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Development and Implementation of Effective Schemes for the Use of Mineral Fertilizers in the Forest-Steppe Zone of the North Kazakhstan Region

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Abstract: Nitrogen fertilizers in liquid form have become the most common ones in recent years. Since North Kazakhstan is located in a zone of risky farming, liquid fertilizers are a very productive solution. The purpose of the study was to develop and evaluate the implementation of effective schemes for the use of mineral fertilizers in the forest-steppe zone of the North Kazakhstan region. In the experimental areas of the fields, studies were carried out on cereals and oilseeds, with spring wheat as the preceding crop. Sowing was carried out five days after the introduction of the urea ammonium nitrate solution UAN-32. The use of the UAN-32 preparation in experiments with cereals and oilseeds gave a positive effect. Thus, in compliance with all agrotechnical measures and optimal sowing dates, the introduction of fertilizers in pure form into the soil before sowing and into fertilizing did not cause heat damage in plants. The increase in yield compared to the non-fertilized background averaged 39.4% for wheat, 42.9% for rapeseed, and 63.2% for flax. According to the results of the conducted studies, it can be noted that oilseeds, due to their greater consumption of nutrients for the formation of the crop, in particular nitrogen, are more responsive to the introduction of readily available forms of mineral fertilizers.

Keywords: Yield, Oilseeds, Nitrogen, Liquid Fertilizers

Introduction

In a harsh continental climate, with sudden temperature changes, long hot periods, and lack of moisture and precipitation necessary for plants, nitrogen fertilizers in liquid form help to minimize risks, allowing crops to receive vital substances from the first days of sowing, having not only instantaneous but also long-lasting effect throughout the entire growth period (Łuczkowska *et al.*, 2015; Milyutkin *et al.*, 2021; Vasin *et al.*, 2022).

Considering the high practicality and the need to restore and improve soil fertility, which ensures an increase in crop yields and their quality, it seems a reliable and convincing option to focus on liquid mineral fertilizers when choosing types of mineral fertilizers, taking into account the dynamics of the growth of popularity and the volume of application (Marchenko *et al.*, 2015; Milyutkin *et al.*, 2020a; Kechasov *et al.*, 2021).

In countries with highly developed agriculture, for example in the USA, these fertilizers are already used on more than a third of farmland and 55% of nitrogen fertilizers are produced in liquid form. In Europe, 10-15% of liquid fertilizers are used (the largest amount in France and Austria). In the Commonwealth of Independent States (CIS) countries, the largest amount of mineral fertilizers in liquid form is used in the Republic of Belarus. Most of the consumption of liquid mineral fertilizers falls on Urea Ammonium Nitrate (UAN) and Liquid Complex Fertilizer (LCF) (Milyutkin *et al.*, 2020b; MASR, 2020; Ufimtsev *et al.*, 2022). The consumption of UAN in the Kazakh market according to open data of the Qoldau Information System (IS) for 2019 amounted to more than 20,000 t, of which almost 90% was used in the north of Kazakhstan.

Technological and economic processes of UAN application give us not only flexibility in use but also some other advantages in comparison with dry nitrogen fertilizers (Gagnon *et al.*, 2012). UAN is the only nitrogen fertilizer to date that contains three forms of nitrogen, thanks to which this fertilizer acts longer due to the:

- Nitrate nitrogen (8%) which ensures its instant assimilation
- Ammonium nitrogen (8%), which in the process of nitrification turns into a nitrate form
- Amide nitrogen (16%), which, as a result of the activity of soil microorganisms, turns into ammonia form and then into nitrate (Nikolajsen *et al.*, 2020; Ren *et al.*, 2021)

UAN works both through the leaves and through the roots: The amide form is absorbed through the leaf surface and the nitrate and ammonium forms are absorbed through the root system. When applying UAN sprayers, better uniformity and high dosing accuracy are achieved than when applying dry fertilizers with mechanical spreaders. UAN can be used on any soil, as it does not acidify it, unlike some dry mineral nitrogen fertilizers in any region, as well as in mini-till and no-till technologies (MASR, 2020).

