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Effects of Nitrogen Fertilizer Doses and Application Methods on the Yield of Syr Suluy Rice in the Kyzylorda Region

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ABSTRACT

The purpose of this research is to study the effect of doses of nitrogen fertilizers and methods of their application on the development and yield of rice plants of the Syr Suluy variety in the Kyzylorda region of the Republic of Kazakhstan. To study the effectiveness of methods for applying nitrogen fertilizers, options for their fractional application were provided at a rate of 120 kg/ha and 150 kg/ha. The ammonium nitrogen in the soil and the intensity of dry matter accumulation during the vegetation phases were analysed. The biometric parameters of rice plants were also studied, and the yield was estimated. Increasing the dose of nitrogen fertilizers led to increased accumulation of dry matter throughout the various phases of the rice vegetation. The improvement of the nitrogen regime of the soil contributed to an increase in yield by 3.29 t/ha or 85% compared to the variant without nitrogen fertilization. It was also found that with fractional application and 150 kg/ha of nitrogen fertilizer, the maximum economic profitability of 78.1% was achieved. The obtained data, which indicates the benefits of fractional application and increased doses of nitrogen fertilizers, can be used to optimize agricultural technology by refining fertilization schedules and dosages. This will aid in achieving the maximum possible and economically viable yield of rice of the Syr Suluy cultivar, ultimately improving farming practices in the Kyzylorda region of the Republic of Kazakhstan.

1. INTRODUCTION

Rice is one of the most important grain crops in the world [1]. At the same time, Asia accounts for 90% of its global production [2]. That is why it is urgent to create optimal conditions for growing this crop, which will ensure increased productivity and product quality. The yield of agricultural crops and the quality of products depends on how plants are provided with all the necessary mineral elements. Among the various nutrients, nitrogen has the greatest impact on the growth, development, and productivity of rice [3], it also plays an important role in maintaining and regulating its physiological functions [4-8]. Nitrogen deficiency during the growing season leads to a decrease in the synthesis of chlorophyll and proteins, which reduces the intensity of photosynthesis and the formation of dry matter [9]. It is important to consider that an excess of this nutrient leads to excessive tillering of plants, as a result, the light transmission of crops decreases, which increases their vegetation period. In addition, the number of pests and diseases is increasing [10-12]. Proper use of nitrogen fertilizers will not only increase the yield of rice, but also reduce their negative impact on the environment [13, 14].

Rice production in the Kyzylorda region of Kazakhstan is a significant agricultural activity that faces challenges and undergoes changes. The region, known for its sharply continental climate with hot dry summers and cold winters, has historically been a major hub for rice cultivation [15, 16]. Existing systems for fertilizing agricultural crops, as a rule, do not take into account environmental safety, since the required norms of mineral fertilizers are calculated according to the indicators of the removal of nutrients with the planned harvest, and the degree of use of active substances from fertilizers is quite low [17-19]. Most nitrogen fertilizers (>60%) used in rice cultivation technology are not completely absorbed by plants and remain in the soil in the form of ammonia, nitrates and nitrogen oxide, which leads to serious environmental problems [5, 20, 21]. That is why it is relevant to study the use of specific doses. mineral fertilizers to determine their environmental acceptability. A number of studies have shown that high yields of grain crops can be obtained with a moderate amount of fertilizers [22]. Therefore, the regulation of nitrogen doses is of particular importance for its effective consumption by plants and their yield. The need to develop sustainable agronomic practices calls for more efficient use of nitrogen fertilizers [23]. Modern methods of fertilizing crops with nitrogen have the potential to reduce environmental pollution [24]. Among them are the application of fertilizers in optimal doses necessary for plant growth, the use of new forms of fertilizers with a slow release of nitrogen, soil treatment with nitrification inhibitors, which significantly reduces nitrogen losses and increases yields [25-29]. Nutrient management principles can be seen as guidelines for improving traditional agronomic practices.

