaves to tubers.

In autumn, the introduction of potash fertilizer to the entire depth of the arable layer had an expected extremely positive effect on the potato yield, providing an increase for each variety: by 5.4 t/ha for the standard Vineta variety (slightly more than 19%), 9.9 t/ha for Labella (26.1%), and 4.0 t/ha for Granada (9.5%).

In all the years of studies (Table 2), the starch content in tubers on the whole corresponded to the biological description of the varieties. The autumn introduction of potassium chloride led to a slight increase in the starch content of tubers, which was noted at the trend level (with the exception of the Labella variety in 2016). It was the most noticeable in the Labella variety: the starch content increased by 5, 6.8, and 3.6 relative percent in 2015, 2016, and 2017, respectively. The starch yield was maximal for the Granada variety: on average over the years of studies without the autumn application of potassium chloride (the NPK background), its increase was 11.6 c/ha (31%) in comparison with the Labella variety and 26.6 c/ha (72%) in comparison with the standard Vineta variety. In case of introducing potash fertilizer in autumn, the increase in starch yield for the Granada variety was slightly lower compared to the Labella and Vineta varieties and amounted to 3.1 c/ha (~7%) and 26.1 c/ha (58%). As a whole, the Labella variety proved to be the best among early-ripening varieties as regards the starch content of tubers and starch yield: the increase in starch yield in comparison with the Vineta variety was 40% without potassium chloride and 51% with the autumn application of potash fertilizer.

Thus, the use of solid mineral fertilizers (diammophoska, potassium chloride, ammonium nitrate), the Extrasol microbiological drug, Isabion and Agris Phosphor liquid complex organomineral fertilizers, and the systems of plant protection drugs (Selest Top insectofungicide, Zenkor Ultra herbicide, Concerto, Acrobat, Revus Top and Zummer fungicides, and Reglon Forte desiccant) was effective, and the average

Table 2. Starch content in tubers and starch yield in harvested potatoes

Option	Variety	Starch content, %			Starch yield, c/ha		
		2015	2016	2017	2015	2016	2017
NPK	Vineta standard	13.3	12.8	13.4	45.5	30.7	34.6
	Labella	14.0	13.2	13.7	56.6	43.8	55.2
	Granada	15.3	14.8	15.2	63.5	50.0	77.1
NPK + K_{cl}	Vineta standard	13.5	13.4	13.3	52.2	38.1	44.2
	Labella	14.7	14.1	14.2	68.4	58.8	76.1
	Granada	15.6	15.3	15.4	69.3	56.2	87.1
	LSD_{05}	0.8	0.7	0.6			

yield of the Labella early ripening potato variety over the years of studies was 38.0–47.9 t/ha with a variation over the years from 33.2 to 53.6 t/ha.

Among the early ripening potato varieties, the Labella variety proved to be the most high-yielding, stable in changing weather conditions, and good for ensuring the maximum starch yield per unit of area: in comparison with the Vineta standard variety, the increase in its tuber yield amounted to 10.0–14.5 t/ha (35–43%) and the growth in starch yield was 15–23 c/ha (40–51%). The middle-late Granada variety was noted to have a high tuber yield of 42.0–46.0 t/ha and the maximal farm's starch yield of 63.5–70.9 c/ha without and with applying potassium chloride, respectively.

Mineral fertilizers at a dose of $N_{120}P_{156}K_{276}$ (2 c/ha of potassium chloride before deep tillage) in contrast to the background dose of $N_{120}P_{156}K_{156}$ (6 c of diammophoska + 2 c of ammonium nitrate per hectare) increased the yield of the studied potato varieties and the starch content in tubers by 4–10 t/ha and 0.3–0.7%, respectively.

COMPLIANCE WITH ETHICAL STANDARDS

The authors declare that they have no conflict of interest. This article does not contain any studies involving animals or human participants performed by any of the authors.

