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Original article

Utilization of poultry manure when cultivating potatoes in the southern steppe of the Republic of Bashkortostan

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ABSTRACT

The goal of the research is to determine the effect of pretreated poultry manure and irrigation on the yield and quality of potatoes (Solanum tuberosum) grown in fields located on the southern steppe of the Republic of Bashkortostan. Field experiments were repeated every three years. During vegetation, potato leaves and tubers were studied at the full blossom, leaves' decay, and potato harvest. The results showed that applying pretreated poultry manure at the rate of 120 t/ha favored higher tuber weight both on the rainfed and irrigated plots (from 0.23 to 0.82 kg/plant and from 0.24 to 1.02 kg/plant, respectively). On the rainfed and irrigated plots where poultry mature was not applied (control fields) the tubers' weight ranged from 0.08 to 0.31 kg/plant and from 0.16 to 0.50 kg/plant, respectively. Upon application of 40 t/ha of manure, under irrigation, the highest marketable value of tubers was 78%. On the rainfed plots the same value was 72% when applying poultry manure at a dose of 120 t/ha. Soil moisture monitoring showed that the potatoes did not get adequate water during the growing season. When the soil moisture on irrigated plots was 70% less than its minimum water capacity, potato plantings were watered.

1. Introduction

Potato (*Solanum tuberosum*, Latin) is a leading crop that responds well to organic fertilizers and irrigation. It is essential as a food crop and raw material for the food processing industry (Maggio et al., 2008; Lutaladio and Castaldi, 2009). It contains starch, an essential carbohydrate that determines the nutritional and energy value of the processed potato, making it more floury. Higher starch content in tubers provides the better nutritional status of the plant, increases its shelf life. Starch makes up the bulk of the tuber dry matter, varying from 8 to 29%, depending on the potato cultivar (Mushinsky et al., 2016).

The total cultivated area for potatoes worldwide is more than 24.0 million hectares, with a gross harvest of 487 million tons. Today Russia is one of the largest potato producers in the world (more than 29.6 million tons) after China (99.2 million tons) and India (48.6 million tons) (FAO, 2017).

Farms in the Republic of Bashkortostan grow potatoes on 90 thousand hectares, which amounts to about 4% of the Russian Federation's territory. In the Republic of Bashkortostan, agricultural enterprises, associations, and peasant farmers cultivate potatoes on 3.3–3.5 thousand hectares, which is about 4% of the total potato growing area in the republic. About 590 thousands of private farms cultivate the remaining 96%.

When growing row crops, particularly potatoes, the humus content in the soil decreases due to the lower intake of plant residues. There is evidence of the humus level decline after potato harvesting compared to its amount in the spring (Ulyanova et al., 2020). Organic fertilizers are quicker absorbed by plants because they contain not only sources of carbon and nitrogen but also complexes of other microelements of a more available for plants form. The amount of nutrients in poultry manure is almost equal to the amount of nutrients in mineral fertilizers. The only disadvantage of using poultry manure is the instability of the nitrogen fraction relative to the fraction of carbon, which can lead to soil leaching. In view of this, it is critical to apply the right quantity of it (Thomas et al., 2019). Poultry manure improves the soil's humus content and nutrient status (Gubeidullin et al., 2014). With a single application of 30 t/ha, the soil receives 48 kg of nitrogen, 45 kg of phosphorus, and 24 kg of potassium (Bezzubtsev and Schmidt, 2013).

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Scientific literature provides information on the application of different amounts of poultry manure on different crops.

Taking into account the natural soil humidity in the Republic of Bashkortostan, the fertilizer guide recommends applying poultry manure at a rate of 5–7 t/ha for cereals and 10–12 t/ha for vegetable and industrial crops (Komissarov and Shafeeva, 2017). Currently, there is an accumulation of poultry manure on production sites. The manure is used irregularly due to the absence of technologies for its application in plant growing.

The issue of poultry manure utilization is topical worldwide. Thus, the rapidly growing poultry sector in India faced the challenge of bird dropping disposal. They found a solution by applying it to the fields as a fertilizer. As a result, the soil quality has been improved (Ezhilvalavan et al., 2016).

The poultry farmers found the most straightforward, cheapest, and most biohazardous way to dispose of poultry manure. They transfer and store poultry manure in the fields, in areas close to horticultural farms. However, dumping a large amount of poultry farm waste on the limited area is detrimental to the environment because poultry manure, in its raw form without pretreatment, is a caustic agent that destroys soil microflora and reduces soil fertility. It contaminates plants with potentially harmful microorganisms and heavy metals (Xiong et al., 2010).

Chinese scholars claim that poultry manure requires chemical treatment (Xu et al., 2019).

Mushtaq et al. (2019) describes the way owners of poultry farms in Lahore, the Islamic Republic of Pakistan, process the poultry droppings. They deal with large amounts of poultry manure daily. They have no means to store, recycle, and process it. Therefore, the manure is managed by composting and humification.

Potato producers worldwide seek ways to rationally use poultry manure to increase organic matter in the soil and improve soil quality in potato fields. The same opinion is shared in Western Kazakhstan (Braun et al., 2015). The authors analyzed poultry manure applications ranging from 2.8 t/ha to 9.9 t/ha. The innovation they studied demonstrated soil improvement and the production of higher quality potatoes.

Application of poultry manure, amounting to 40–80 t/ha, in the Republic of Bashkortostan's southern steppe zone, contributes to the increased organic matter in the soil and improves its structure and nutrient supply (Gabbasova et al., 2016).