In the work, Tkach [30] shows options for selecting the optimal diet for rice. At the same time, a number of factors were taken into account: the ratio of nitrogen and phosphorus, growing conditions and crop variety, soil type, sowing dates, methods of fertilizing. This approach ensures the intensive development of the photosynthetic apparatus of plants and, as a result, the greatest increase in yield. Voronyuk et al. [31] confirm that the yield and quality of rice grains depend on the conditions of its cultivation and doses of mineral fertilizers. The experience of Biseneva [32] proves that nitrogen is better absorbed by rice plants with fractional application of mineral fertilizers throughout the growing season. Kuzdanova and Zhailaubaikovyna [33] show the effect of different doses of mineral fertilizers on the intensity of plant development and the activity of physiological processes, which ensures an increase in yield. Medeuova [34] confirms the dependence of rice productivity on nitrogen doses, since their amount affects the plant density in agrocenoses and the intensity of the formation of productive stems. The optimal dosage of mineral fertilizers provides more intensive development of plants and a high level of net productivity of photosynthesis, resulting in an increase in crop yield [35, 36]. The influence of the amount of nitrogen applied on the development of the root system of rice plants, their ground parts, photosynthetic apparatus and the quality of the products obtained was proved by Zhumataeva et al. [37].

Despite the fact that scientists around the world have been studying the loss of nitrogen and minimizing environmental pollution as a result of the use of mineral fertilizers for several decades, this issue is still relevant [38-40]. Until now, the issue of developing effective agrotechnical measures to obtain the maximum and economically viable yield of rice plants remains unresolved. In this regard, studies aimed at studying the influence of various factors, such as methods and doses of nitrogen fertilizers, on the yield and quality of rice grain for certain regions are of particular importance.

Despite extensive research on the use of nitrogen fertilizers in rice cultivation, there is still a significant research gap, particularly in region-specific studies that focus on optimizing nitrogen doses and application methods to maximize rice yield and quality while minimizing environmental pollution. This gap is especially pronounced for the Syr Suluy variety of rice in the Kyzylorda region of the Republic of Kazakhstan.

The purpose of the study is to investigate the effect of doses of nitrogen fertilizers and methods of their application on the growth and development of rice plants and on the yield of grain of the Syr Suluy variety in the Kyzylorda region of the Republic of Kazakhstan. The study will investigate the effect of different nitrogen fertilizer doses on the growth and development of Syr Suluy rice plants in the region. The aim of this research is to investigate the effects of various nitrogen fertilizer application methods on the yield and quality of Syr Suluy rice grain in the same region. The study aims to identify the most effective nitrogen fertilizer dose and application method to maximize the yield and quality of Syr Suluy rice grain while minimizing environmental pollution.

The study's novelty lies in its ambition to address the research gap by providing region-specific recommendations for optimizing nitrogen fertilizer doses and application methods tailored to the unique conditions of the Kyzylorda region. The goal is to contribute to the development of sustainable agronomic practices in the region.

The significance of this research cannot be overstated. The study's results could benefit rice farmers in the Kyzylorda region by helping them optimize their nitrogen fertilizer usage. This could lead to increased crop yields, improved grain quality, and reduced environmental pollution. The findings also hold promise for application in other rice-growing regions with similar environmental conditions, contributing to global food security and the advancement of sustainable agriculture.