REFERENCES

1. Torikov, V.E., Kotikov, M.V., and Bogomaz, A.V., Effect of various cultivation technologies on the yield and crop structure of different cultivars of potatoes, *Vestn. Bryansk. Gos. S-kh. Akad.,* 2008, no. 3, pp. 54–60.
2. Monastyrskii, O.A., Glinushkin, A.P., and Sokolov, M.S., The problem of ensuring food security of Russia and ways to solve it, *Agrokhimiya,* 2016, no. 11, pp. 3–11.
3. Belous, I.N. and Prishchep, D.N., Agroeconomic efficiency of potato cultivation technologies, *Vestn. Bryansk. Gos. S-kh. Akad.,* 2009, no. 6, pp. 40–45.
4. Yanaeva, L.T. and Chekaev, N.P., Yield and quality of potato tubers, depending on the fertilizers used and means of chemicalization during irrigation, *Agrarn. Nauchn. Zh.,* 2015, no. 2, pp. 38–41.
5. Qasem, J.R., Herbicides applications: Problems and considerations, herbicides and environment, *Herbic. Environ.,* 2011, vol. 32, pp. 643–664.
6. Raghavendra, K.S. and Gundappagol, R.C., Effect of herbicides on soil microcosm, nodulation and yield in chickpea, *J. Pharmacogn. Phytochem.,* 2017, vol. 6, no. 5, pp. 1649–1655.
7. Zhuchenko, A.A., Basics of an adaptively integrated system for the protection of agrocenoses, agroecosystems and agrolandscapes from harmful species, in *Rol' mobilizatsii geneticheskikh resursov tsvetkovykh rastenii* (The Role of Mobilization of Genetic Resources of Flowering Plants), Saratov, 2012, pp. 180–195.
8. Vasil'ev, A.A., The balance of mineral nutrition determines the yield and quality of potatoes, *Vestn. Ross. Akad. S-kh. Nauk,* 2013, no. 4, pp. 21–23.
9. Voloshin, E.I., The influence of potash fertilizers on potato productivity on leached chernozem of the Krasnoyarsk forest-steppe, *Vestn. Krasnoyarsk. Gos. Agrarn. Univ.,* 2006, no. 11, pp. 80–85.
10. Liljeroth, E., Lankinen A., Lars, W., and Dharani, Dh.B., Potassium phosphite combined with reduced doses of fungicides provides efficient protection against potato late blight in large-scale field trials, *Crop Prot.,* 2016, vol. 86, pp. 42–55.
11. Seraya, T.M., Bogatyreva, E.N., Belyavskaya, Yu.A., and Zhukova, M.I., Efficiency of potato cultivation under various farming systems, *Agrokhimiya,* 2017, no. 7, pp. 34–41.
12. Zakharenko, V.A., Herbicides in the integrated management of the weedy component of agro-ecosystems in the context of reforming the agricultural sector of Russia, *Sovremennye problemy gerbologii i ozdorovlenie pochv: Mat-ly Mezhdunarodn. nauchno-prakt. konf. 21–23 iyunya, 2016* (Current Problems of Herbology and Soil Rehabilitation: Proc. International Scientific and Practical Conference, June 21–23, 2016), Bolshie Vyazemy: VNIIF, 2016, pp. 36–43.
13. Artokhin, K.S. and Ignatova, P.K., On some trends in the development of plant protection, in *Agrotekhnicheskii metod zashchity rastenii ot vrednykh organizmov*

(The Agrotechnical Method of Protecting Plants from Harmful Organisms), Krasnodar, 2015, pp. 14–17.

14. Morozov, A.I., Nizhny Novgorod oblast: Successes and prospects, *Kartofel Ovoshchi,* 2018, no. 1, pp. 8–10.
15. *Metodicheskie ukazaniya po provedeniyu kompleksnogo monitoringa plodorodiya zemel' sel'skokhozyaistvennogo naznacheniya* (Guidelines for Conducting Integrated Monitoring of Agricultural Land Fertility), Moscow: VNIIA, 2003.
16. Yakimenko, V.N., The effect of potash fertilizers on the yield and quality of potato tubers in the Forest-Steppe of Western Siberia, *Agrokhimiya,* 2017, no. 9, pp. 39–48.
17. Zavalin, A.A., Blagoveshchenskaya, G.G., Shmyreva, N.Ya., Chernova, L.S., Sokolov, O.A., Alferov, A.A., and Samoilov, L.N., The current state of the problem of nitrogen in world agriculture, *Agrokhimiya,* 2015, no. 5, pp. 83–95.
18. Nugmanova, T.A., Biological products in vegetable and potato production, *Kartofel Ovoshchi,* 2017, no. 6, pp. 2–5.
19. Fedotova, L.S., Kravchenko, A.V., Timoshina, N.A., and Tuchin, S.S., Use of foliar fertilizing of microfertilizers for growing potatoes, *Niva Povolzh'ya,* 2011, no. 1, pp. 67–72.
20. Fedotova, L.S., Timoshina, N.A., and Knyazeva, E.V., The reaction of potato cultivars to increasing doses of fertilizers, *Selektsiya, semenovodstvo i tekhnologiya plodovo-yagodnykh, ovoshchnykh kul'tur i kartofelya: Sbornik nauchnykh trudov* (Breeding, Seed Production, and Technology of Fruit, Vegetables, and Potatoes: Collection of Scientific Papers), Chelyabinsk, 2017, vol. 19, pp. 375–386.
21. Kol'bin, D.A., Protection of seeds of hybrid cultures, *Zashch. Karantin Rast.,* 2014, no. 2, pp. 23–24.

Translated by L. A. Solovyova