Scientists worldwide have invented many ways to manage poultry manure by recycling, burning, vacuum drying, and turning it into a compound fertilizer with mineral additives (Keyu, 1998; Dalólio et al., 2017).

The application of mineral fertilizers has a significant impact on the environment.

Different toxic impurities, unsatisfactory quality of mineral fertilizers, as well as irregularities in their preparation and application, can have serious negative consequences (Abitova, 2010). It is impossible to ignore the high cost of mineral fertilizers (Gamajunova and Iskakova, 2015). The cost of mineral fertilizers' active nutrients is as follows: 20,304 rubles/t for nitrogen, phosphorus, and potassium, and 28,067 rubles/t for nitrogen, phosphorus, potassium, and sulfur.

Plant growing without fertilizer application leads to higher soil acidity, lower moisture saturation, and drying. Soil fertility deteriorates; nutrients removed from the soil with the harvest are not compensated. Introducing mineral fertilizers provokes a definite increase in acidity. All these problems can be solved by applying organic fertilizers (Khaibullin et al., 2018). They can be used in combination with inorganic substances. Thus, a group of scientists examined the effect of different rates of farmyard, poultry manure, and vermicompost applied together with inorganic fertilizers on the growth and productivity of rainfed potato. Their results showed higher tuber yields when poultry manure was combined with inorganic fertilizers (Kumar et al., 2013).

With a science-based approach, the application of poultry manure will become a valuable organic fertilizer and an additional source of income.

Every climatic zone with its landscape, vegetation, and soil variety requires a specific amount of organic fertilizers and soil moistening. Among the main types of soils, researchers distinguish loamy, middle loamy, sandy-gravel, and leached chernozems, the predominant soil type on farms (Abakumov et al., 2020). In recent years (2002–2016), the Republic of Bashkortostan's average potato yield was 11.1 t/ha. In 2010, an arid year, the potato yield was only 4.1 t/ha, as well as in 2000 and 2012, which were also arid years, the yields were – 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 losses (Atampugre et al., 2019).

Timely water supply to the fields improves soil fertility. Regulation of the water regime under plant requirements has a transformative effect on the soil, expands the content of valuable high-yielding crops for each zone (Ishbulatov and Khasanova, 2011).

In the Moscow region, potato cultivation on sod-podzolic sandy loam soils accompanied by irrigation using sprinkler machines "Fregat", led to consistently high yield (29.7 t/ha, for comparison – in the conditions of rainfed agriculture – 15.3 t/ha), and the additional costs for irrigation (15–19 thousand rubles/ha) were fully recovered. There were 5–8 irrigations during the growing season with an irrigation rate of 950–1200 m3/ha (Priamov et al., 2014).

The application of pretreated poultry manure as organic fertilizer in potato fields has already been studied. However, the effect of potato growing with the poultry manure application on the southern steppe of the Republic of Bashkortostan has been poorly studied.

Therefore, this study aims to highlight the effect of poultry (chicken) manure and irrigation on the yield and quality of potato tubers grown on the leached black soils of the southern steppe of the Republic of Bashkortostan.

2. Material and methods

2.1. Field experiment

For three years, field experiments were conducted to study potato responses to different poultry manure amounts on the southern steppe of the Republic of Bashkortostan under irrigation and rainfed schemes. The experiment was performed on the experimental field of the water-balance station of the state-owned company Bashmeliovodkhoz, which is under the department of the Bashkir State Agrarian University for field internship. Poultry manure was applied at different doses in fields during spring cultivation. Then the fields were planted with potatoes, which were cultivated with irrigation.

The experimental plot is located at 54.84° N, 55.75° W.

The soil was shallow, with loamy medium-humic slightly eroded leached chernozem with alluvial-diluvial limestone clay (Luvic Chernic Phaeozem (Loamic). The arable layer contained 6.1% of humus, 154 mg/kg of alkaline hydrolyzed nitrogen, 4.4 mg/kg of labile phosphorus, and 75 mg/kg of exchangeable potassium. The soil medium reaction was subacid (pH = 5.0). The soil for agrochemical analysis was taken from the arable horizon (0–30 cm). The composite soil sample was collected from 5 points using the envelope method. The factorial experiment in randomized block design involved two factors with three replications:

the rate of poultry manure (40, 60, 80, 100, and 120 t/ha) and the type of soil moistening (natural and artificial irrigation). The total area of the experimental plot was 700 m2 with 36 registration plots. Potato yields were determined for registration plots with an area of 16 m2 each.

Planting density was 37.5 thousand/ha; row spacing is 70 cm, tuber weight is 60–70 g, tuber-planting depth was 6–8 cm.

During the field experiment, the authors determined the effect of poultry manure on the yield and quality of potato tubers.

Mid-season recognized Nevsky potato variety was tested.

The potato was grown on the fallow after perennial grasses.

The experiment included phenological observations:

- visual registration of the vegetation: timing, plant growth, and development stages; the number of stems per plant and their height were taken into account.
- sampling to analyze the potato plant and tubers in the phase of full blossom, potato top falling over (plant senescence), and harvesting. Five plants were dug up in random from every registration plot. The structure of the underground part of plants was studied by weighing commercial and non-commodity tubers on electronic scales CAS MWP-150 (CAS Corporation, South Korea), followed by counting their number. The marketable value of tubers was defined with the size of transverse diameter: 50 mm or more – marketable, other – non-marketable fraction. The structural study of the aboveground part included: weighing the potato vine, counting the number of stems, and measuring their height (using boards with markings).

