

Original Research

Cattle Manure Disposal on Potato Growing Fields in Conditions of the Southern Forest-Steppe of the Bashkortostan Republic

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Abstract

Higher yields of environmentally friendly potato require more organic fertilizers and irrigation. The most common organic fertilizer is cattle manure. The research goal is to study the effect of irrigation and high rates of cattle manure used in conditions of the southern forest-steppe of the Bashkortostan Republic on the yield and quality of potato tubers. The conducted study demonstrates increased potato tuber growth from 0.12 to 0.72 kg/plant and 0.30 to 0.79 kg/plant with a higher rate of cattle manure (120 t/ha) under rainfed and irrigation conditions, respectively. Cattle manure disposal is one of the most acute issues in terms of environmental conservation. It is a great concern in farming practice worldwide that requires the scientifically-proven use of farmyard manure. To get consistently high yields of crops and maintain soil fertility becomes possible when taking into account local agro-meteorological and soil conditions. The optimal rates of cattle manure for potatoes cultivated on leached chernozem in the southern forest-steppe of the Republic of Bashkortostan under irrigation and rainfed conditions were found. Potato growing at different rates of cattle manure application has been studied. There is an economic assessment of efficiency to apply different rates of manure.

Keywords: cattle manure, organic fertilizer, potatoes, recycling

Introduction

The potato is the most important food crop, indispensable for food and other industries [1-4]. Around 19 million hectares of land across the world are

used for growing potatoes. Their total yield is 328 mln tons. To date, the Russian Federation is the third-largest potato producer in the world (more than 29.5 million tons of potato in 2012) after China (about 86 million tons) and India (more than 44 million tons) [5].

Currently, there is a lack of a developed technology of manure use in plant growing [6]. This cheap fertilizer is being used irrationally. There are large stocks of farmyard manure around cattle breeding enterprises

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and farms. It causes significant damage to the environment. A wise solution is to use cattle manure in plant growing. It can increase crop yields and improve soil fertility. Thus, it is critical to study the effect of different rates of cattle manure on the yield and quality of potato tubers grown in the south-steppe black leached soil of Bashkortostan. Sustainable agriculture can be achieved by using organic fertilizers.

Mineral fertilizers have a great impact on the environment [7]. Improper manure contains toxic impurities [8]. Unsatisfactory fertilizers can result in serious negative consequences: lower quality of agricultural products, soil salination, and acidification [9, 10]. Another concern is the high cost of mineral fertilizers [11, 12]. Currently, nitrogen-phosphorus-potassium is 20,304 rubles/t, nitrogen-phosphorus-potassium-sulphur is 28 067 rubles/t.

Crop growing without fertilizers brings in higher acidity [13], reduced base saturation, draining [14], poor soil fertility. Removal of nutrients is not compensated with their supply [15], while the application of mineral fertilizers leads to higher acidity. This problem can be solved by using organic fertilizers. Disposal of manure is being discussed across the world. In Nigeria, manure is used in the development of the fishery industry and aquaculture. It solves the problem of manure disposal [16]. O'Callaghan et al. [17] claim that soil fertilization should be the primary method of cattle manure disposal, as it normalizes the balance of nutrients in the soil: plants harvested take out nutrients being restored by application of manure.

In south-eastern Nigeria, intensive use of fertilizers in growing sweet potatoes depleted nutrients in the soil. Over the years, due to financial difficulties, farmers could not buy expensive chemical fertilizers, and the latter was replaced with cattle manure. As a result, the soil condition and yield of sweet potatoes improved [7]. Studies conducted in Alberta, Canada, have shown that 40 g of cattle manure per 1 kg of soil reduces its acidity by an average 1 unit of pH [18].

Balemi [19] claims that 10-30 t/ha of the manure is equivalent to 33.3% and 66.6% of nitrogen-phosphorus inorganic fertilizers, respectively, without a significant reduction in the total number and quality of potato tubers.