Methods of introduction and use of UAN:

- For vegetation: Sprayers with large-drop nozzles
- In the root zone: Sprayers with extension
- To the root zone: Cultivators, injectors, plant feeders, combined tillage machines, and seeders

The norms and doses of UAN application depend on the type of crops, the time and method of application, the preceding crop, and other factors (Antonova and Latartsev, 2022; Wierzbowska *et al.*, 2022). When applying UAN, it is necessary to use sprayers for the large drop application of liquid fertilizers. To obtain maximum results from the use of UAN fertilizers, it is necessary to take into account all application factors, both favorable and unfavorable ones (MASR, 2020).

The best time for foliar fertilizing with UAN solutions is in the morning (in the absence of dew) and the evening. In cool and cloudy weather, this study can be carried out during the day. Plants should not be fed with UAN solutions at temperatures above 20°C, with a low relative humidity of less than 56%, or on a clear sunny day. Immediately after rains or with heavy dew, it is impossible to use UAN, since precipitation makes the structure of the upper plate of the leaf more permeable. Therefore, crop treatment should be carried out after the drying of the leaves. The optimal time of day for the introduction of UAN in a mixture with chemical plant protection products is in the evening (MASR, 2020).

Tankers, cassettes or euro cubes, railway tanks, and tank containers are used for the transportation of UAN. UAN solutions can be stored in containers previously used for storing ammonia water, LCF, or Fuel and Lubricants (FL), used railway tanks, as well as any plastic containers with a volume of 25, 50, 75, 100, and 250 m^3. Pumping of UAN solutions can be carried out both by electric and gasoline centrifugal pumps, which are connected by pipelines and shut-off valves (MASR, 2020).

The country's food security can be ensured with the transition from an extensive path of development to an intensive one, which is based on more efficient use of the potential of existing varieties and hybrids of crops, material resources, and, first of all, the fertility of arable land. With extensive farming, the yield depends on soil fertility and weather conditions by 50-60%, and with intensive farming, by 30-35% (Antonova, 2018).

In the production of cereals in Western Siberia, chemicals account for 64.3% of the process, the variety for 17.6%, and all other factors for 18.1%. There are many examples showing a direct dependence of yield increase on the fertilizers applied. A good example is China, where the yield has increased from 1 to 5-8 t/ha since 1987. Currently, China uses >300 kg/ha of mineral fertilizers, the USA >170 kg/ha, and the Russian Federation >10 kg/ha (Antonova, 2018).

To obtain the productivity of the main crops up to 4 t/ha, it is necessary to increase the application of nitrogen from 26-50 to 104-228 kg/ha, of phosphorus from 10-30-40-120 kg/ha, and of potassium from 19-60 to 38-240 kg/ha, depending on the crop. The content of these elements in the soil should be taken into account. Among all crops, rapeseed, sugar beet, potatoes, and vegetable crops are characterized by the highest consumption of nutrients. Unlike cereal crops, they take out at least 2 times more nitrogen, phosphorus, and potassium from the soil, so they need large doses of fertilizers to preserve fertility (Antonova, 2018).

The purpose of the study was to develop and evaluate the implementation of effective schemes for the use of mineral fertilizers in the forest-steppe zone of the North Kazakhstan region.

Materials and Methods

Agrotechnics

Research on the development and implementation of effective schemes for the use of mineral fertilizers in the forest-steppe zone was carried out in one of the leading farms of the North Kazakhstan region of the Mambetov and Co. Credit Society (CS) in the Mamlyutsky district. The date of fertilization before sowing was May 14, the sowing was performed on May 22, leaf treatment was performed on June 15, and ear treatment on July 26.

The fertilizers tested had been produced in Kazakhstan. In the basic farm, a selection of experimental plots of fields was carried out for conducting research on cereals and oilseeds, where the preceding crop was spring wheat. The total area of the experimental plots was 105 ha (35 ha for each crop). Fertilization before sowing was carried out by a self-propelled Apache sprayer using large drop FD nozzles followed by harrowing.