2. MATERIALS AND METHODS

The research was carried out in 2019 year at the experimental site of the Kazakh Rice Research Institute named after Ibrai Zhakhayev. The experimental site is located in the Kyzylorda region of the Republic of Kazakhstan, which is characterized by a continental climate with hot summers and cold winters. During the experimental period (April to October 2022), the average monthly temperatures ranged from 13.5°C to 28.3°C, with the highest temperature recorded in July (38.9°C) and the lowest temperature in April (1.4°C). The average monthly relative humidity ranged from 35% to 55%, with the highest humidity recorded in April (65%) and the lowest in July (25%). In the surface layer of the soil (0-20 cm), the amount of humus composition and lo 0.9-1.1%, the amount of easily hydrolysable nitrogen, mobile phosphorus and exchangeable potassium was also determined using standard methods as described by Bray and Kurtz [41] for available phosphorus, ammonium acetate extraction for exchangeable potassium [42], and the Kjeldahl method for easily hydrolysable nitrogen [43]. The object of study is the zoned rice variety Syr Suluy. For the field experiment, simple superphosphate containing 19% active substance was used as a source of phosphorus. Phosphorus fertilizer was applied to the soil in the amount of 120 kg/ha in all variants before sowing rice. Carbamide containing 46% active substance served as a nitrogen fertilizer in the experiment. The studies were carried out with nitrogen doses of 120 kg/ha and 150 kg/ha. To study the effectiveness of methods for applying nitrogen fertilizers, options for their fractional application are provided. Dosing N_{120} carried out in two periods: before sowing rice and during the tillering phase of plants (N_{60}+N_{60}). A dose of N_{150} was applied before sowing the studied crop, in the tillering phase and in the phase of plant emergence (N_{60} + N_{60} + N_{30}). Field experience scheme:

1. Background – R_{120}.
2. Background + N_{120} before sowing.
3. Background + N_{150} before sowing.
4. Background + N_{120} (N_{60} before sowing + N_{60} tillering).
5. Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bubbling).

The area of the accounting area was 15 m^2. Variants are placed in a randomized manner. The experiment was repeated four times. Field studies were carried out according to generally accepted methods. To assess the ammonium nitrogen in the soil, depending on the doses and methods of applying nitrogen fertilizers, soil samples were taken at different periods: before sowing, during the tillering phase of rice, heading, and full ripeness of the grain. The content of ammonium nitrogen in the selected samples was determined by the phenol method. Determination of the accumulation of dry matter by rice plants in the phases of vegetation was determined using generally accepted methods. For biometric analysis, 15 plants were selected from each repetition of the field experiment. The following parameters were determined: plant height, number of plants before harvesting, number of productive stems, grain weight per plant, empty grain percentage, and weight of 1000 grains. The height of plants was measured in the phase of full ripeness of rice from the soil surface to the top of the longest panicle of the plant. To determine the void, five panicles were selected from each repetition and calculated as the ratio of the number of empty spikelets to the total number of spikelets on the panicle, multiplied by 100. The weight of 1000 grains were determined by randomly selecting a thousand grains from each experimental site and weighing them on an electronic scale. The number of productive and unproductive stems was determined by counting the stems with panicles into which at least one full grain was carried. The length of the panicle was determined from the basal node to the apex. The grain yield was taken into account from an area of 5 m^2 in the centre of each repetition in the phase of full ripeness of the plant grain. Panicles and grains were detached from the stem. The filled and empty panicles were separated, and their number was counted, the grains were weighed.

3. RESULTS

Rice cultivation has a significant impact on the nitrogen regime of the soil. The flooding of the rice field leads to changes in the mobile forms of nitrogen – there is a decrease in the content of the nitrate form and an increase in the ammonium form. Ammonium nitrogen remains the main source of nutrition for rice, which is replenished in rice fields mainly due to the intake of mineral and organic fertilizers, as well as nitrogen released during the decomposition of organic matter in the soil. In addition, some nitrogen may also come from the irrigation water, further affecting the overall nitrogen balance in the rice system. The study of the dynamics of ammonium nitrogen at various stages of the rice vegetation, depending on the methods and doses of nitrogen fertilizer application, contributes to the development of effective schemes for using the soil nitrogen fund while maintaining fertility and optimal use of fertilizers (Table 1).

Table 1. Dynamics of ammonium nitrogen in soil depending on doses and methods of applying nitrogen fertilizers when growing rice of the Syr Suluy variety, mg/kg

Experience Options	**Ammonia Nitrogen Content, mg/kg**			
	Before Seeding	**Rice Development Phase**		
		Tillering	**Wameting**	**Full Maturity**
Background-R_{120}	5.1	9.5	6.8	4.2
Background+N_{120} before sowing	5	31.7	15.6	5.7
Background + N_{150} before sowing	5.2	33.8	16.9	6
Background + N_{120} (N_{60} before sowing + N60 tillering)	5	36.3	18.3	6.6
Background + N_{150} (N_{60} before sowing + N_{60} tillering + $N3_0$ bubbling)	5.2	37.1	21.2	7.8

Source: Compiled by the authors.

