Bulgarian Journal of Agricultural Science, 25 (Suppl. 2) 2019
Agricultural Academy

Biological quality and preservation of potato under drip irrigation and different fertilizers

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Abstract

Butov, A., Zakharov, V., & Zubkova, T. (2019). Biological quality and preservation of potato under drip irrigation and different fertilizers. *Bulgarian Journal of Agricultural Science, 25* (Suppl. 2), 37–44

The article states the necessity of obtaining biologically valuable, environmentally friendly and well preserved potatoes grown under drip irrigation. Field experiments were conducted at the agricultural company "CJSC Annenskoe" Voronezh region (Russian Federation). The soil is leached black earth (chernozem). The experiment included 12 variants with different doses and ratios of N:P:K. With the increase in fertilizer doses under drip irrigation from 0 (without fertilizers) to $N_{150}P_{210}K_{180}$ potato yield increased from 22.1 to 46.1 t/ha. To get tubers with good biological, culinary properties, optimal preservation capacity and the level of yield in the range of 40-44 t/ha, it is necessary to apply $N_{90\text{-}120}P_{150\text{-}180}K_{120\text{-}160}$ kg/ha of primary nutrient along with mineral fertilizers under drip irrigation with a ratio of N:P:K not less than 1:1.5-1.7:1.3. To obtain environmentally friendly products for nitrate which are used for adult nutrition, it is necessary to prevent the excess of nitrogen level of more than 120 g/ha; for child nutrition – 60 kg/ha of primary nutrient. For obtaining ecologically clean pesticide-free products, we determined periods of potato harvesting. The conditioning period from the last treatment with chemical insecticides till harvesting is 35 days, with fungicides is 20 days, with herbicides depending on the type is 45-65 days.

*Keywords***:** potato; fertilizer; drip irrigation; yield; tubers preservation; pesticides

Introduction

Potato in Russia is strategically important food crop and socially significant food product. An important task of the modern branch of agriculture – potato-growing – is to achieve not only the increase in its harvest, but also to get tubers with the best biological characteristics of food quality, and high level of tubers preservation. It is quite possible to solve such tasks in the Central Black Earth Region of Russia with the use of drip irrigation and optimal fertilizer doses. Russia, which has the largest land area on the planet, ranks only the third for gross potato harvest after China and India. However, the crop yield in the country and the quality of its produce, are ranked one of last among other countries in the world. Annually, moreover, up to 25-53% or more of produce is lost due to various diseases over the period of storage in our country. This results in Russia's need to import potato from abroad (Tulcheev & Yagforov, 2014).

To increase the potato yield and recoupment of expenses, a number of agricultural firms and farms in the region, in the presence of a natural water source (river or pond), began to use drip irrigation. It is rational as the drip irrigation of potato requires several times less water than ordinary overhead irrigation (Erdem et al., 2005; Shock et al., 2007).

Combine harvesting and subsequent unloading, transportation and reloading operations damage potato tubers. From bruises of tubers the pulp under the peel begins to darken (Rady et al., 2017; Gabitov et al., 2018). The cause of pulp darkening of mechanically damaged raw tubers is enzymatic, and it becomes visible when they are peeled (Djilani & Senoussi, 2013). The sensitivity of tubers to damage and, consequently, to the pulp darkening depends largely on the growing conditions. Mineral fertilizers and manure in moderate doses decrease the damage of tubers and pulp darkening (Shpaar, 2007). The correct and balanced application of fertilizers for potatoes under irrigation conditions is one of the factors which can help reduce the pulp darkening of raw tubers to minimum (Järvan & Edesi, 2009). Simakov et.al. (2013) believe that potash and phosphate fertilizers play an important role in preventing damage. They also accelerate the ripening of tubers, increase the density of tubers and the strength of the peel.

Pesticides have been applied in agricultural production for many decades, ensuring rapid growth of plants, and improving their appearance. But chemical pesticides are poisons that have a poisonous effect on the warm-blooded species, including humans (Damodaran et al., 2012). Getting into the human body with food, water even in small quantities, pesticides accumulate in it and are not removed. Afterwards, they cause irreversible changes in health status (Al-Sahaf & Atee, 2007).