Soil moisture determination on the top layer with a depth between 0 and 50 cm (thermostatic-weight method, layer by layer every 10 cm: at the time of planting and harvesting, and every ten days during the growing season).

Irrigation was conducted when the soil moisture at a depth of 0–50 cm dropped to 70% of the available range of moisture.

Potato productivity was estimated by the continuous method (by harvesting and weighting of the total yield) for each registration plot.

Laboratory analysis of potato tubers was conducted by studying the following indicators – starch and nitrates (using the standard analytical laboratory protocol of the Bashkir State Agrarian University). These indicators were determined on tubers of average weight for every experiment.

Chemical indicators of manure and soil:

- pH (determined by the CINAO method, Russian State Standard GOST 26483–85);
- labile potassium and labile phosphorus (determined using Chirikov's method modified by CINAO; GOST 26204–91);
- humidity and dry residue were determined using the GOST 26713–85 protocol;

organic matter content (total humus) – determined by the Tyurin method, modified by CINAO (1937) (GOST 26213–91).

Statistical analysis of the data was done through variance, correlation, and regression analysis using Microsoft Excel.

Economic efficiency was calculated according to technological maps for potato cultivation – based on the potato production costs and selling price.

2.2. Treatment to suppress pathogenic microflora occurring in the poultry manure

Pathogenic microflora of poultry manure was pretreated with "Baikal M." "Baikal M" is the trade name for a microbiological fertilizer designed to improve soil fertility, regardless of its structure. It contains lactic acid bacteria, nitrogen-fixing bacteria, photosynthetic bacteria, saccharomycetes (microscopic yeast), actinomycetes (radiant fungi), and the by-products produced by all these microorganisms. By pretreating poultry manure with this agent (dilution 1:100, at 25 °C, 1 l per 4 kg of manure), the authors sought to shift microflora composition to less pathogenic.

Soil conditions were mainly favorable for potato growing by applying additional organic or mineral fertilizers, and irrigation was required.

During the experiments, the meteorological conditions during the potato-growing season were characterized by extremely uneven natural moisture and fluctuations in the average daily atmospheric temperatures. There were drought and heavy rainfalls during the growing season. The vegetation during 2014 was arid, with a Selyaninov's hydrothermal coefficient (HTC) = 0.69, 2015 – dry (HTC = 0.77), 2016 – very dry (HTC = 0.56). Meteorological conditions show that potato growing requires irrigation.

Annually, at the end of September, autumn plowing was performed to prepare the soil. In spring, when the soil reached physical maturity, it was cultivated and harrowed.

Pretreated organic fertilizer was applied by hand and soil-incorporated with a cutter before potato planting.

Tubers were also pretreated with insectofungicide "Prestige" (manufactured by the Bayer Company, Germany) to protect against pests and diseases.

In 2014 and 2015, the potatoes were planted on May 29–31 and harvested on September 2–6. In 2016 due to early spring, the potatoes were planted on May 7. Accordingly, the subsequent phenological phases took place earlier than the average time. The three-year average growing period for the potatoes was 115 days (from planting to harvesting).

Regular observations of soil moisture in the 0–50 cm soil depth were recorded to find optimal irrigation rates.

For optimizing soil moisture, irrigation was done using – a portable sprinkler system of a 4-meter wetted radius and an application rate of 0.2 mm per minute.

3. Results

3.1. Soil moisture in the experimental plots

Observations showed that there was soil moisture deficiency in 2014 under the rainfed scheme from the moment of potato planting until seedling emergence (June 17), and plants began to wither on 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, there was a shortage of soil moisture 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 harvesting (Fig. 1).

The moisture content of the calculated soil layer in irrigated areas was maintained in the range of 70 to 100% of the low-moisture content limit.

Thus, the irrigated plot had better soil moisture for potato growth (Fig. 2).

Irrigation and watering rates were directly dependent on the prevailing meteorological conditions during the growing season. The irrigation rate ranged between 643 m^3 and 2350 m^3/ha.

Watering rates depended on pre-irrigation soil moisture and meteorological forecasts.

On average, for three years of research, the total water use of potatoes was 255 mm on the irrigated plots and 194 mm under rainfed conditions. The average daily water use of potatoes for