Table 2. The influence of doses and methods of applying nitrogen fertilizers on the accumulation of dry matter in rice plants of the Syr Suluy variety

Experience Options	**Dry Matter Accumulation by Vegetative Phases, g/100 plants**		
	Tillering	**Wameting**	**Full Ripeness**
Background-R_{120}	49.5	260.3	487.3
Background + N_{120} before sowing	68.6	513.4	957.3
Background + N_{150} before sowing	71.2	531.0	978.8
Background + N_{120} (N_{60} before sowing + N_{60} tillering)	72.1	603.1	996.5
Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bubbling)	74.6	623.6	1074.1

Source: Compiled by the authors.

As can be seen from the data presented in Table 1, after the flooding of rice fields, an increase in the amount of exchangeable ammonium was noted. This phenomenon is due to several factors. On the one hand, there was a decrease in oxidized compounds in the soil. On the other hand, mineralization of organic nitrogen took place before the formation of mineral compounds. This process was carried out ammonifying microorganisms that decompose organic matter with the formation of ammonium nitrogen. The peculiarity of ammonium nitrogen is its good ability to be retained in the soil, and thus, it becomes an effective form of nutrition for rice plants. From the beginning of the tillering phase, active consumption of ammonium nitrogen by rice plants was observed. During this period, the content of NH_{4+} in the soil varied from 9.5 mg/kg to 37.1 mg/kg, depending on the method of applying nitrogen fertilizers. The highest rate of ammonium nitrogen was noted in the variant with a fractional application of a dose of N_{150}. In the variant with the same dose of fertilizer applied before sowing, the content of NH_{4+} in the soil turned out to be lower by 10% and amounted to 33.8 mg/kg. A similar pattern was noted at the stage of rice heading and in the phase of full ripeness: the optimal nitrogen supply for rice crops at these phenological stages was achieved by using fractional application of N_{150}.

The main function of the production process of plants is the formation of dry matter. This indicator is closely related to the metabolic activity of plants and productivity: the higher the metabolic activity of plants, the more they accumulate dry matter and the higher their yield. Table 2 shows the dynamics of dry matter accumulation by rice plants of the Syr Suluy variety in the phases of vegetation, depending on the doses and methods of applying nitrogen fertilizers.

According to Table 2, it can be seen that an increase in the dose of nitrogen fertilizers led to an increased accumulation of dry matter throughout all phases of the vegetation of rice plants. Thus, fractional application of doses of N_{120} and N_{150} provided an increase in dry matter in the tillering phase by 46% and 51%, respectively, compared with the Background-

R_{120} variant. In the variant with the introduction of the same doses of fertilizer just before sowing, improvements in this indicator were achieved by 39% and 44% for doses N_{120} and N_{150}, respectively. A similar pattern was observed during the entire growing season of rice plants of the variety Syr Suluy. A fractional application of a dose of N_{150} in the heading phase resulted in an increase in dry matter by 40% and 17% compared to the Background-R_{120} and Background + N_{150} variants before sowing. In the phase of full ripeness, the highest dry matter content of 1074.1 g/100 plants was also noted in the variant with fractional application of N_{150}. Thus, nitrogen fertilizers are assimilated to the maximum when they are fractionally applied.

An increase in the accumulation of dry matter by rice plants is associated with an increase in yield. Table 3 shows the effect of mineral fertilizer doses and methods of their application on rice yield. It follows from the presented data that the yield of rice varied from 3.86 t/ha to 7.15 t/ha. It depended on the methods of application and the dose of nitrogen fertilizers.