Sowing was carried out five days after the introduction of the UAN containing UAN-32 preparation. Seeding rate: Rapeseed: 3.3 kg/ha, flax: 25 kg/ha, wheat: 130 kg/ha. The depth of seeding of wheat seeds was 4-6 cm and for rapeseed and flax 2-5 cm. The top dressing was carried out during the growing season in the tillering phase of wheat, in the 2-3 true leaves phase for rapeseed, and the phase of three pairs of true leaves for flax. As a top dressing, UAN was used in its pure form, sprayed with a self-propelled sprayer using large drop nozzles.

All work was carried out according to the recommendations on the use of UAN-32. It was used in calm weather, at an air temperature of 20-22°C in the evening. In all variants of the experiment, fertilizers were applied in pure form.

Study Design

The design of the study, doses, and methods of application was the same (uniform) for all crops: Wheat, rapeseed, and flax (Table 1).

Study Methodology

To achieve the purpose of the study, the following observations and records were carried out:

- Breakdown of the experimental site
- Phenological observations during the plant growing season
- Sheaf analysis
- Yield forecasting

To determine the biological yield of cereals and oilseeds, the selection of sheaves was carried out, followed by analysis with the determination of the structure. Sheaf samples for laboratory analysis were taken at the onset of yellow (economic) ripeness for all varieties from the experimental sites allocated for calculating the density of the herbage. In addition to indicators characterizing the biological and economic properties of the variety, the degree of disease damage and damage by agricultural pests were determined.

The analysis of the sheaf sample and the calculation of indicators were carried out in the following order. In the sheaves of each variant, the total number and number of productive plants of this crop were calculated, they were combined into a common sheaf and the sample was weighed. The following indicators were additionally determined:

1) Average ear length: Measuring the length of 25 years with an accuracy of 0.5 cm, the numbers were summed up and divided by 25
2) The average number of spikelets in an ear: The number of spikelets on 25 ears was counted and the resulting values were summed and divided by 25
3) The mass of 1,000 seeds
4) Calculation of the biological yield

The height of the plants was determined before harvesting by measuring the distance from the soil surface to the top of the main stem, not counting the spikes of the ears. Harvesting to determine the biological yield was carried out in the phase of yellow (economic, harvesting) ripeness. The quality indicators of the crop were determined in the laboratory:

- Wheat grain: Total protein content, amount of gluten (USSR Gosstandart, 1993; Rosstandard, 2011)
- Oilseeds: Oil content, fat, and protein content (Rosstandard, 2015a-b)

Seed quality was determined in a laboratory building using specialized Foss equipment. The key indicators were determined, namely, the content of gluten and protein in wheat grains. The percentage quantitative value of the protein characterizes its content. According to the State Standard (GOST), all classes of wheat should have an indicator at the level of 11-14%. A lower or higher value negatively affects the quality of products containing such flour. In addition, such changes are reflected in the gluten content, which can double with an increase in the protein index by 1.4 times.

Table 1: Design of the study

Variant	Before sowing, active ingredient	Top-dressing tillering, active ingredient	Top-dressing during ear formation, active ingredient	Dose of fertilizers in physical weight, kg	Area of the plot, ha	Fertilizers in physical weight, kg
Control without fertilizers	-	-	-	-	5	-
N_{60} (before sowing)	60	-	-	188	5	940
N_{80} (before sowing)	80	-	-	250	5	1,250
N_{25} (top dressing)	-	25	-	78	5	390
N_{30} (top dressing)	-	30	-	94	5	470
N_{60} (before sowing + top dressing)	55	-	5	188	5	940
N_{80} (before sowing + top dressing)	75	-	5	250	5	1,250

The effects of fertilizers and plant protection products on the protein structure of grain were also studied. Thus, it is recognized that an increased dose of fertilizers per 1 c/ha additionally increases the protein content by more than 0.5% and each of the plant protection agents (PPA: Herbicide, fungicide, insecticide, etc.), multiplies by an average of 0.44% to this indicator.

Gluten content is the ratio of the gluten content in raw form to the total protein content. This indicator characterizes the quality of flour, which is made from different classes of wheat. According to Kazakh standards, grain should contain 18-28% gluten. Fertilizers and plant protection products directly affect the gluten content in proportion. Wheat gluten classes are defined as follows: The higher the wheat class, the greater the value of this indicator.