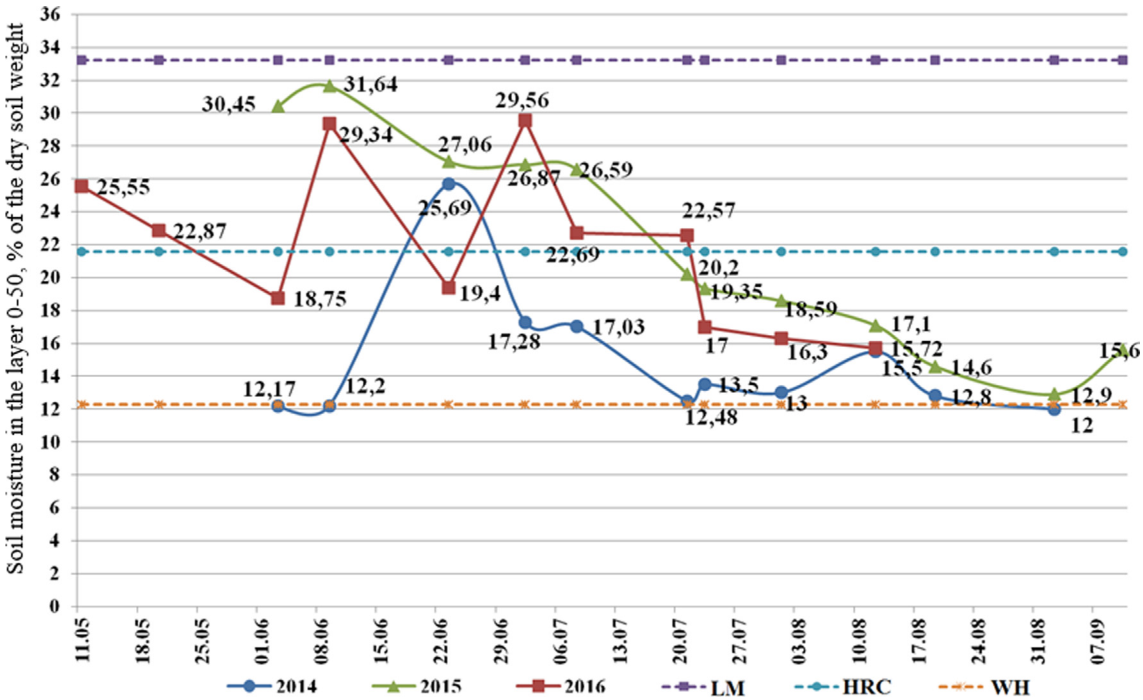

Fig. 1. Dynamics of soil moisture on non-irrigated plots for potato growth during 2014–2016 Key: LM – lowest moisture content limit, HRC- humid rupture of capillaries, WH-wilting humidity.

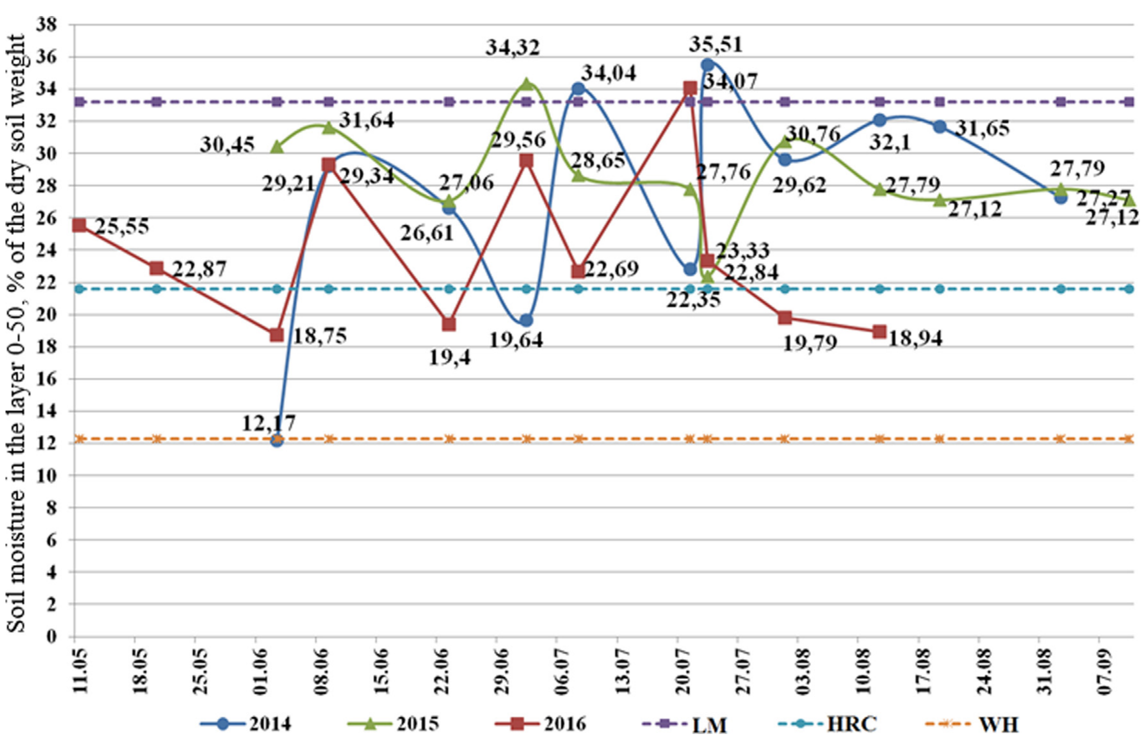

Fig. 2. Dynamics of soil moisture on irrigated plots for potato growth during 2014–2016.

Table 1
Chemical composition of used organic fertilizers.

Humidity, %	The contents in the air-dry matter			
	pH	organic substance, %	nitrogen, %	phosphorus %
59.4	7.8	62.7	2.9	0.3

three years was 2.2 mm in irrigated areas and 1.7 mm in rainfed areas.

Chemical composition of organic fertilizers.

Table 1 shows the poultry manure chemical composition (acidity and the content of water and substances).

As can be noticed, the pH of hen manure is weak-alkaline. The C/N ratio is 21.6/1.

3.2. The study of the potato structure development

The study of plant growth with different amounts of fertilizer showed that in the absence of irrigation, raising the concentration of poultry manure led to an increase in potato weight, mainly due to enhanced tuber size (Fig. 3).

The study of the potato tuber weight dynamics upon applying different amounts of poultry manure showed the following (Fig. 4).

Tuber weight increased intensively with a higher rate of manure application (120 t/ha) both under rainfed and irrigation conditions (from 0.23 to 0.82 kg/plant and from 0.24 to 1.02 kg/plant, respectively).

Non-fertilized tuber growth was slower on both the rainfed and irrigated plots (from 0.08 to 0.31 kg/plant and from 0.16 to 0.5 kg/plant).

There was a significant difference in tuber weight for all the samples under rainfed conditions at harvest compared to those with a manure application rate of 100 and 120 t/ha.