In the variant with a one-time application of doses of N_{120} and N_{150} by sowing, an improvement in yield was obtained by 40% and 61%, respectively, compared to the Background-R_{120} variants. Improvement of nitrogen nutrition with fractional application of doses of N_{120} and N_{150} led to an increase in yield by 2.61 t/ha and 3.29 t/ha, or by 68% and 85%, respectively. Thus, the improvement of nitrogen nutrition with fractional application of nitrogen fertilizers provides higher yields of rice grains in comparison with other variants of the experiment (Table 4).

Table 3. Influence of doses and methods of applying nitrogen fertilizers on the yield of Syr Suluy rice

Experience Options	Yield, t/ha	Addition to the Harvest	
		t/ha	%
Background-R_{120}	3.86	-	-
Background + N_{120} before sowing	5.39	1.53	40
Background + N_{150} before sowing	6.23	2.37	61
Background + N_{120} (N_{60} before sowing + N_{60} tillering)	6.47	2.61	68
Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bubbling)	7.15	3.29	85

Source: Compiled by the authors.

Table 4. Structure of rice yield depending on the doses and methods of applying nitrogen fertilizers

Experience Options	Plant Height, cm	Number of Plants before Harvesting	Productive Bushiness, pcs/plant	Grain Weight, g/plant	Empty-Grain Content, %	Weight of 1000 Grains, g
Background-R_{120}	87.2	197.5	1.3	2.47	4.7	32.7
Background + N_{120} before sowing	105.6	206.3	2.5	4.88	9.2	31.9
Background + N_{150} before sowing	107.9	208.1	2.9	4.95	11.6	31.4
Background + N_{120} (N_{60} before sowing + N_{60} tillering)	108.4	210.3	3.1	5.17	9.7	32.8
Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bubbling)	110.8	211.6	3.2	5.23	9.3	33.1

Source: Compiled by the authors.

Productivity is determined by the intensity of growth and the physiological activity of the aboveground organs of plants. Growth is the main indicator of the active life of plants and depends on many metabolic processes within them. These processes can be assessed by various characteristics, including changes in the size of the plant and its individual organs, as well as an increase in the number of organs. As can be seen from Table 4, the dose and method of applying nitrogen fertilizers influenced the growth of rice plants. Thus, with the option without applying nitrogen fertilizers, the height of rice plants of the Syr Suluy variety was 87.2 cm. The application of one-time doses of N_{120} and N_{150} increased this figure by 21% and 23%, respectively, while with fractional doses of N_{120} and N_{150} this figure improved by 24% and 27% respectively. According to the data presented in Table 4, higher yields with fractional application of nitrogen fertilizers were achieved by increasing the weight of grain per plant and improving the productive tillering of rice.

In the Background-R_{120} variant, the productive bushiness was 1.3, and with a fractional application of the N_{150} dose, it was 3.2. The use of nitrogen fertilizers created more favourable conditions for the nutrition of rice plants, which contributed to the development of productive side shoots. Such patterns were also reflected in the change in the mass of grain on the panicle, depending on the dose of nitrogen fertilizer. In the variant without nitrogen, the weight of rice grains was 2.47 g/plant, with an increase in the dose of nitrogen, this figure increased by 112% and reached 5.23 g/plant (in the variant Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bobbing). The number of empty spikelets in a panicle is an indicator of the optimal dose of nitrogen nutrition. The minimum empty grain content was observed in the variant without nitrogen application – 4.7%. The addition of nitrogen led to an increase in the number of empty spikelets in all studied varieties. When using a one-time dose of N_{150}, this value reached 11.6%; with fractional application of the same amount of fertilizer, this figure was 9.3%.

The weight of 1000 grains of rice are an important varietal characteristic. During the research, it was shown that the influence of doses and methods of applying nitrogen fertilizer has only a slight effect on the weight of 1000 grains of the rice variety under consideration: this indicator varied from 32.7 to 33.1 g. This behaviour of this trait indicates its conservatism and stability. Harvest formation is influenced by various factors. One of the powerful tools for controlling the level of yield is the selection of the optimal dose and methods of applying nitrogen fertilizer for each plant variety. Currently, the priority is not the maximum yield, but economically justified. Table 5 presents the results of the economic evaluation of the application of the annual dose of nitrogen fertilizers before sowing rice of the Syr Suluy variety.