Iranian scientists suggest using manure together with chemical fertilizers. According to their findings, the maximum output of potato tubers (36.8 t/ha) was harvested when 20 t of manure was combined with 150 kg/ha of nitrogen [20]. Optimum rates of manure are found according to the characteristics of natural-climatic zones, topography, type of soil, and nutrient availability. For most Russian regions, the most effective application of cattle manure for potato growing is at the rate of 20-40 t/ha. Studies conducted in the pre-mountain subprovince of the Republic of Dagestan have shown that the application of 10, 20, 30, 40, and 50 t/ha of manure in dark-chestnut soils contributed to potato

yields; 7.8; 12.9; 16.6; 18.3, and 19.7 t/ha respectively [21].

In this research, cattle manure is offered to be disposed of in potato growing. Being used according to a scientifically sound and systematic approach, it can be an indispensable organic fertilizer and a source of additional income. Cattle manure in potato growing technology for soil and climatic conditions of the southern forest-steppe of the Bashkortostan Republic remains poorly studied. Therefore, this paper is aimed to study the effect of high rates of farmyard manure and irrigation on the yield and quality of potato tubers grown in conditions of this area.

Experimental Procedures

Ninety thousand hectares of land in Bashkortostan are used for growing potatoes. It is about 4 % of the total area of the Russian Federation under potatoes. According to the Russian Federal State Statistics Service, Bashkortostan ranks the fifth among other subjects of the country (after the Voronezh district, the Krasnoyarsk and Altai territories, the Republic of Tatarstan). They are the leading suppliers of potato to the domestic market. Potato yield was 126 c/ha in 2015 and 123.1 c/ha in 2016).

The efficiency of different rates of cattle manure used for the leached chernozem in the southern forest-steppe of Bashkortostan was studied in conditions of dryland and irrigation. A field experiment was conducted on the water-balance station of the Bureau for Land Reclamation and Agricultural Water Supply in 2014-2016.

According to the B.A. Dospekhov's methodology [22], field research includes experiment planning, observation, and accounting, land selection and preparation, field experiment establishment and performance methods, the basics of statistical analysis as well as a simple and multifactorial mathematical processing of field and vegetation experiment results. The conducted experiment relied on the only difference method. All conditions had to be the same, except for the condition under the study that was different rates of manure and soil moisture. The research target was the most common middle-early potato of the Nevsky variety. The area of the registration plot is 16 m².

The field experience was to study the impact of cattle manure on crop yields and the quality of potato tubers grown with or without irrigation. 40, 60, 80, 100, and 120 t/ha of farmyard manure was introduced in spring, during soil treatment. The forecrop was fallow.

The soil on the experimental site is leached chernozem. It is low potent, medium humus, slightly eroded alluvial-diluvial carbonate clay.

The arable layer contains 6.1 % of humus (the soil humus content was measured by the Tyurin's

method in the modification of CINAQ (Russian national standard GOST 26213-91), 154 mg/kg of alkaline hydrolyzed nitrogen (determined by a CINAQ method (Russian national standard GOST 26486-85), 4.4 mg/kg of labile phosphorus, and 75 mg/kg of exchangeable potassium (the phosphorus and potassium content was estimated by the Chirikov's method in the modification of CINAQ (Russian national standard GOST 26204-91). The soil medium reaction is subacid ($\text{pH} = 5.0$). The chemical composition of cattle manure is given in Table 1. The nitrogen content was evaluated according to I. Romashkevich's colorimetric analysis [23], the phosphorus concentration was found by Denise's procedure. The content of organic matter was found using the thermogravimetry-mass spectrometry (Russian national standard GOST 27980-88).

Table 1 demonstrates the alkaline pH value of manure.

Soil conditions are mainly favorable for potato growing though they require additional organic or mineral fertilizers and irrigation.

During the conducted experiment, weather conditions were characterized by extremely uneven natural moisture and fluctuations in average daily air temperatures: the vegetation period of 2014 was characterized as very dry (Selyaninov's hydrothermal coefficient ($\text{HTC} = 0.69$), 2015 – dry ($\text{HTC} = 0.77$), 2016 – very dry ($\text{HTC} = 0.56$). According to meteorological conditions, it is clear that the production of potatoes requires additional soil moisture in the form of vegetative irrigation.