Under irrigation conditions, all the collected samples had different weights of tubers as well. Samples with a manure application rate of 60, 80, and 100 t/ha in the wilting phase and 40, 60, 80 t/ha in the harvesting phase were the exception.

The height and weight of the aerial parts of the potato plants were studied to determine their dependence on the application of a different amount of poultry manure.

The poultry manure application had a strong influence on the height of the stems (Fig. 5).

The potato stems grew most intensively during the full blossom stage. The turgor pressure had started to decline; the plants changed from the state of growth to aging and, lastly, decay. Plant height varied from 27 to 50 cm. Plants grew higher in the areas under rainfed and irrigation conditions where poultry manure was applied with 100 – 120 t/ha (44 and 45 cm) and 120 t/ha (50 cm), respectively.

Higher poultry manure amounts contributed to the larger aerial parts of the plants (from 0.13 to 0.23 kg/plant) (Table 2). The highest weight of leaves was both on irrigated and rainfed plots with applied manure (80 t/ha).

Records of the biological productivity indicated that poultry manure's application contributed to higher yield from 14.1 to 31.7 t/ha under rainfed conditions and from 20.2 to 33.9 t/ha under irrigation conditions.

Higher amounts of manure applied under rainfed conditions result in different biological productivity of potatoes (at the least significant difference (hereinafter LSD) = 1.20). There was a significant difference between the biological productivity of potatoes in the control field and the plot with applied poultry manure at the rate of 40 t/ha (HCP = 1.53). In other plots, the biological productivity of potatoes did not differ significantly (Fig. 6).

Experiments proved that the biological productivity of potatoes increases with a higher amount of poultry manure and reaches 31.7 t/ha under rainfed and 33.9 t/ha under irrigation conditions.

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

At a dose of 40 t/ha under irrigation, the poultry manure application resulted in the highest marketable value. When poultry manure was applied at a dose of 120 t/h under the rainfed scheme, the marketable value was 72%.

The highest marketable tuber yield (24 t/ha) was achieved under irrigation on the plot with applied poultry manure of 40 t/ha. A higher yield of potatoes (23 t/ha) was realized on the rainfed plot with 120 t/ha of poultry manure applied.

Different amounts of poultry manure had different effects on the quality of potato tubers.

The analysis showed that starch content ranged from 12.9% (irrigated area with 80 t/ha poultry manure applied) to 19.2% in the rainfed area without fertilizers.

The starch content in all the studied variants was within the optimal range (12–28%) (Fig. 7).

The applied poultry manure had a high nitrogen content, which can worsen the quality of tubers and poses a danger to human health.

Laboratory tests showed that the nitrate content was 169.80 mg/kg on the unfertilized plot under rainfed conditions. The nitrate content ranged from 171.80 (the amount of 40 t/ha) to 215.90 mg/kg (the amount of 120 t/ha) when poultry manure

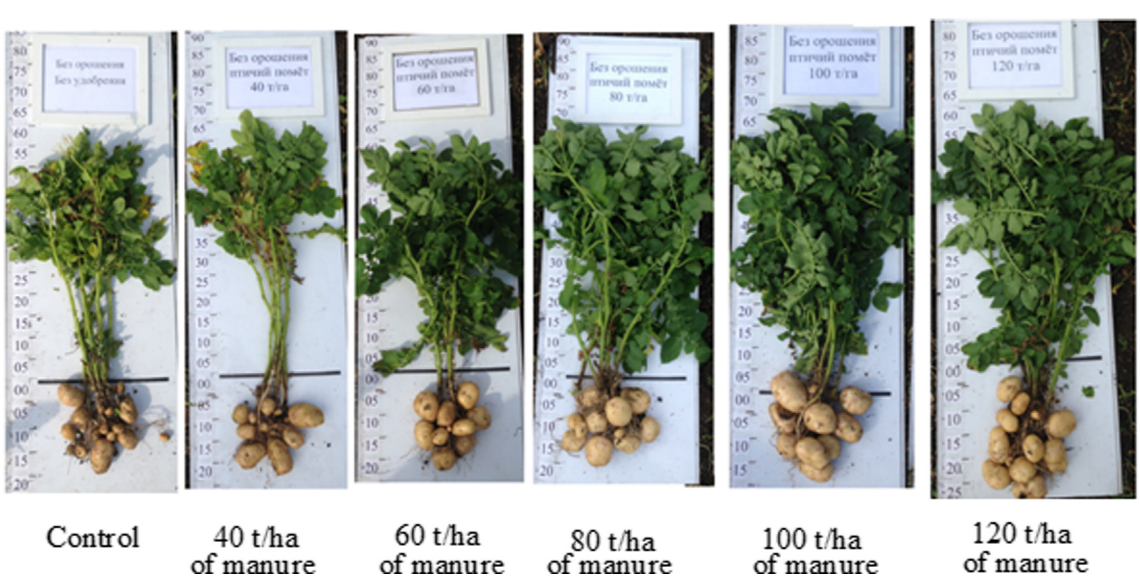

Fig. 3. Potato plant structure. Wilting phase. Rainfed plot.