Table 5. Economic efficiency of using nitrogen fertilizers for Syr Suluy rice

Experience Options	Yield	Increment, t/ha	Total Costs per 1 ha, thousand tenge	Cost of Additional Production, tenge	Cost of 1 Ton of Grain, tenge	Profit, tenge	Profitability, %
Background-R_{120}	3.86	-	370	-	95855	-	-
Background+N_{120} before sowing	5.39	1.53	425	198900	78850	143900	33.9
Background + N_{150} before sowing	6.23	2.37	438	308100	70305	240100	54.8
Background + N_{120} (N_{60} before sowing + N_{60} tillering)	6.47	2.61	441	339300	68161	268300	60.8
Background + N_{150} (N_{60} before sowing + N_{60} tillering + N_{30} bubbling)	71.5	32.9	448	427700	62657	349700	78.1

Source: Compiled by the authors.

To calculate the economic efficiency of using mineral fertilizers in rice growing technology, 2019 prices were taken. Thus, the cost of 1 ton of rice grain without the use of nitrogen fertilizers was equal to 95855 tenge. At the same time, the selling price of unpeeled shala rice was 130 thousand tenge/t. The maximum level of profitability in relation to the control variant of the experiment in the studies was shown by the variant with a fractional dose of N_{150}, which was 78.1%. In the variant of a one-time dose of N_{150}, this figure was 54.8%.

The presented data indicate that the phased application of N_{150} during the growing season of rice provided the greatest increase in the yield of the crop under study and an improvement in its quality compared to other options for the field experiment. In addition, fractional application of mineral nitrogen is economically feasible when growing Syr Suluy rice.

4. DISCUSSION

The productivity of crops depends on many natural and cultural factors, with the key being the availability of sufficient nutrients, especially nitrogen [44]. Rice plants have high requirements for nitrogen nutrition. Like other crops, rice can use both nitrate (NO_{3-}) and ammonium nitrogen (NH_{4+}). During the growing season of rice, due to soil flooding and the creation of recovery processes, nitrogen compounds are transformed. At this time, NH_{4+} compounds become the dominant form of nitrogen in the soil [35, 37].

As a result of the author's research, it was found that rice varieties Syr Suluy are optimal for the development and productivity of rice plants. is the dose N_{150}. This is confirmed by studies conducted by A. Jahan et al. studied the effect of nitrogen fertilizers under different climatic conditions on the growth and productivity of two high-yielding rice varieties (BRRI dhan58 and BRRI dhan75) depending on the amount of mineral fertilizers and their application during the growing season of plants [45]. In their experiments, scientists tested the work with a wide range of doses of nitrogen fertilizers with the following amount of active ingredient: 0, 25, 50, 75, 100, 125, 150 and 175 kg/ha. The source of nitrogen was carbamide, which was introduced fractionally in three terms: before sowing, in the tillering phase and in the phase of panicle formation. Plant height in these studies was highest in the variant with the highest nitrogen dose (175 kg/ha). For the formation of the panicle, the most optimal was the introduction of nitrogen in the amount of 150 kg/ha, while the empty grain content has significantly decreased. It should be noted that the lowest values of this parameter were observed in the variant with the amount of nitrogen 125 kg/ha, it is natural that when the same dose of nitrogen was applied, the grain yield was higher compared to other options. The development and yield of plants varied depending on the variety. Rice variety BRRI dhan58 is characterized by responsiveness to higher nitrogen levels, its highest yield was achieved with an application of 125 kg/ha. Variety BRRI dhan75 had higher productivity with application of N_{75}. Based on the results of the studies, scientists calculated the optimal nitrogen rates for feeding rice using quadratic regression equations, according to which they are 142 kg/ha for BRRI dhan58 and 82 kg/ha for BRRI dha75. As a result of the research, scientists came to the conclusion that in order to increase the yield of rice and the assimilation of nitrogen by plants, it is necessary to take into account the varietal characteristics of the crop, the climatic conditions for its cultivation and the growing season for fertilizing. This approach will help to avoid the irrational use of mineral fertilizers.