Significant danger to the health of people and the warm-blooded species are nitrates, from which nitrites are formed in the gastrointestinal tract of the man and animals. Nitrites, as well as secondary amines and nitrosamines, cause diseases of people and animals due to the formation of methemoglobin in blood, which blocks the transfer of oxygen to cells of the body. It is especially dangerous for children. Nitrosamines and nitrosamides, formed from nitrates in the human body, have pronounced carcinogenic, mutagenic and embryotoxic properties (Moore et al., 2011).

The preservation and resistance of potatoes to diseases are closely related to breathing, wound healing and germination of tubers. The output of products, that are not secured with a path from the field to the shop's shelves, is not only a failure, but also leads to a useless waste of human and material resources (Rakhimov et al., 2018). To produce one hundred tons of high-quality potatoes should be more profitable than to exceed the target and produce 120 t, 30 t of which will be doomed to rotting (Zeyruk et al., 2005).

One of the important issues of preservation and environmental safety of potatoes is the rational selection of doses and ratios of mineral fertilizers, the use of biological methods for protecting crops from diseases and pests. It is inadmissible to obtain high yields to the detriment of their quality, shelf life, suitability for processing, otherwise huge losses are inevitable (Järvan & Edesi, 2009; Djilani & Senoussi, 2013).

Storage losses can definitely be (and must be) reduced. Therefore, it is important to find ways to manage and regulate the processes that ensure the improvement of tubers preservation (Pshechenkov et al., 2007). In this regard, the aim of our research was to determine the residual amounts of pesticides in tubers at different periods after the last potato plant treatment as well as to provide the recommendations on the harvesting periods in order to obtain ecologically clean products.

Material and Methods

The research was carried out in field experiments and during storage periods in standard storage facilities in 2011-2014 at the agricultural firm "CJSC Annenskoe" (Voronezh region) in the forest-steppe subzone. The experiments were carried out with the organizational and financial support of the director general of the firm. The soil is leached medium loamy black earth. The humus content in the topsoil is high – 7.4%. Water from the nearby pond with the surface area of about 5 ha was used for drip irrigation. The total volume of water in the pond was 135 thousand m^3. The pond has engineering communications in the dam for discharging melt water. Field experiments were carried out in the total amount of irrigated potato. The potato variety is middle-late Picasso. The area of the experimental plot is 54 m^2, the repeatability of the variants in field experiments and during storage is 4-fold. Planting density of tubers is 55 thousand/ha, row-spacing is 75 cm. Mineral fertilizers were applied manually in spring after laying the plots. It was done in line with the developed scheme of studies for preplant soil cultivation. During experiments elements of Dutch technology and imported equipment were used while growing potato. During the vegetation period, the soil moisture under the plants was maintained at the level of 72-75% of the maximum field water capacity (FWC) by means of drip irrigation. The FWC determined by us on the irrigated field was 32.4%. Immediately after potato harvesting, the taste was determined according to the method which was proposed by Veselovskiy and Boykova (1972), where the sum of the first category is multiplied by 4, and the sum of the second one is multiplied by 2. Eventually, the results of the first and second categories are added up, and the total number of points is determined.

To determine nitrates in potatoes we used the procedure with the instrument pH-meter-ionomer "Expert-001" liquid analyzer (Mineev, 2011). The total amino acid content in tubers was determined with the amino acid analyzer ND-1200E after hydrolysis with 6N HCI solution, BV of tubers – in line with the content of 8 essential amino acids in the protein: valine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, and phenylalanine. Calculations were made using the formula of Karpatsi, Lander and Varga (Methodology of physiological and biochemical studies of potato, 1989). The concentration of pesticides in potato tubers was determined in the technologic and analytic laboratory of "Rosselkhoztsentr of the Lipetsk region" by the inversionvoltammetry method (State standard R 51301-99). To study the degree of tuber pulp darkening from mechanical damage, the methodology described in Methodology of physiological and biochemical studies of potato was used (Methodology of physiological and biochemical studies of potato, 1989). The striking was carried out with a dynamic strength device PDP-1. The diameter of the spherical impactor is 20 mm, the height of the fall of the striker is 250 mm, and the weight of the striker is 100 g. The pulp darkening at various depths from the surface of the tubers was determined after 10 days of storage. Tubers for analysis were chosen during harvesting. To study the preservation of potatoes, tubers (10 kg) were chosen from each experiment during the harvesting period. They were placed into bags in 4-fold replication and put in a vault with active ventilation in layers at a depth of 30-50 cm. At the end of storage in spring losses from rot, natural loss and total weight loss of tubers were determined. Mathematical processing of data on harvest, nitrate content and total losses was carried out by the method of variance analysis according to Dospekhov (1985).