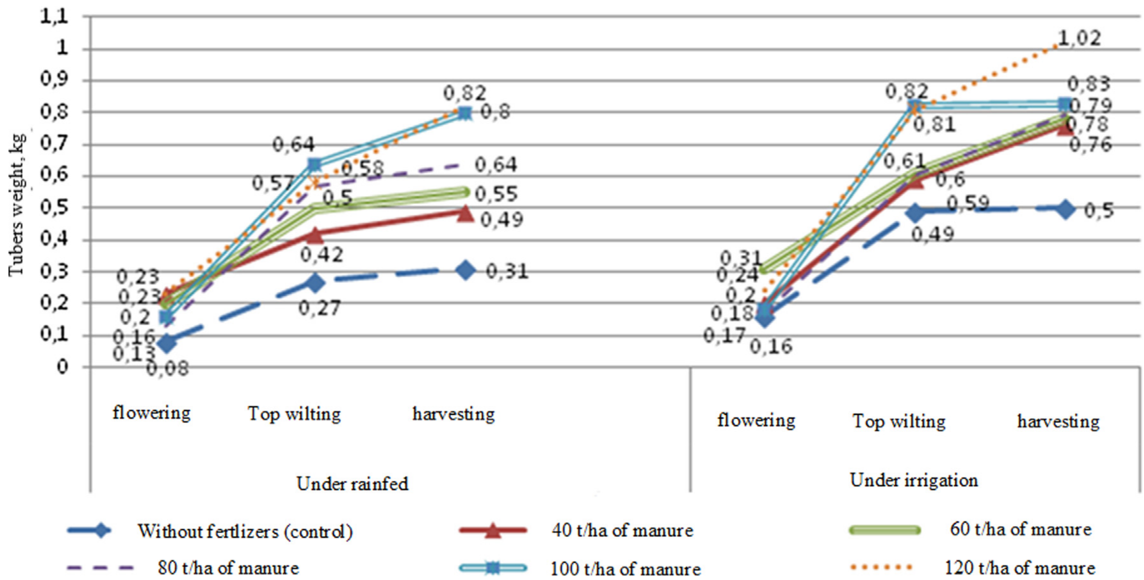

Fig. 4. Dynamics of potato tubers weight with different application rates of poultry manure, kg/plant (average for 2014–2016).

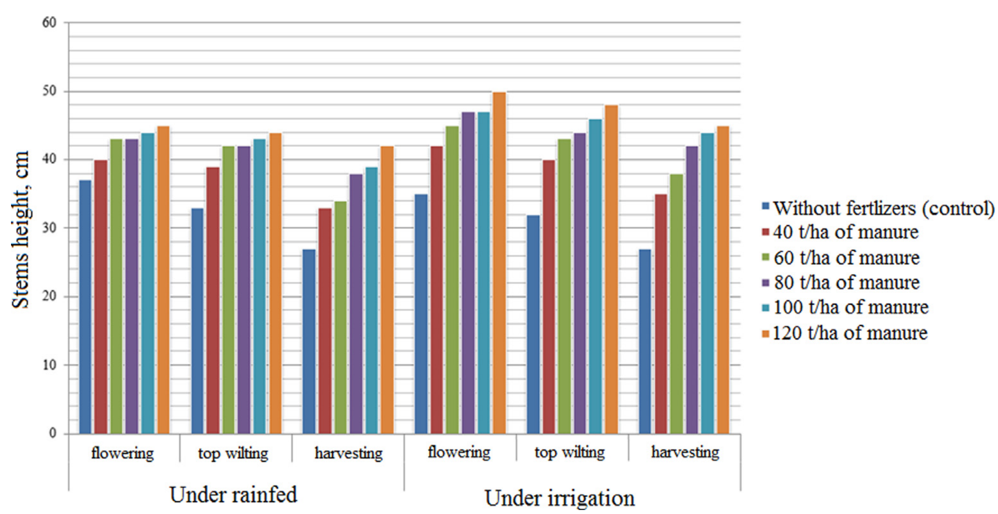

Fig. 5. Dynamics of the potato stem height for various growth phases under irrigation and rainfed conditions with application of poultry manure, cm (average for 2014–2016).

Table 2
Weight dynamics of the aerial part of plants in full blossom, upon wilting and at harvest under irrigation and rainfed conditions, kg/plant (average for 2014–2016).

Availability of organic fertilizers in the soil	Rainfed			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
40 t/ha	0.19	0.21	0.09	0.26	0.27	0.12
60 t/ha	0.20	0.22	0.13	0.27	0.30	0.14
80 t/ha	0.23	0.43	0.13	0.28	0.40	0.17
100 t/ha	0.22	0.24	0.12	0.25	0.35	0.15
120 t/ha	0.21	0.22	0.11	0.22	0.28	0.12

was introduced to the rainfed plots. On irrigated land, it varied from 197.89 (the amount of 40 t/ha) to 232.98 mg/kg (the amount of 120 t/ha). The obtained values of nitrate content in all the studied variables did not exceed the maximum concentration limit (250 mg/kg) (Fig. 8).

With the current market conditions, it is vital to determine the economic efficiency of any production.

To evaluate the economic efficiency of potato production, the authors calculated the production costs according to the technological design: costs of soil preparation, transportation, and processing of organic fertilizers, irrigation, etcetera.