Annually, at the end of September, the soil was prepared by the primary tillage and autumn plowing. The soil was cultivated and harrowed after spring tilth. Before potato was planted, organic fertilizers were applied by hand and closed with a cutter. Potato tubers were treated with «Prestige» insectofungicide (manufactured by the Bayer Company, Germany) to protect against pests and diseases.

In 2014 and 2015, the potato was planted on May 29-31 and harvested on September 2-6. In 2016, there was early spring. Planting was performed on May 7. Accordingly, the subsequent phenological phases took place earlier than the average time. Three-year average vegetation period of potato was 115 days (from planting to harvesting).

There was a regular analysis of the soil moisture in the calculated soil layer of 0-50 cm to find optimal irrigation rates.

Results

Before considering the results of the potato study, it is necessary to characterize the results on soil moisture. Observations showed that in 2014 under the rainfed scheme, there was soil moisture deficiency from the moment of potato planting until the emergence (June 17) and from the beginning of top wilting (July 30) until the end of the growing season. In 2015, moisture deficiency lasted from the beginning of the flowering phase (July 20) until the end of the growing season. In 2016, the shortage of soil moisture was observed during budding (from May 25 to June 5), then from the beginning of flowering to full bloom (June 22 – June 27) and from the end of flowering (July 23) until the harvest.

Optimal soil moisture was provided by sprinkling using the "Tuchka" installation. The moisture content of the calculated soil layer in irrigated areas was maintained in the range from 70 to 100 % of the lowest moisture content. These are optimal conditions for potato growing. Irrigation and watering rates were directly dependent on the prevailing meteorological conditions during the growing season. The irrigation rate varied from 643 to 2350 m^3/ha . Watering rates depended on pre-irrigation soil moisture and meteorological forecasts.

On average, for three years of research, the amount of potato water consumption was 255 mm on irrigated plots, and 194 mm on non-irrigated fields. The average daily water consumption of potatoes for three years was average 2.2 mm in irrigated areas and 1.7 mm in rainfed ones. The study of the potato structure development with introducing different rates of cattle manure showed that higher fertilizer rates resulted in larger above-ground part and higher yield of potato tubers (Fig. 1).

When examining the weight dynamics of potato tubers at different rates of manure, the following results were obtained (Fig. 2).

The study of the potato tuber growth showed its active increase with higher cattle manure rate of 120 t/ha both under rainfed and irrigation conditions (from 0.12 to 0.72 kg/plant and from 0.30 to 0.79 kg/plant, respectively). When fertilizers were not applied, there was a slower growth of tubers on irrigated plots (from 0.08 to 0.31 kg/plant) and rainfed fields (from 0.16 to 0.5 kg/plant).

The application of cattle manure had a strong influence on potato stems (Fig. 3).

Potato stems reached the highest height at full blossom. With lower turgor pressure in stems, plants from the state of growth went to withering. Plant height

Table 1. Chemical composition of organic fertilizers.

Type of organic fertilizer	Humidity, %	The contents in the air-dry matter			
		pH	Organic substance, %	Nitrogen, %	Phosphorus, %
Cattle manure	43.1	7.9	69.5	2.1	0.6



Fig. 1. Potato structure. Beginning of the top wilting. Non-irrigated areas.

varied from 27 to 42 cm. The maximum height was observed on the plot with manure applied at the rate of 120 t/ha (42 and 47 cm on the dryland and irrigated field correspondently).

Higher rates of fertilizers contributed to the larger aboveground part of the plants (from 0.13 to 0.23 kg/plant) (Table 2). The largest weight of the top was on the site with introduced cattle manure at the rates of 80 t/ha on the rainfed field and 120 t/ha on the irrigated land. The lowest top weight was on the control plot, having been watered and fertilized with cattle manure.

The analysis showed that the application of cattle manure increased biological yield from 14.1 to 24.6 t/ha on the dryland and from 20.2 to 31.1 t/ha on the

irrigated plot. The highest yield was obtained when applying 120 t/ha of manure (Fig. 4).

In potato production, the marketability of tubers is essential (Table 3).