Results and Discussion

Drip irrigation in our experiments had a considerable impact on the effectiveness of mineral fertilizers. Thus, with the increase in their doses from 0 (without fertilizers) to $N_{150}P_{210}K_{180,}$ the average yield of tubers in 2011-2013 increased from 22.1 to 46.1 t/ha.

When $N_{30}P_{90}K_{30}$ was applied, the yield was 27 t/ha; with $N_{60}P_{120}K_{90}$ it was 33.4 t/ha; with $N_{90}P_{150}K_{120}$ – 39.7 t/ha; with $N_{120}P_{180}K_{150}$ – 43.8 t/ha; with $N_{150}P_{210}K_{180}$ – 46.1 t/ha as compared to the check amount of 22.1 t/ha without fertilizers.

Unfortunately, along with the increase in yield, the increase of doses of mineral fertilizers leads simultaneously to greater accumulation of nitrates in tubers. The content of nitrates in raw tubers on the plot without fertilizers (check) was on average 14.9 mg/kg for 3 years. With the minimum dose of nitrogen in complete fertilizer $N_{30}P_{90}K_{60}$, it increased insignificantly – up to 20.8 mg/kg. The application of the average dose for the Central Black Earth Region ($N_{60}P_{90}K_{60}$) increased the nitrate level to 47.7 mg/kg, but it was found to be much lower than permissible concentration for potatoes for children and dietary nutrition. With higher doses of $N_{90-120}P_{150-180}K_{120-150}$ fertilizers, the content of nitrates increased to the level of 106.6-164.9 mg/kg, respectively. Further increase in the doses of complete mineral fertilizers to the level of $N_{150}P_{210}K_{180}$ increased the accumulation of nitrates in tubers to 234.3 mg/kg (Table 1).

Thus, with small doses of nitrogen in complete mineral fertilizer from 30 to 60 kg/ha of primary nutrient and the ratio of N:P:K equal to 1:2:1.3, the accumulation of nitrates was 20.8-47.7 mg/kg. Such a level meets even the stringent requirements of MPC for the potato products for children and clinical nutrition (EEC, 2011). At higher doses of nitrogen of 90-120 kg/ha (ratio of N:P:K = 1:1.5-1.7:1.3), though the concentration of NO_3 increased to 106.6-164.9 mg/kg, but its value was at an allowable level in relation to the established MPC of 250 mg/kg for food potato (Sanitary Rules and Regulations, 2001; EEC, 2011). When we applied the maximum fertilizer dose $N_{150}P_{210}K_{180}$, which we studied, the accumula-

Table 1. Nitrate content and pulp darkening of raw tubers under impact loads depending on fertilizers under drip irrigation, 2011-2013

$N-P_2O_5-K_2O$ variant [kg/ha of primary nutrient]	Nitrates [mg/kg]	Average grade of darkening	Tubers with pulp darkening [%]	Including	
				to the depth of over 3 mm	to the depth of less than 3 mm
0-0-0 (without fertilizers)	14.9	2.39	51	17	34
30-90-60	20.8	2.27	47	15	32
60-120-90	47.7	2.43	52	18	34
90-150-120	106.6	2.51	55	19	36
120-180-150	164.9	2.65	60	21	29
150-210-180	234.3	2.85	66	28	38
120-90-60	–	3.05	70	31	39
30-180-60	–	2.29	48	15	33
30-90-150	–	2.27	47	14	33
120-180-60	–	2.71	60	22	38
120-90-150	–	2.97	69	28	41
30-180-150	–	2.03	41	10	31
HCP_{05} [mg/kg]	11.2				