In rice growing technology, it is important to choose the optimal dose, time, and method of applying nitrogen fertilizers, since a lack or excess of nitrogen can negatively affect plant productivity [46]. According to the data presented in this study, the most optimal nitrogen regime during the growing season of rice variety Syr Suluy is formed when using fractional application of nitrogen fertilizers at a dose of N_{150}. Research conducted by Gou et al. [47] confirmed the results obtained. The authors came to the conclusion that fractional application of nitrogen fertilizers ensures the optimal soil nitrogen regime for the growth and development of rice plants. In this work, the effect of nitrogen added in an amount of 350 kg/ha was studied according to the scheme: N_{130} before sowing + N_{130} in the tillering phase + N_{90} in the phase exit to the tube. A smaller dose of nitrogen was also analysed (240 kg/ha), applied in four periods: N_{96} before sowing + N_{48} in the tillering phase + N_{48} in the booting phase + N_{48} in the panicle formation phase. The data obtained indicate that both methods of fertilizing had a positive effect on the development of the photosynthetic apparatus of rice plants, which ensured an increase in the productivity of the crop under study. At the same time, the work noted that fractional application of nitrogen fertilizers throughout the entire growing season of plants ensures better absorption of nitrogen by plants, but it is not advisable to increase the dose, since at 240 kg/ha rice yield was higher than at 350 kg/ha.

This work shows that increasing the dose of nitrogen fertilizers leads to increased accumulation of dry matter throughout all phases of the rice growing season. These data are consistent with the work of other authors. The accumulation of dry matter in the aerial parts increases in the process of orgagonesis of plants of various rice varieties and depends on the doses and methods of nitrogen fertilizers [48-50]. The authors noted that an increase in the dose of nitrogen fertilizers is associated with the accumulation of dry matter in different varieties of rice. However, according to this work, the dose of N_{180} was excessive for all varieties, but the dose of nitrogen fertilizers for the optimal development of rice plants should be above 120 kg/ha.

The obtained results indicate that the higher yield of Syr Suluy rice was achieved by increasing the mass of grain per plant and improving the indicator of productive tillering. Obviously, the use of nitrogen fertilizers created more favourable conditions for the nutrition of rice plants, which contributed to the development of productive side shoots. N. Wang et al. confirm the role of nitrogen in the formation of rice yield and grain quality [25]. At the same time, they emphasize that the level of plant density almost did not depend on the amount of nitrogen applied. Nevertheless, the use of nitrogen fertilizers contributed to an increase in the survival of young plants, which in turn favourably affected the tillering process of plants. According to the authors, increasing the dose of nitrogen slows down the vegetation of rice plants. And the introduction of doses of nitrogen fertilizers in excess of the norm leads to an increase in by-products.

Indonesian scientists Ikbar Bahua and Gubali [51] conducted research on increasing the yield and biometric characteristics of rice as a result of applying liquid organic fertilizers at a dose of 25 l/ha, 35 l/ha, 45 l/ha and the method of growing crops. Their papers show that a direct rice seeding system combined with 45 l/ha of organic fertilizer was more effective than the seedling system. Scientists came to this conclusion after analysing the biometric parameters of plants. It was in this variant that the indicators of panicle length, weight of 1000 grains and yield were the highest. Although no studies have been conducted in this work on the fractional application of organic fertilizers in rice cultivation, the results of the studies confirm the need for additional feeding of rice during the growing season.

The study of the effect of different doses of mineral fertilizers, their forms, and methods of application is relevant for increasing the yield of rice and the quality of the resulting products, since high doses of fertilizers are not always the key to maximum nitrogen uptake by plants, and low doses are not sufficient to increase their yield. The efficiency of nitrogen assimilation depends on the varietal characteristics of rice, climatic conditions, the growing season of plants and combination with other macronutrients, which should be taken into account when growing a crop [52-54].