The research considers the current prices for agricultural products, costs associated with labor intensity according to the technological design, poultry manure preparation (processing) for

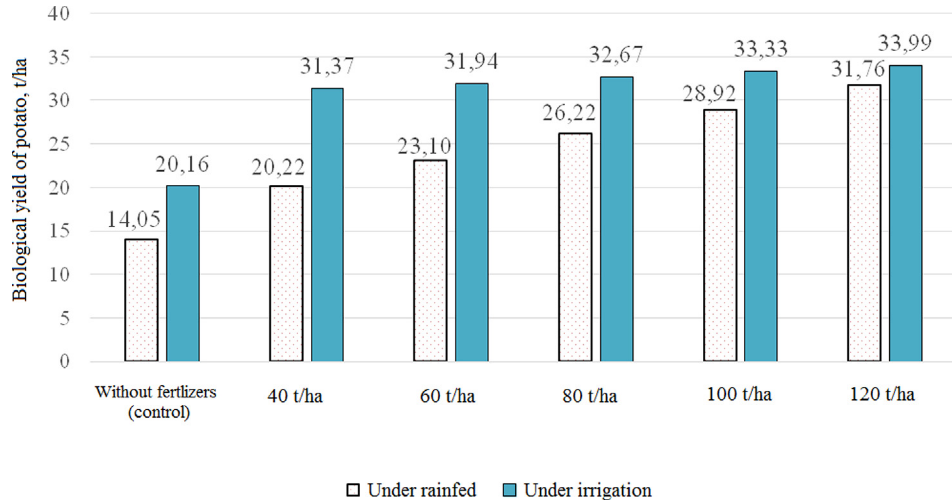

Fig. 6. Biological yield of potatoes depending on the rate of poultry manure, t/ha.

Table 3
Biological productivity and marketable tuber yield depending on the amount of poultry manure (average for 2014–2016).

Availability of organic fertilizers in the soil	Biological productivity, t/ha	Marke-table value, %	Marketable tuber yield, t/ha	Biological productivity, t/ha	Marke-table value, %	Marketable tuber yield, t/ha
	rainfed conditions			irrigation conditions		
Without fertilizers (control)	14.05	42	5.90	20.16	69	13.91
40 t/ha	20.22	48	9.71	31.37	78	24.47
60 t/ha	23.10	68	15.71	31.94	76	24.27
80 t/ha	26.22	71	18.62	32.67	74	24.18
100 t/ha	28.92	71	20.53	33.33	73	24.33
120 t/ha	31.76	72	22.87	33.99	71	24.13
HCP_{05}	*1.20*	–	–	*1.53*	–	–

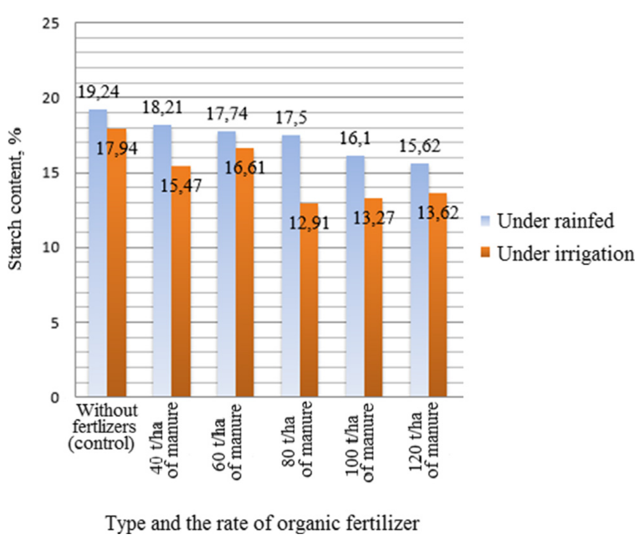

Fig. 7. Starch content in potato tubers depending on the amount of organic fertilizer and irrigation, in % (average for 2014–2016).

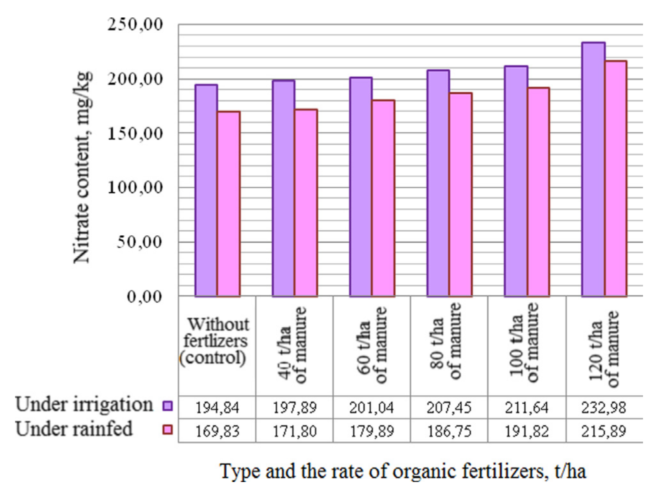

Fig. 8. Nitrate content in potato tubers depending on the amount of organic fertilizer and irrigation, mg/kg (average for 2014–2016).

application in the soil, the transportation of organic fertilizers, and irrigation. The economic efficiency of potato production depends on the type and application of organic fertilizers and irrigation treatments.

The calculation considered an average of 3 years for an area of 100 ha.

Marketable tuber yield was adjusted to the technological losses, which amounted to 20% at harvesting.

The selling price of potatoes was 9.0 rubles/kg.

The highest profit in the areas under irrigation was achieved by applying poultry manure amounting to 40 t/ha (55.1 thousand rubles/ha), and under rainfed conditions, it was at the poultry manure rate of 120 t/ha (30.0 thousand rubles/ha). The results are not shown.

Table 4
Results of two-factor variance analysis.

Source of variation	Sum of squares	Degree of freedom	Dispersion	F actual	F table, 0.95
Factor A (Poultry manure)	939.19	5	187.84	9.51	2.70
Factor B (humidification)	384.09	1	384.09	19.44	4.30
AB interaction	74.82	5	14.96	0.76	4.60

3.3. Statistical analysis

To test the hypotheses on the factors (fertilizers and irrigation) that influence potato yield, the authors performed a two-factor variance analysis. Poultry manure was factor A (6 values), and the humidification condition was factor B (2 values).