The biological yield of oilseeds is determined by sampling before the harvesting process. To determine the biological yield of oilseeds, there is a specific algorithm of action:

- An eye-measuring analysis of rapeseed (flax) crops is carried out to determine the appearance of plants typical for a particular field
- On 5-10 typical plants, the number of pods (bolls) is calculated to determine the average number of pods (bolls)
- The average number of seeds in one pod (boll) is determined. On average, this indicator for rapeseed is 18-25 seeds
- The number of plants per ha of the field is determined
- The mass of 1,000 seeds of rapeseed (flax) is calculated

The mass of 1,000 seeds of rapeseed is the number of pods (bolls) multiplied by the number of plants per ha. The resulting number is multiplied by the average number of seeds in the pod (bolls). The resulting number is multiplied by the mass of 1,000 seeds of rapeseed (flax). This figure is an indicator of biological yield or yields on the root of rapeseed (flax).

Results and Discussion

Phenological Observations in Wheat Crops

Even sprouts were noted on all crops in all variants. At the initial stage of germination, tillering was strongly affected by the lack of moisture due to the lack of precipitation. Only moisture from the soil was available to the seeds. The data of phenological observations in the wheat variant are presented in Table 2. Phenological observations did not show significant differences between the variants of the experiment.

When taking into account the phenological phases, the date of the onset of the next phase was recorded in more than 75% of plants. The use of nitrogen fertilizers mainly affects the increase in vegetative mass. The use of top dressing in late terms increases the duration of ripening by an average of 7 days. Top dressing during tillering and one-time pre-sowing application slightly increased the ripening period by an average of 2 days in comparison with the control variant.

Along with the determination of phenological phases, biometric measurements of plant density and height from germination to harvesting were also carried out. The results are presented in Table 3. Intensive technology of spring wheat cultivation is aimed at obtaining the greatest increase in agricultural products at a minimal cost. An important place in the intensive farming system is occupied by the use of modern varieties and the use of fertilizers. In this regard, the greatest interest is the study of the productivity of varieties of spring soft wheat of intensive and semi-intensive types at different levels of mineral nutrition (Oxukbayeva *et al*., 2023).

Table 2: Dates of occurrence of phenological phases of wheat with different doses and timing of UAN-32 application

Experiment variant	Sowing	Sprouts	Tillering	Stem elongation	Ear formation	Ripening	Growing season
Control variant	22.05	01.06	21.06	06.07	25.07	17.08.2021	88
N_{60} (before sowing)	22.05	01.06	20.06	05.07	26.07	19.08.2021	90
N_{80} (before sowing)	22.05	01.06	21.06	06.07	27.07	18.08.2021	89
N_{25} (top dressing)	22.05	01.06	21.06	06.07	23.07	31.08.2021	90
N_{30} (top dressing)	22.05	01.06	21.06	04.07	24.07	24.08.2021	93
N_{60} (before sowing + top dressing)	22.05	01.06	21.06	06.07	23.07	25.08.2021	94
N_{80} (before sowing + top dressing)	22.05	30.05	19.06	06.07	27.07	27.08.2021	96

Table 3: Determination of the density and height of wheat plants during the tillering period for various applications of UAN-32

Experiment variant	Plants per 1 m^2		Tilling capacity, pcs. per 1 m^2	Height of plants to be harvested, cm
	Sprouts	Harvest		
Control variant	309.4	263	1.3	52.1
N_{60} (before sowing)	291.8	248	1.9	51.4
N_{80} (before sowing)	320.5	292	2.0	53.7
N_5 (top dressing)	296.5	252	1.7	55.6
N_{30} (top dressing)	310.6	264	1.8	52.5
N_{60} (before sowing + top dressing)	327.6	287	1.7	51.3
N_{80} (before sowing + top dressing)	307.1	261	2.0	54.2

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To form a high yield, the sowing of an agricultural crop should be characterized by good development of all plants, resistance to lodging, and the density of the productive stem optimal for these environmental conditions and varieties. It is proved that the density index of the productive stem has up to 50% effect on the yield level, the number of grains in the ear has a 25% effect and the mass of 1,000 grains has a 25% effect (Abdryaev, 2018).