tion of NO_3 increased to 234.8 mg/kg and approximate to the established MPC (250 mg/kg). The obtained data indicate the excessive accumulation of nitrates at the maximum nitrogen dose (N_{150}) in complete fertilizers, applied during the experiments. And they also indicate a significant decrease in the biological value of the produce. To achieve the goals of obtaining environmentally friendly products in the Central Black Earth Region under drip irrigation, one should not increase the nitrogen dose in complete mineral fertilizer above 120 kg/ha of primary nutrient. The pulp darkening of raw tubers occurs in most cases because of mechanical damage during harvesting. This worsens their commercial quality, and then the culinary properties. In our experiments, after striking tubers with the PDP-1 device, the darkening of the pulp varied appreciably depending on the doses and ratios of mineral fertilizers applied under conditions of drip irrigation. When mineral fertilizers were applied in optimal proportions from 0 (check without fertilizers) to the level of $N_{90}P_{150}K_{120}$ (Table 1), a slight increase in the number of tubers with pulp darkening was noted – up to 55% as compared to the check percentage of 51%. $N_{120}P_{180}K_{150}$ variant showed satisfactory pulp darkening results. Further increase in fertilizer doses to the level of $N_{150}P_{210}K_{180}$ increased the pulp darkening by a more significant amount – by 15% as compared to the check.

The ratios of nutrients in complete mineral fertilizer influenced the darkening of potatoes even more significantly. So, one-sidedly strengthened nitrogen nutrition in complete mineral fertilizer ($N_{120}P_{90}K_{60}$ variant) under conditions of drip irrigation increased the number of damaged tubers by 19%. We also noted the increase in the number of tubers with the damage to the depth of over than 3 mm – 31%, as compared to the check of 17%.

With one-sided increase in doses of nitrogen-potash fertilizers ($N_{120}P_{90}K_{150}$ variant), pulp darkening rate was slightly smaller in comparison with the $N_{120}P_{90}K_{60}$ variant, and made 69%, including 28% to the depth of over than 3 mm. In variants with enhanced nitrogen, and nitrogen-potash fertilizer, the biggest average grade of darkening was 3.05-2.97, as compared to the check grade of 2.39.

With enhanced phosphorous and, especially, phosphorous-potassium nutrition ($N_{30}P_{180}K_{60}$ and $N_{30}P_{180}K_{150}$ variants), the rate of pulp darkening resulting from impact loads significantly decreased, which means that the quality of tubers improved.

Our data show that on leached black earth of the Central Black Earth Region under drip irrigation of potato, it is possible to significantly increase the resistance of tubers to pulp darkening from mechanical damage by establishing the ratios of doses of nitrogen, phosphorus and potassium in complete mineral fertilizer at the level of N:P:K equal to 1:1.5-1.7:1.3 and not to exceed doses of nitrogen fertilizers of more than 120 kg/ha of primary nutrient.

To obtain tubers with the best BV in combination with high yield, we conducted studies on 6 basic variants with a balanced ratio of nutrients, including check without fertilizers. The task was to determine optimal increased doses of mineral fertilizers under drip irrigation, which influenced not only the achievement of high yields, but also the achievement of tubers with the best biological qualities, including BV.

After applying small and moderate doses of fertilizers, the biological value of protein of potato tubers slightly improved (Table 2).

BV of tubers in $N_{30}P_{90}K_{60}$ and $N_{60}P_{120}K_{90}$ variants was at the level of 80.4-81.0%, as compared to the check of 79.8% without fertilizers. The characteristics of BV were at a fairly high level after the application of increased doses of fertilizers $N_{90\text{-}120}P_{150\text{-}180}K_{120\text{-}150}$, as compared to the check which was 80.1-79.4%.