When applying cattle manure under irrigation, the highest marketable value of tubers (76%) was obtained on the plot with a rate of 40 t/ha, under rainfed condition (marketable value 80%) on the plot with the rate of 100 t/ha.

Different rates of cattle manure had different effects on the quality of potato tubers. Starch is the most important carbohydrate. It determines the nutritional value of potatoes, as well as its caloric content and friability during cooking. It is the main dry matter in

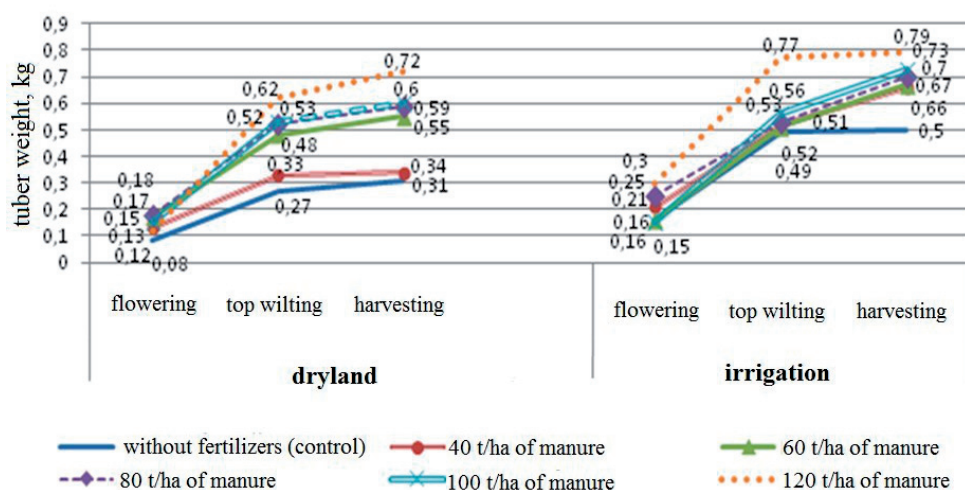


Fig. 2. Dynamics of potato tubers weight when applying different rates of cattle manure, kg/plant.

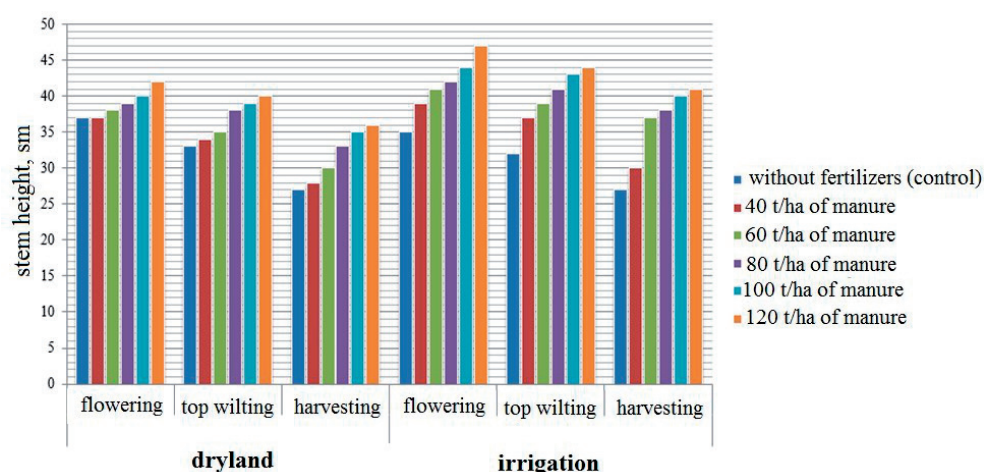


Fig. 3. Dynamics of potato stems height by vegetation phases on irrigated and rainfed areas with the use of cattle manure, cm.

Table 2. Weight dynamics of the above-ground part of potato by vegetation phases on irrigation and dryland, kg/plant.