Productive tilling capacity is one of the important indicators of the density of the productive stem (Zelenev *et al.*, 2020; Wang *et al.*, 2022). The formation of productive plant stems is influenced by many elements of agricultural technology. Fertilization before sowing improves the survival of plants and provides even sprouts. Plant protection measures reduce the contamination of crops, thus reducing competition with weeds, while pest control protects the crop from damage. These and other elements of agricultural technology make it possible to obtain crops that are uniform in the degree of plant development and their distribution in the field (Alyoshin, 2021; Vasiliev *et al.*, 2022).

The plant density and tilling capacity are presented in our study in Table 3. Differentiation at the early stages of growth only increases in the future and leads to competition and death of weak plants, as a result of which the yield decreases. To obtain uniform and even sprouts, it is necessary to use seeds treated and aligned in size and weight. Seeding should be carried out to the same depth, on a moist and dense bed (Chasovskikh, 2016).

As can be seen from Table 3, the use of mineral fertilizers had a positive effect on the tilling capacity. Thus, at the maximum dose of N_{80}, this indicator was 2.0 stems and on average, this indicator for all variants varied from 1.7-2.0, whereas in the control variant, this indicator was 1.3 stems. Similarly, to this indicator, the height of plants also changed. Against the background of the use of fertilizers, it was 3-5 cm higher in comparison with the control variant.

Structural Analysis of Sheaf Material and Determination of Biological Yield of Spring Wheat

The analysis of sheaf samples was carried out on the 3rd day from the date of their collection and showed that the use of made-in-Kazakhstan mineral fertilizers had a positive effect on the structure and yield of seeds (Table 4). The degree of disease damage and damage by agricultural pests was determined (none were found in the experimental plots).

As can be seen from Table 4, the introduction of mineral fertilizers, regardless of the timing and methods of application, had a positive effect on grain yield. Thus, the best variant turned out to be in the variant of application before sowing together with late fertilizing and it gave the best result equaling 32.6 c/ha. On average, the experimental plots outperformed the control plot by an average of 7.7 c/ha, which is a good result under unfavorable humidification conditions.

The introduction of increased doses of N_{80} both before sowing and with top dressing stands out noticeably against the background of variants with N_{60}, where the difference is 11.2 and 2.8 c/ha, respectively. The leaf treatments were also noticeably better, where the yield was 9.2 higher than the control variant. They also exceeded the variants with a dose of N_{60} by 6.4 c/ha.

Based on the data obtained, it can be concluded that in the conditions of this year, in the absence of precipitation during the growing season (only productive moisture was available to the plants, which was in a meter layer of soil), the introduction of UAN-32 before sowing in large doses and fertilizing gave results in the form of an increase in yield.

Determination of the Quality of Wheat Seeds

The definition of seed quality is shown in Fig. 1. Optimization of mineral nutrition of crops had a positive impact on the main indicators of grain quality, which according to the classification belongs to the first class.

Thus, it can be concluded that the fractional use of mineral fertilizers in pre-sowing treatment at a dose of N80+ top dressing had a positive effect on both yield and grain quality. In the conditions of the dry year, leaf fertilizing showed good results, which did not differ significantly according to these indicators with the pre-sowing application.

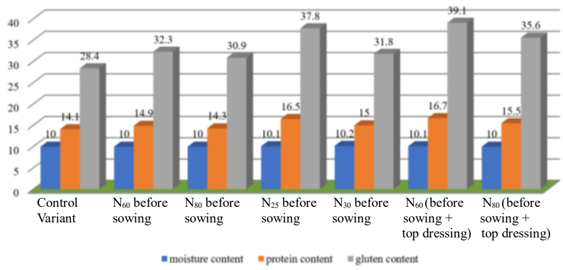

Fig. 1: Quality of wheat seeds

Table 4: Structure and biological yield of spring wheat

Variant	Sheaf weight, g	Number of ears, 1 m^2	Ear size, cm	Number of grains per ear, pcs.	Weight of 1,000 grains (g)	Biological grain yield, c/ha	In %, compared with the control variant
Control variant	280	263	6.0	18.5	40.5	19.7	-
N_{60} (before sowing)	340	248	6.1	21.0	43.8	22.8	15.7
N_{80} (before sowing)	440	292	6.5	23.9	41.8	29.2	48.2
N_{25} (top dressing)	460	252	6.4	27.5	41.8	28.9	46.7
N_{30} (top dressing)	400	264	6.7	27.4	40.1	29.0	47.2
N_{60} (before sowing + top dressing)	360	265	6.7	20.4	41.3	22.3	13.2
N_{80} (before sowing + top dressing)	480	287	6.5	28.1	40.5	32.6	65.5