Every combination of variables had three observations. They are presented in Table 4.

Table 4 shows that F actual for factor A = 9.51. It is more than the table value of the Fisher criterion (F_{table} = 2.70). Therefore, the data contradict the H_0 hypothesis (for all types of A_i, there is no difference between the average yield result of potatoes), and it should be assumed that factor A affects the average yield result.

Factor B levels should also be considered to have an impact on the average yield result. F actual for the interaction of factors A and B is less than the table value of the criterion. Thus, the data do not contradict the H_0 hypothesis (factor A and factor B have no interaction effect on the yield result). The levels of factors A and B are supposed not to affect the average yield result.

To assess the homogeneity (absence of omissions) of test results, the authors use the Cochran Criterion. The Cochran Criterion = 0.142 (results not shown), with the critical value for the Cochran Criterion = 0.3924. Since $0.142 \leq 0.3924$, the authors conclude that the groups' variances were equal (the hypothesis of variance equality is accepted. The experiments are considered reproducible, and the estimates of variances were homogeneous).

4. Discussion

Relatively cheap organic fertilizers improve the physical, chemical, and mechanical properties of the soil, water, and air quality; reduce the harmful effects of acidic soils on plant development and microorganism activity (Vasiliev, 2014). The authors suggest applying poultry manure with irrigation. The conducted experiments showed that poultry manure and proper watering contributed to higher potato yields. As a result, the population's need for the product is met, and the challenge of bird droppings disposal is solved.

The current study shows that the application of poultry manure as organic fertilizer (even at the amount of 120 t/ha), pretreated with "Baikal M," does not worsen the yield and quality of potato tubers. Simultaneously, it was assumed that the annual application of a large amount of such fertilizer could lead to deterioration of the agrochemical properties of the soil and the state of plants. Yaubasarov (2016) studied the territory nearby the fields under the authors' experiment. The authors analyzed the effect of poultry manure as a fertilizer (up to 120 t/ha) on the soil: the content of ammonium nitrogen soon after the manure introduction increased tenfold (494.1 mg/kg with manure amounting to 120 t/ha.) compared to the control version (5.8 mg/kg). By the end of the growing season, the ammonium nitrogen content decreased (23.1 mg/kg).

The nitrogen stability was determined by the content of its alkaline hydrolyzable form, being the closest reserve for plant nitrogen requirements.

It consistently rose with higher poultry manure application rates, from 150 (on the control plot) to 1000 mg/kg of soil (120 t/ha of manure). Overall, its dynamics corresponded to changes in the content of ammonium nitrogen.

The effect of poultry manure on potatoes was studied on a private farm close to the faculty of agriculture of the University "Al-Qasim Green University," Babylon, Iraq. Scientists combined manure with dry yeast extract. According to the researchers, the higher amount of poultry manure from 1.5 t/ha to 3 t/ha combined with 200 g/l of the dry extract resulted in the larger tubers and maximum commercial yields. There was a maximum percentage of dry matter and starch at the interaction of 1.5 t/ha of poultry manure with 8 g/l of dry yeast.

The best response was recorded using 3 t/ha of poultry manure combined with 200 g/l of dry yeast extract (Manea et al., 2019).

Indisputably, irrigation increases potato yields. Each natural and climatic zone has its own soil moistening needs. When conducting irrigation, it is crucial to maintain a balance between the watering and fertilizer application rates (Hegney and McPharlin, 2000, Khosravifar et al., 2020). The authors found that 1–3 irrigations during the growing season at an irrigation rate of 650–2400 m3/ha, depending on the moisture content provides optimal soil moisture.

The conducted studies have proved that poultry manure applied at the recommended rates increases potato productivity without compromising the tuber quality. In arid climates, irrigation neutralizes the effects of drought and guarantees higher yields.

5. Conclusions

The optimal amount of poultry manure that can be applied for potatoes cultivated on leached chernozem in the southern steppe of the Republic of Bashkortostan under irrigation and rainfed was determined. Potato growth, with the application of different amounts of poultry manure, was studied. There was an economic efficiency assessment of the introduction of different poultry manure and irrigation amounts.

It was found that 120 t/ha of organic fertilizer in potato growing provides the highest marketable tuber yield under rainfed conditions (22.87 t/ha). The highest marketable tuber yield (24.47 t/ha) was obtained in the irrigated area upon the poultry manure's application, amounting to 40 t/ha. The highest dry matter content in tubers was found in potatoes cultivated under rainfed conditions with 40 t/ha (26.88%) and irrigated areas without fertilizer application (24.38%). The highest starch content in potato tubers was realized when 100 t/ha of manure were applied: 20.6% under rainfed and 19.26% under irrigation.

To get 15.0–19.6 t/ha of Nevsky potato variety on leached chernozem in the southern steppe of the Republic of Bashkortostan, it is recommended:

1. Under rainfed conditions:
   - to apply 120 t/ha of poultry manure after the primary tillage (autumn) or spring rototilling.
2. Under irrigation conditions:

- to apply 40 t/ha of poultry manure after the primary tillage (autumn) or spring rototilling.
- to irrigate 1–3 times, with an irrigation rate of 650–2400 m^3/ha, depending on the degree of moisture during the growing season to ensure optimal soil moisture.

Future studies are proposed to concentrate upon the effect of applying poultry manure on the growth and development of other potato varieties and crops to establish the best option for its application.

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Data availability statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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