If we apply the maximum dose of fertilizers $N_{150}P_{210}K_{180}$, the content of BV is reduced to 76.1%, i.e., it gets depressed, which is expressed quite sharply. With properly selected and

Table 2. The content of amino acids, crude protein and the biological value of protein at different levels of mineral nutrition under drip irrigation, 2012-2013

$N\text{-}P_2O_5\text{-}K_2O$ variant	Total amount of amino acids	Amount of essential amino acids	Biological value of protein [%]	Crude protein [mg %]
	[mg] % of dry matter			
0-0-0	4950	1620	79.8	2.10
N_{30} P_{90} K_{60}	6200	1880	80.4	2.18
N_{60} P_{120} K_{90}	6600	2150	81.0	2.21
N_{90} P_{150} K_{120}	7020	2270	79.9	2.32
$N_{120}P_{180}$ K_{150}	8230	2740	79.2	2.39
$N_{150}P_{210}$ K_{180}	7810	2360	76.1	2.41

balanced increased doses of fertilizers under drip irrigation of potato, on the one hand, you can achieve high yield, on the other hand, keep tubers from the deterioration of BV and improve the overall biological quality of the product compared to the unfertilized variant.

The nutritional value of proteins is determined by the presence of amino acids, which cannot be synthesized in the human body. From this point of view, the content of protein (or "crude" protein, as in our studies) in tubers is one of the important indicators of crop quality. The results of studies show (Table 2) that with the increase of doses of the complete balanced mineral fertilizer, the content of crude protein increased by 0.08-0.31% as compared to the check.

The best culinary properties of boiled potato tubers were obtained at check without fertilizers and in variants with small and moderate doses of mineral fertilizers (Table 3).

With the application of nitrogen of 30-60 kg/ha, phosphorus of 90-120 kg/ha and potassium of 60-90 kg/ha of primary nutrient, the score was 72.0-70.4, the taste was 4.3-4.1, as compared to the check with 71.8 and 4.2 points for the variant without fertilizers. When increased doses of fertilizers of nitrogen 90-120, phosphorus 150-180, potassium 120-150 kg/ha, (ratio of N:P:K = 1:1.5-1.7:1.3) were applied, the score was 68.8-65.0, taste 3.9-3.6, as compared to the check with 71.8 and 4.2 points. These are quite good culinary properties for human nutrition.

The increase in fertilizer doses to the maximum in the experiment – $N_{150}P_{210}K_{180}$ – worsened more significantly both the taste (3.4 points), and the total score to 62.4 as compared to the check with 4.2 and 71.8 points.

Phosphorus improved culinary properties. Potato tubers had the best taste, mealiness, less wateriness and a pleasant smell in variants with enhanced phosphate nutrition and a smaller portion of nitrogen in complete mineral fertilizer. So, when $N_{30}P_{180}K_{60}$ was applied, the taste was 4.2, and the score was 72.0, compared to 71.8 and 4.2 points at the check without fertilizes.

A sharp deterioration in the culinary properties of tubers occurred in $N_{120}P_{90}K_{60}$ with a one-sided increase in nitrogen nutrition. One-sided increase in doses of nitrogen-potash fertilizers in chlorine type ($N_{120}P_{90}K_{150}$) resulted in the greatest decrease in culinary properties. The taste in these variants fell to 3.3-3.1, and the total score to 60.0-56.8, respectively. A certain negative effect of one-sidedly increased doses of potash fertilizers in chlorine type on the culinary properties was revealed.

Culinary properties declined to a greater extent due to the fact that taste and mealiness became worse, wateriness of tubers increased. In general, taste and mealiness of tubers became worse, wateriness increased in the variants with high doses of mineral fertilizers. But the worst culinary properties were found if unfavorable ratios of elements of mineral nutrition were applied – one-sidedly enhanced doses of nitrogen and nitrogen-potash fertilizers.

Thus, to obtain tubers with good culinary properties, it is necessary to strictly observe the optimal ratio between macro elements of mineral nutrition of plants on leached black earth of the Central Black Earth Region under drip irrigation of potato.