Table 5: Dates of onset of phenological phases of rapeseed with different doses and timing of UAN-32 application

Experiment variant	Crops	Sprouts	Budding	Blossom	Ripening	Growing season
Control variant	20.05	02.06	11.06	22.07	16.08.2021	87
N_{60} (before sowing)	20.05	31.05	12.06	21.07	19.08.2021	92
N_{80} (before sowing)	20.05	03.06	10.06	22.07	15.08.2021	88
N_{25} (top dressing)	20.05	01.06	11.07	23.07	17.08.2021	90
N_{30} (top dressing)	20.05	30.05	12.06	20.07	18.08.2021	91
N_{60} (before sowing + top dressing)	20.05	01.06	10.06	25.07	21.08.2021	94
N_{80} (before sowing + top dressing)	20.05	01.06	15.06	27.07	22.08.2021	95

Table 6: Dates of onset of phenological phases of flax with different doses and timing of UAN-32 application

Experiment variant	Crops	Sprouts	Three pairs of true leaves phase	Sprouts	Blossom	Ripening	Growing season
Control variant	23.05	02.06	15.06	01.07	23.07	22.08.2021	92
N_{60} (before sowing)	23.05	03.06	16.06	03.07	25.07	24.08.2021	94
N_{80} (before sowing)	23.05	01.06	21.06	06.07	23.07	22.08.2021	92
N_{25} (top dressing)	23.05	02.05	14.06	02.07	24.07	22.08.2021	92
N_{30} (top dressing)	23.05	31.05	17.06	03.07	27.07	26.08.2021	96
N_{60} (before sowing + top dressing)	23.05	01.06	21.06	04.07	25.07	25.08.2021	95
N_{80} (before sowing + top dressing)	23.05	02.06	25.06	07.07	27.07	29.08.2021	99

Table 7: Determination of the density of oilseed plants in the period of 2-3 leaves and the three true leave pairs phase with various applications of UAN-32

	Rapeseed		Flax	
	Plants per 1 m^2			
Experiment variant	Sprouts	Harvest	Sprouts	Harvest
Control variant	78.6	68	358.0	315
N_{60} (before sowing)	66.8	60	355.1	320
N_{80} (before sowing)	81.2	78	368.4	336
N_{25} (top dressing)	70.4	60	352.4	311
N_{30} (top dressing)	83.4	76	368.2	328
N_{60} (before sowing + top dressing)	75.5	68	360.5	324
N_{80} (before sowing + top dressing)	76.5	72	367.2	330

Phenological Observations of the Growth and Development of Oilseeds

Even sprouts were noted on all crops in all variants. At the initial stage of germination, tillering was strongly affected by the lack of moisture due to the lack of precipitation. Only moisture from the soil was available to the seeds.

Phenological observations revealed that nitrogen fertilizers prolonged the growing season by improving growth, which contributed to improving the crop yield. The data of phenological observations in variants with oilseeds are presented in Tables 5-6. The date of fertilization before sowing was May 15, sowing was performed on May 20-23, leaf treatment was performed on June 15 and treatment in the budding phase was performed on July 26.

When considering the phenological phases, the date of the onset of the next phase was recorded in more than 75% of plants. The use of mineral fertilizers also affected the ripening period of oilseeds in a similar way to cereal indicators. The use of top dressing in late terms increases the duration of the ripening period of rapeseed and flax by 4-8 days and 2-7, respectively. Top dressing during tillering and one-time pre-sowing application slightly increased the ripening period by an average of 2 days in comparison with the control variant.

Along with the determination of phenological phases, biometric measurements of plant density and height from germination to harvesting were also carried out. The results are presented in Table 7.

As can be seen from Table 7, the use of mineral fertilizers in the pre-sowing treatment had a positive effect on the density of plants for harvesting.