Type and rate of organic fertilizers	Dryland			Irrigation		
	Full Blossom	Top wilting	Crop Harvesting	Full Blossom	Top wilting	Harvesting
Without fertilizers (control)	0.17	0.09	0.02	0.18	0.25	0.03
Manure 40 t/ha	0.11	0.14	0.04	0.13	0.17	0.05
Manure 60 t/ha	0.15	0.16	0.05	0.14	0.16	0.05
Manure 80 t/ha	0.17	0.21	0.10	0.18	0.26	0.10
Manure 100 t/ha	0.13	0.22	0.09	0.19	0.28	0.13
Manure 120 t/ha	0.14	0.20	0.07	0.22	0.33	0.15

potato tubers ranging from 8 to 29%. This indicator depends on the potato variety [24]. The analyses showed that starch content varied from 16.7% to 20.8% with applied cattle manure under dryland at 40 to 120 t/ha. For all the studied variants, the starch content was within optimal limits (Fig. 5).

Cattle manure has a high content of nitrogen being a hazard to human health at exceeding MAC values.

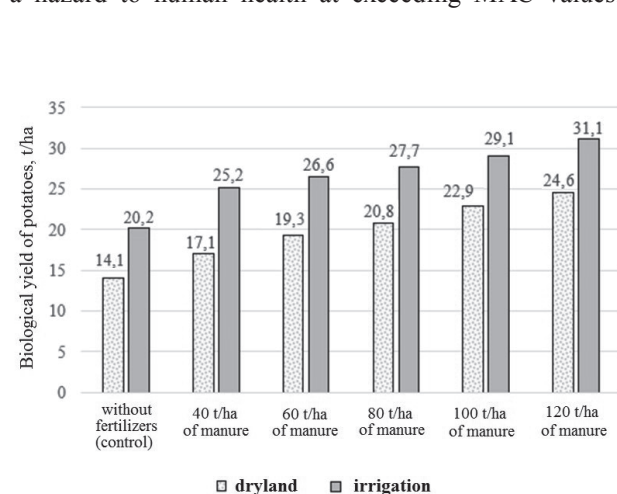


Fig. 4. Biological yield of potatoes depending on the rate of cattle manure, t/ha.

Laboratory tests showed that the nitrate content was 169.8 mg/kg on the unfertilized plot under rainfed. Under rainfed conditions, the nitrate content ranged from 186.67 (the rate of applied cattle manure being

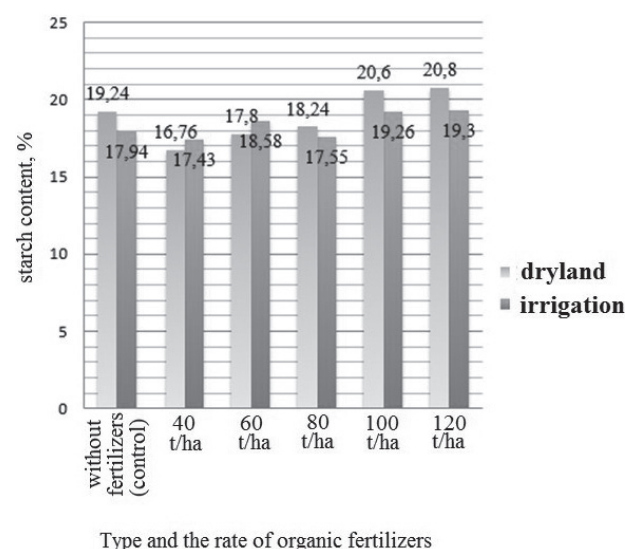


Fig. 5. Starch content in potato tubers depending on the rate of organic fertilizers and irrigation, %.

Table 3. Biological yield with marketable tuber yield according to the rate of the applied cattle manure.

Type and dose of organic fertilizers	Biological yield, t/ha	Marketable value, %	Marketable tuber yield, t/ha	Biological yield, t/ha	Marketable value, %	Marketable tuber yield, t/ha
	dryland			irrigation		
Without fertilizers (control)	14.05	42	5.90	20.16	69	13.91
Manure 40 t/ha	17.07	45	7.68	25.21	76	19.16
Manure 60 t/ha	19.29	52	10.03	26.57	74	19.66
Manure 80 t/ha	20.8	67	13.94	27.71	70	19.40
Manure 100 t/ha	22.9	80	18.32	29.1	64	18.62
Manure 120 t/ha	24.55	69	16.94	31.13	59	18.37
HCP ₀₅	0.98	-	-	1.33	-	-

40 t/ha) to 210.37 mg/kg (the rate of applied manure being 120 t/ha). On irrigated land, it varied from 174.26 (the rate of 40 t/ha) to 212.32 mg/kg (the rate of 120 t/ha). The received values of nitrate content in all the studied variants of experiments do not exceed the maximum permissible concentration (250 mg/kg) (Fig. 6).