According to our research, good culinary properties can be formed by applying doses of complete mineral fertilizers, where phosphorus prevails over nitrogen by 1.5-1.7 times, with the ratio of N:P:K = 1:1.5-1.7:1.3. The maximum dose of fertilizer $N_{150}P_{210}K_{180}$ is unreasonable due to a more sig-

Table 3. Culinary properties of boiled tubers at different doses and ratios of fertilizers under drip irrigation, 2012-2013

N-P_2O_5-K_2O variant [kg/ha of primary nutrient]	I category (x4)				II category (x2)				
	taste	wateriness	mealiness	score	smell	cooking properties	consistence	total score	Score of I and II categories
0-0-0	4.2	4.6	4.7	54.0	2.8	3.2	2.9	17.8	71.8
30-90-60	4.3	4.6	4.7	54.4	2.8	3.2	2.8	17.6	72.0
60-120-90	4.1	4.5	4.4	52.0	2.8	3.6	2.8	18.4	70.4
90-150-120	3.9	4.3	4.2	49.6	2.8	4.1	2.7	19.2	68.8
120-180-150	3.6	4.1	3.7	45.6	2.8	4.4	2.5	19.4	65.0
150-210-180	3.4	3.8	3.3	42.0	2.6	4.9	2.3	20.4	62.4
120-90-60	3.3	3.6	3.2	40.4	2.6	5.0	2.2	19.6	60.0
30-180-60	4.2	4.6	4.7	54.0	2.8	3.4	2.8	18.0	72.0
30-90-150	3.8	4.6	4.4	51.2	2.8	3.8	2.5	18.2	69.4
120-180-60	3.7	4.2	3.8	46.8	2.8	4.2	2.5	19.0	65.8
120-90-150	3.1	3.3	3.1	38.0	2.4	5.0	2.0	18.8	56.8
30-180-150	3.9	4.6	4.4	51.6	2.7	3.9	2.7	18.6	70.2

nificant deterioration of culinary properties in comparison with the previous $N_{120}P_{180}K_{150}$ one.

Due to the fact that our experiments were carried out in total amount of potato under drip irrigation, a single intensive system of plant protection by chemical preparations against pests, diseases and weeds was applied to plantings. To determine periods of harvesting potato in order to obtain ecologically clean pesticide-free products, we selected samples of tubers for determining the residual amounts of harmful substances at different periods after the last spraying.

According to the obtained test reports from the Technological and Analytical Laboratory of the "Rosselkhoztsentr" branch of the Lipetsk Region, the residual amount of the insecticide Actara (thiamethoxam), which is used against the Colorado beetle at recommended doses (Reference book of pesticides and agrochemicals allowed for the use on the territory of the Russian Federation, 2015-2016), on the 5th day after treatment was 0.087 mg/kg in tubers, with allowable MPC of 0.05 mg/kg. 10 days after insecticide treatment its amount in tubers decreased to 0.063 mg/kg, but still exceeded the MPC by 26%. In the samples of tubers taken 20 days after thiamethoxam treatment, its concentration decreased to 0.021 mg/kg, that is, it was 2.38 times less than the MPC – 0.05 mg/kg. The residual amount of thiamethoxam 25 days later decreased to 0.0023 mg/kg, 30 days later – 0.0006 mg/kg. 35 days after chemical treatment, no insecticide was found in the tuber samples.

The potato plants were treated with fungicides from the diseases: they were Profit Gold and Ridomil Gold in recommended doses (Reference book of pesticides and agrochemicals allowed for the use on the territory of the Russian Federation, 2015-2016). In the tuber samples taken 5 days after treatment with Profit Gold fungicide (cymoxanil), there was an increased fungicide concentration in tubers – 0.12 mg/kg, in comparison with MPC which allows 0.05 mg/kg. 10 days after treatment its content decreased to 0.005 mg/kg, and 20 days later there was no cymoxanil in tubers. Residual amount of Ridomila Gold (mancoceba) in tubers of potato 5 days after treatment was 0.067 mg, 10 later – 0.003 mg/kg, at MPC equal to 0.1 mg/kg. In the samples taken 20 days after treatment, the preparation was not found.