Determination of Biological Yield of Oilseeds

The use of mineral fertilizers produced in Kazakhstan had a positive effect on the structure and yield of seeds. The results are presented in Table 8.

As can be seen from Table 8, the application of mineral fertilizers, regardless of the time of application, had a positive effect on seed yield. In particular, the introduction in pure form as a top dressing in both variants gave a maximum increase in yield by 11.4 and 13.7 c/ha in variants with N_{25} and N_{30}, respectively. The combined application of fertilizers had a positive effect on the formation of pods and the weight of 1,000 seeds in comparison with a one-time pre-sowing application and consequently, the yield was slightly higher by 3.4 and 2.1 c/ha. On average, the experimental plots exceeded the control variant by an average of 9.6 c/ha.

Table 8, there was an increase in yield due to the use of mineral fertilizers. At the same time, with the main application and with top dressing, the dose of N_{80} was the most effective one. In the features of this year, the best option was the use of liquid forms of fertilizers in the phase of 3-4 true leaves, where the highest yield was recorded. At a dose of N_{30} in pure form, there was no heat damage in plants.

Determination of the Quality of Wheat Seeds

Seed quality was determined in a laboratory building using specialized FOSS equipment. The key indicator of spring rapeseed was oil and protein content. The results are shown in Fig. 2. As can be seen from Fig. 2, the optimization of mineral nutrition of crops had a positive impact on the main indicators of seed quality, which according to the classification belongs to the first class. The moisture content of the seeds during the measurements was optimal and ranged from 6.2-7.2%. The highest oil content was noted in variant N_{80} before sowing + top dressing and amounted to 47.61%, while the protein content in variant N_{60} before sowing was 29.1%. In general, the difference in the oil content in rapeseed seeds in the variants exceeded the control variant by 3.4%. The content of oil and protein in seeds is higher than 40 and 24%, respectively.

Structural Analysis of Sheaf Material of Oilseed Flax

The use of mineral fertilizers produced in Kazakhstan positively affected the structure and yield of oilseed flax seeds. The results are shown in Table 9. Similarly, the introduction of mineral fertilizers had a positive effect on the yield of flax seeds. The best option was noted with the use of large doses before sowing together with late fertilizing. The best result was 26.6 c/ha in the variant with a dose of N_{60} before sowing.

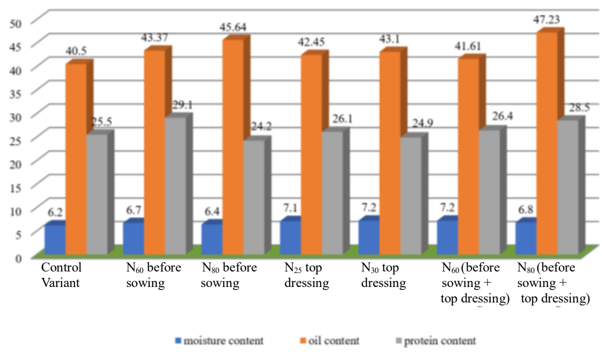

Fig. 2: Quality indicators of spring rapeseed

Table 8: Structure and biological yield of spring rapeseed

Variants	Number of plants, 1 m²	Pods on plants	Number of seeds in a pod, pcs.	Weight of 1,000 from 1 plant (g)	Biological grain seeds (g)	In %, yield, c/ha	compared with the control variant
Control variant	64	60	20.7	3.8	2.8	22.3	-
N_{60} before sowing	64	75	22.8	5.1	2.6	28.5	27.8
N_{80} before sowing	63	64	23.6	4.6	3.1	29.5	32.3
N_{25} top dressing	64	86	21.1	6.1	2.9	33.7	51.1
N_{30} top dressing	65	83	20.2	5.9	3.3	36.0	61.4
N_{60} before sowing + top dressing	65	76	20	4.7	3.1	30.6	37.2
N_{80} before sowing + top dressing	62	82	19.6	6.3	3.3	32.9	47.5