With market relations between people, economic efficiency is an indispensable condition in any production. It determines the relevance of an issue under discussion and the feasibility of its implementation into the production process. To determine potato production efficiency at different rates of cattle manure and irrigation, production costs, namely spending on soil preparation, transportation, and processing of organic fertilizers, irrigation, etc., are calculated according to the process charts.

Taking into account the level of prices of agricultural products and the associated costs of labor-intensive production, the economic efficiency of potato production was analyzed according to the manure (type

and application rate) and the availability of irrigation for an area of 100 ha for average three years. Spending on potato growing. Cattle manure preparation to be applied to the soil, transporting organic fertilizers, and watering is calculated according to the process charts. Marketable tuber yield was adjusted to the technological losses, being taken equal to 20% at potato harvesting. The selling price of potatoes was 9.0 rubles/kg. As a result, the highest profit from 1 ha under rainfed was 22.7 thousand rubles received at applying 100 t/ha of cattle manure. It was 25.2 thousand rubles under irrigation with the manure rate of 80 t/ha.

Discussion

Potatoes respond well to fertilizer applications [25, 26], especially to those rich in nitrogen. Organic fertilizers have proved to increase potato production. Their application has a beneficial effect on yields and provides disposal of cattle manure stored in farmyards.

Overall, the conducted research demonstrates that higher rates of cattle manure used in potato growing as an organic fertilizer increases biological yields of the crop both under irrigation and dryland conditions. Applying 120 t/ha of manure does not worsen yield indicators and tuber quality. The given rate is not critical. Meanwhile, the marketable value data (Table 3) indicate that 100 t/ha under dryland and 40 t/ha under irrigation provide better results. This adjusts biological yields. Vegetative irrigation also contributed to higher biological yields of potatoes by average 1.3 times compared to dryland. Iranian scientists having applied cattle manure for potatoes (at the rate of 5, 10, 15, and 20 t/ha), got the highest yield of tubers (36.8 t/ha) with 20 t of animal manure. However, they combined organics with nitrogen at a rate of 150 kg/ha.

According to the results of domestic and foreign scientists, potato crop yields can reach 40-100 t/ha or more [27, 28]. There is no doubt that the role of fertilizers varies markedly depending on the biological fertility of the soil, its type, and its variety. When

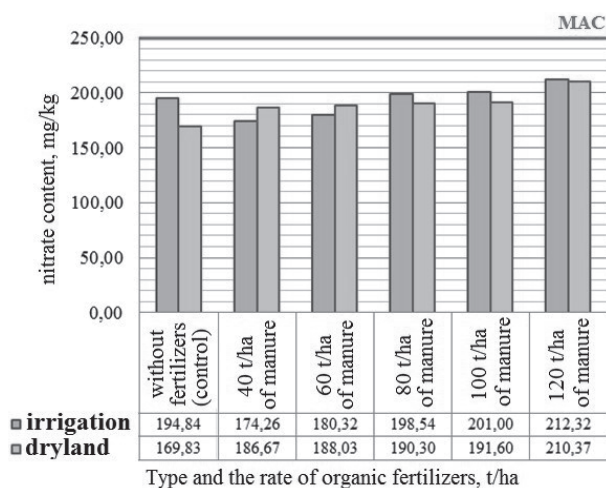


Fig. 6. Nitrate content in potato tubers depending on the rate of cattle manure and irrigation, mg/kg.

a crop gets the primary nutrients from the soil, it is less affected by adverse conditions [29].