The herbicides from the pesticidal group used to protect potato plants from weeds persisted in tubers the longest. When herbicide Rimus (rimsulfuron) was used for the protection of plants from weeds at a dose of 50 g/ha (Reference book of pesticides and agrochemicals 2015-2016), its concentration in tubers 30 days after treatment was 0.062 mg/kg; 40 days – 0.47 mg/kg; 50 days – 0.19; 60 days – 0.003 mg/kg, and by the end of August 65 days later (after treating shoots of 5 cm high) it was not detected at all (MPC = 0.01 mg/kg). Herbicide Zenkor (metribuzin) (MPC = 0.25 mg/kg) had a shorter cumulative period compared to Rimus. Its residual amount in tubers was not detected 40-45 days after treatment of plantings (3-4 days before shoots appear – 1.1 kg/ha, and for small shoots – 0.3 kg/ha).

The obtained data indicate that to get ecologically clean potatoes, it is necessary to calculate the harvesting period on the basis of the duration of preservation of residual amounts of a pesticide in the produce. Particular attention should be given to so-called "long-life" pesticides, such as the herbicide Rimus (rimsulfuron), as well as chemical insecticides.

Potato weight loss during storage in our studies depended to a large extent on the doses and ratios of mineral fertilizers applied to potatoes under conditions of drip irrigation during the vegetative period of plants (Table 4).

Table 4. Potato loss during storage, yield during autumn harvest and including losses in spring (2011-2014)

$N-P_2O_5-K_2O$ variant [kg/g of primary nutrient]	Total loss [%]	Including		Potato yield [t/ha]	
		natural loss	waste	during harvest	including losses during storage
0-0-0	7.7	6.2	1.5	22.1	20.4
30-90-60	8.0	6.4	1.6	27.3	25.1
60-120-90	8.7	6.7	2.0	33.4	30.5
90-150-120	9.3	6.9	2.4	39.7	36.0
120-180-150	10.4	7.3	3.1	43.8	39.2
150-210-180	12.5	7.9	4.6	46.1	40.3
120- 90- 60	13.0	8.1	4.9	38.1	33.1
30-180- 60	7.6	6.3	1.3	36.2	34.0
30- 90-150	7.8	6.4	1.4	31.4	29.4
120-180- 60	11.0	7.6	3.4	40.7	37.2
120-90-150	12.6	8.2	4.4	39.1	35.4
30-180-150	7.5	6.4	1.1	37.2	35.0
$HCP_{05. \%.}$ [t/ha]	0.54			1.95	

The greatest losses were observed in variants with enhanced nitrogen and nitrogen-potassium nutrition. So, in $N_{120}P_{90}K_{60}$, $N_{120}P_{90}K_{150}$ variants the losses for the storage period were 13.0-12.6%, as compared to the check amount of 7.7% without fertilizers. When storing, tubers of these variants had lower content of starch and dry substances, weak peel. In the same variants, the highest losses from rot and natural loss are noted. In the variant with the maximum fertilizer dose of $N_{150}P_{210}K_{180}$, though with a relatively balanced ratio of N:P:K=1:1.4:1.2, total losses were also significant – 12.5%. The one-sided increase in the proportion of phosphate or potassium nutrition in complete mineral fertilizer reduced total losses, natural loss and waste during storage. In $N_{30}P_{180}K_{60}$, $N_{30}P_{90}K_{150}$ variants total losses were 7.6- 7.8%, as compared to the check of 13.0-12.6% in variants with enhanced nitrogen or nitrogen-potash fertilizer.

Potato, grown with enhanced phosphorous-potassium nutrition in $N_{30}P_{180}K_{150}$ variant, showed the least amount of total losses – 7.5%.

Variants that combine high yields (40-44 t/ha) and good quality of tubers ($N_{90}P_{150}K_{120}$ and $N_{120}P_{180}K_{150}$) under drip irrigation, despite their high enough level, with the optimal ratio of elements of mineral nutrition (1:1.5-1.7:1.3) showed good keeping capacity. Total losses in these variants increased only by 1.6-2.7%, as compared to the check. Therefore, the optimization of mineral nutrition under drip irrigation can help obtain potatoes with quite good keeping capacity in the autumn-winter period.