Table 9: Structure and biological yield of oilseed flax

	Number plants, 1 m²	Number of bolls, pcs./plant	Number of seeds in a boll, pcs. variant	Weight of 1000 seeds (g)	Biological grain yield, c/ha	In %, compared with the control variant
Control variant	315	12.0	6.8	5.9	15.2	-
N_{60} before sowing	311	17.2	7.9	6.3	26.6	75.0
N_{80} before sowing	314	16.0	7.4	7.0	26.0	71.1
N_{25} top dressing	318	15.7	7.7	6.0	23.1	52.0
N_{30} top dressing	312	15.2	7.2	6.9	23.6	55.3
N_{60} before sowing + top dressing	320	14.0	7.8	6.6	23.1	52.0
N_{80} before sowing + top dressing	317	15.0	7.5	7.4	26.4	73.7

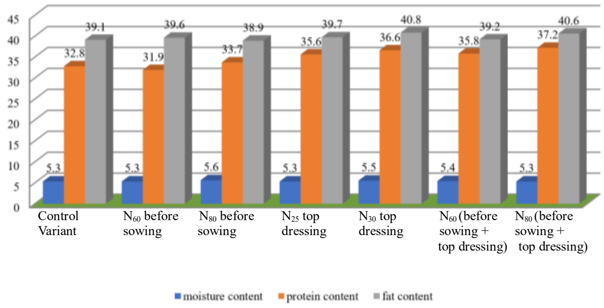

Fig. 3: Quality of oilseed flax

On average, the difference with the control variant was 9.6 c/ha. Leaf treatment showed good results, where the seed yield was almost the same and amounted to 23.3 c/ha, which exceeded the control variant by 8.1 c/ha.

As can be seen from Table 9, to obtain high yields of flax, it is preferable to introduce it in its pure form before sowing in the main dose of N_{80} and N_{60}. However, from an economic point of view, it is possible to make a half smaller dose of UAN-32 (N_{30} and N_{25}) in the form of top dressing for vegetation, which in unfavorable moisture conditions will give a tangible increase in yield at the level of 23.3 c/ha. It is important to prevent heat damage in plants. Therefore, mineral fertilizer in its pure form will be used in compliance with the recommended agrotechnical operations.

When determining the quality of flax seeds, the fat and protein content was taken into account. The definition of seed quality is shown in Fig. 3. As can be seen from Fig. 3, the optimization of mineral nutrition of crops had a positive impact on the main indicators of seed quality, which according to the classification belongs to the first class.

When determining the quality, the moisture content of the grain was at the level of 5.4%. The protein content ranged from 32.8% in the control variant to 37.2% in the variant of the combined application of N_{80}. The fat content was at the level of 39.7%. The maximum indicator was noted in the variant with double application of N_{80} and top dressing N_{30}, where the indicator was higher than 40%.

Based on Fig. 3, it can be seen that the use of fertilizers gave an increase in quality on average for the variants of 0.7% fat and 2.3% protein. There was no big difference between the methods of application. Thus, it seems more practical to limit treatment during the growing season at a dose of N_{30}.

Conclusion

In connection with the data obtained, it can be concluded that the use of the made-in-Kazakhstan preparation UAN-32 in the arid conditions of the current year, it is more economically practical to apply it in the form of top dressing in the tillering phase of wheat, in the 3-4 leaves of spring rapeseed and the three pairs of true leaves phase of oilseed flax. It can be used in a dose of $N_{25\text{-}30}$ of the active substance since the use of this dose gives an increase in yield compared to the use of high doses of N_{60} and N_{80} before sowing and late fertilizing. At the same time, the quality of the seeds obtained varies slightly.

The use of top dressing in the above-mentioned phases of crop development fully satisfies the plants in nutrients during critical periods, at an early stage of crop formation. Leaf spraying ensures uniform distribution and effective use of the preparation by plants.

The use of UAN-32 before sowing gave an increase in yield and quality comparable to the use of the top dressing, but the doses used were twice as high in the active substance and required additional agrotechnical measures (harrowing, additional treatment, and late top dressing). The relatively small difference was also affected by the lack of rain in the summer.

The use of the Kazakh preparation UAN-32 in the conditions of the forest-steppe zone of northern Kazakhstan is guaranteed to increase the yield of cereals and oilseeds.

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Author’s Contributions

All authors contributed equally to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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