According to Boligłowa and Gleń [30], applied manure brings many macroelements to the soil (525 kg NPK/ha-1). The researchers claim that animal manure provides a better condition of tubers after the harvest and during the storage compared to other field operations (stubble plowing, barley straw introduction, intercrop planting). Taheri et al. [31] also applied cattle manure (10 and 20 t/ha) for potatoes together with zink (50 kg/ha). Their results demonstrate that 10 t/ha of animal manure positively affects the plant dry matter. It increases due to better soil structure and aeration. The scientists claim that the study of 10 and 20 t/ha of cattle manure does not disclose all the potential of this fertilizer. When zink is applied with manure, there are more small tubers.

Scientists from Damatur State, Nigeria, concluded that the application of manure to meet the nutritional needs of crops would be an inevitable practice in the coming years. Their result on studying manure as a fertilizer to be introduced in the soil is as follows: the physical condition of the soil has improved, chemical and biological indicators have normalized, moisture intensity has increased. All this has led to an increase in crop yield [32].

Cattle manure introduced into the soil creates a favorable environment; plants better absorb nutrients, useful microorganisms that improve soil properties are developed [33, 34].

The rate of manure application, as well as the method of application, are crucial. In field experiments in Texas and Pennsylvania, the United States, the soil was oversaturated with phosphorous having entered from surface fertilizers with the runoff. Manure and phosphorus content in the soil was analyzed within 14-17 months. The manure weight was constantly decreasing, while the total amount of phosphorus was constant. As a result of precipitation, phosphorous was washed out [35].

According to Vasiliev [36], relatively low-cost organic fertilizers, being introduced into the soil, improve the physical, chemical, and mechanical properties of the soil, water, and air regimes, reduce the soil acidity, and its impact on plant growth and useful microorganisms. The results of the given paper claim that (dry) cattle manure is better to be applied during spring cultivation. Scientists from North Wisconsin draw attention to the type of fertilizer introduced into the soil. Liquid animal manure applied just before potato planting reduces the yields (production and quality of some varieties is lower) [37].

In recent years (2002-2016), the average potato yield in the Republic of Bashkortostan was 11.1 t/ha. In very dry 2010, the potato yield was only 4.1 t/ha, and in dry 2000 and 2012, 6.6 and 6.8 t/ha, respectively. In West Africa (Republic of Ghana), two-thirds of the territory is highly affected by drought during the growing season. Therefore, small farmers in these areas can expect a

loss [38]. Timely soil moisture improves its fertility. Regulation of the water regime under the requirements of plants expands the composition of valuable high-yielding crops for each zone.

New science-based solutions are required for further development of the potato industry to supply the population with indispensable food and industry with raw material. In the last five years, potato production in Bashkortostan has grown to 270 kg/person and consumption to 180 kg/person [39]. To meet the needs of the population of the country in potato, its production should be increased not only by expanding the area under the crop but also by increasing the yield.

Conclusions

The optimal rates of cattle manure for potatoes cultivated on leached chernozem in the southern forest-steppe of the Republic of Bashkortostan under irrigation and rainfed conditions were found. Potato growing at different rates of cattle manure application has been studied. There is an economic assessment of efficiency to apply different rates of manure.

It has been found that 100 t/ha of cattle manure brings in the highest marketable tuber yield (18.3 t/ha) without irrigation. On the irrigated field, the maximum yield (19.2 t/ha) was received with 40 t/ha of cattle manure. The highest content of dry matter in tubers (25.8 %) was at 40 t/ha under dryland. In conditions of irrigation, it was received with the application rate of 100 t/ha (24%). The highest starch content in potato tubers was at 120 t/ha of manure applied: 20.8% on dry land and 19.3% on irrigated land.

To get 15.0-19.6 t/ha yields of organic Nevskiy variety potatoes in conditions of leached chernozem of the southern forest-steppe of Bashkortostan, it is recommended:

1. Under dryland:
 - in spring, the soil is rotavated and fertilized with 100 t/ha cattle manure.
2. In irrigation conditions:
 - in spring, the soil is rotavated and fertilized with 80 t/ha cattle manure.
 - to ensure optimal soil moisture to perform 1-3 watering with irrigation rate 650-2400 m³/ha, depending on the degree of moisture in the growing season.

Conflict of Interest

The authors declare no conflict of interest.

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