Thus, one-sidedly enhanced doses of nitrogen in complete mineral fertilizer significantly increase natural loss, losses from rot and total losses during storage on leached black earth under drip irrigation. Phosphate and potash fertilizers are a positive, active factor that improves the preservation of potatoes.

The yield of potato, taking into account losses during the autumn-winter period of storage, according to the variants of the experiment (Table 4), differs significantly from the yield during autumn harvesting. It especially concerns variants with one-sided enhanced nitrogen mineral nutrition, and with a maximum fertilizer dose in the experiment. So, for example, if during autumn harvesting there was a reliable yield increase of 2.3 t/ha in $N_{150}P_{210}K_{180}$ variant in relation to $N_{120}P_{180}K_{150}$ variant, then, taking into account losses during the autumn-winter storage period, this increase is brought to naught. The same trend is also observed in variants with one-sided enhanced nitrogen fertilizer.

Drip irrigation has had a significant impact on the effectiveness of mineral fertilizers. In relation to the check (without fertilizers), an increase in the yield of potatoes from 5.2 to 24.0 t/ha was obtained depending on the level of fertilizer doses. However, along with the rise of yield, the accumulation of nitrates in tubers goes up simultaneously with the increase of mineral fertilizers doses. At the maximum dose of nitrogen (N_{150}) in the complete fertilizer in our experiment an excessive amount of nitrates is accumulated in tubers and, accordingly, the biological value of the produce declines significantly. To obtain environmentally friendly products for nitrates in the Central Black Earth Region under drip irrigation it is necessary to limit the dose of nitrogen in complete mineral fertilizer up to 120 kg/ha of primary nutrient – for the nutrition of the adult population. One should not apply nitrogen doses in complete fertilizer above 60 kg/ha of primary nutrient for potato, which is to be used for child nutrition.

Properly selected and balanced increased doses of fertilizers under drip irrigation of potato, on the one hand, can help achieve high yield, on the other hand, keep tubers from the deterioration of BV and maintain a high level of the biological quality of produce.

By optimizing the conditions of mineral nutrition under drip irrigation, one can obtain potato products with good keeping capacity in the autumn-winter period. One-sidedly enhanced doses of nitrogen in complete mineral fertilizer significantly increase natural loss, losses from rot and total losses during storage on leached black earth under drip irrigation. Phosphate and potash fertilizers are a positive, active factor that improves the preservation of potatoes.

Conclusions

To sum up, drip irrigation on leached black earth of the Central Black Earth Region influences significantly the effectiveness of mineral fertilizers for potatoes. Thus, with the increase in their doses from 0 (without fertilizers) to $N_{150}P_{210}K_{180}$, tuber yields increased from 22.1 to 46.1 t/ha.

When applying high rates of mineral fertilizers for potatoes under drip irrigation, strict optimization of their doses and ratios is necessary. To obtain tubers with good biological, culinary properties, optimum preservation and yield level within 40-44 t/ha, that meet the requirements and realities of modern society, it is necessary to apply $N_{90-120}P_{150-180}K_{120-160}$ kg/ha of primary nutrient with the ratio of N:P:K not less than 1:1.5-1.7:1.3 together with mineral fertilizers under drip irrigation. In order to obtain environmentally friendly products for nitrate which are used for adult nutrition, one should not exceed the nitrogen level in complete fertilizer of more than 120 kg/ha, for child nutrition – 60 kg/ha. To obtain ecologically clean pesticide-free products, the deadlines for harvesting food potato are set. The period from the last treatment with chemical insecticides before harvesting is 35 days; with fungicides is 20 days; with herbicides depending on the type is 45-65 days.

Acknowledgements

This research was supported by Indarbiy Akhmedov, the Director General of the agricultural company "CJSC Annenskoe". The authors are also grateful to Alexander Puzatykh, the Associate Professor of Bunin Yelets State University, for the help in translating the article into English.

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