The present study found that fractional application of nitrogen fertilizers resulted in higher yields and improved nitrogen use efficiency compared to a single application before sowing. These findings are consistent with previous studies on nitrogen application in rice.

Regarding the effect of nitrogen application on empty-grain content, the present study found that the highest empty-grain content was observed in the treatment with the highest nitrogen application rate (N_{150}). This finding is consistent with previous studies that have reported increased empty-grain content with higher nitrogen application rates. However, the present study also found that fractional application of nitrogen fertilizers resulted in lower empty-grain content compared to a single application before sowing, suggesting that the timing and method of nitrogen application can have a significant impact on this trait.

Based on this study and previous research, there are key recommendations for rice farmers to optimize nitrogen fertilizer management and enhance crop yield and quality. Firstly, it is beneficial to adopt a fractional nitrogen application approach by splitting doses throughout the season to improve efficiency and reduce empty-grain content. Secondly, farmers should customize nitrogen application rates to their specific conditions, considering factors such as rice variety and soil type. Thirdly, integrating organic fertilizers with mineral fertilizers can improve both yield and quality. Evidence supports the effectiveness of certain systems, such as direct seeding with organic fertilizer. Finally, while aiming for increased profits through optimal nitrogen use, farmers must balance economic gains with environmental concerns, prioritising sustainable practices. The practical implementation of sustainable and profitable agricultural systems for rice farmers involves conducting soil tests, strategically dividing nitrogen applications, experimenting with organic fertilizers, and monitoring crop response for adjustments. By embracing these strategies, rice farmers can achieve their goals.

5. CONCLUSIONS

The obtained results indicate that the optimal nitrogen supply for crops of the rice of variety Syr Suluy in Kyzylorda region at all phenological stages was achieved with the use of fractional application of a dose of N_{150}. This method of applying 150 kg/ha of nitrogen provided an increase in dry matter by 51%, 40% and 120% in the phases of tillering, heading and full ripeness, respectively (compared to the variant without applying nitrogen fertilizer). Increased dry matter accumulation in rice plants of the Syr Suluy variety was associated with an increase in yield, which varied from 3.8 t/ha (option without nitrogen application) to 7.15 t/ha (fractional application of N_{150} dose). Higher yields were achieved by increasing the mass of grain per plant and improving the index of productive tillering. In the variant without nitrogen, the grain weight was 2.47 g/plant, and the productive bushiness was 1.3; with a fractional application of 150 kg/ha of nitrogen, these figures were 5.23 g/plant and 3.2, respectively. It was shown that the introduction of a dose of N_{150} in three terms is also economically justified. With such a dose and method of applying nitrogen fertilizer, the maximum level of profitability was achieved in relation to the variant without the use of nitrogen – 78.1%.

The obtained data provide valuable information for the farms of the southern regions of Kazakhstan, which can use them in their production. This allows optimizing agricultural technology and obtaining the maximum possible and economically viable yield of rice plants. Further investigation is necessary to determine the effect of different nitrogen application timings on rice yield and nitrogen use efficiency. This includes exploring the benefits of early versus late-season application and examining the potential of split applications during various growth stages. The use of slow-release nitrogen fertilizers should be evaluated to reduce nitrogen losses and improve efficiency, potentially leading to higher yields and reduced environmental impacts. Research in the area of rice production could focus on integrating pest and nutrient management strategies to improve yield and quality. This could involve exploring pest-resistant rice varieties, biological control agents, and combining nutrient management practices with pest control measures. Assessing the impact of nitrogen application rates and methods on rice grain quality is crucial for meeting market demands and consumer preferences, particularly with regards to protein content, milling quality, and cooking characteristics. In addition, research into the impact of nitrogen fertilisers on greenhouse gas emissions from rice production is essential. To mitigate nitrous oxide emissions, it is important to explore nitrification inhibitors and other management practices. Also, rice straw and crop residues should be used for renewable energy. Decision support tools for nitrogen management in rice production should be developed, incorporating remote sensing technologies and precision agriculture techniques. This will optimize nitrogen application rates and timings based on real-time crop and soil conditions.

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