Influence of the application of UAN-32 and solid nitrogen and complex fertilizers on the yield and quality of oil flax seeds

O.I. Antonova¹,² and P.Yu. Latartsev²

¹ Federal State Budgetary Educational Institution of Higher Education Altai State Agrarian University, Barnaul, Russia
² JSC Orbita, Barnaul, Russia

* E-mail: niihim1@mail.ru

Abstract. In the course of two years of research, the effect of application of liquid nitrogen fertilizer UAN-32, ammophos and diammophos, as well as their combined use, pre-sowing application of solid nitrogen fertilizers - ammonium nitrate and ammonium sulfate - was studied. Studies have shown that under conditions of unstable moisture supply, pre-sowing and starter application of these fertilizers in combination with N₆₉P₂₆ provides a yield of 17.3 c/ha (54.4% increase) N₄₂P₄₂ - 14.1 c/ha (30.5% increase) and N₅₉P₄₂ - 14.8 c/ha (37% increase). The application of UAN-32 at a dose of 150 l/ha with a high supply of soils with phosphorus and potassium increases the yield by 35.7 (15.2 c/ha). The introduction of UAN-32 at a dose of 150 l/ha, against the background of a high soil supply with phosphorus and potassium, increases the yield by 35.7 (15.2 c/ha). The oil yield for these variants increased from 4.6 - 4.61 c/ha to 7.54; 6.1 and 6.51 c/ha, and protein from 2.8- 1.77 c/ha to 4.35 and 2.29- 2.71 c/ha. Combinations of UAN-32 with ammophos and diammophos contribute to the formation of a higher oil content in seeds, and an increase in the nitrogen dose increases the protein content and yield.

1. Introduction

In the formation of the yield and quality of flax seeds, an important role belongs to the regulation of the nutrient regime of soils.

With a relatively simple technology of cultivation of oilseed flax, there is still a problem of using mineral fertilizers.

In the literature, there is a lot of data on the effectiveness of the influence of the calculated doses of the main nutrients using simple mineral fertilizers when they are applied into the soil before sowing. So Gainulin R. M. notes an increase in seed yield from 1.38 t/ha to 1.54-1.68 t/ha when applying N₄₅P₄₅K₄₅ and N₆₀P₆₀K₆₀ with the increase of oil content from 37 to 37.5-38.8% [1].

Vinogradov D.V. and Kuntsevich A.A. in experiments with the Sanlin variety, when applied N₆₀P₆₀K₆₀ and N₉₀P₆₀K₆₀ to pre-sowing cultivation in the form of ammonium nitrate, KCl and ammophos, obtained an increase in yield from 1.76 t/ha to 1.84-1.86 t/ha. The application of ammonium nitrate, superphosphate and 40% potassium salts in combination N₆₀P₆₀K₆₀N and₉₀P₆₀K₆₀ caused seed yield of flax for 2 years 1.47-1.85 t/ha in control, while in fertilized variants it increased to 1.55-1.98 t/ha and 1.74-2.15 t/ha [3].

Kochkin A.S. and Esaulko A.N. studied the application of combinations of ammonium nitrate, nitroammophoska and ammophos for pre-sowing cultivation at doses of N₆₀P₅₀K₅₄ (calculated for a
yield of 2 t/ha), N\textsubscript{60} P\textsubscript{90} K\textsubscript{20} (to increase oil content) and N\textsubscript{90} P\textsubscript{60} K\textsubscript{20} (to increase protein). On average, over two years, the authors obtained an increase in yield from 1.69 t/ha to 2.1-2.44 t/ha with a change in protein content to 20.9-24.3% (21.5% in control) and oil up to 41.9-46.9 t/ha (43.5% in the control). At the same time, the oil yield increased from 0.74 to 0.91-1.04 t/ha. The variant N\textsubscript{90} P\textsubscript{60} K\textsubscript{60} showed the greatest effect [4].

In the conditions of the Omsk region, with pre-sowing application of various combinations of fertilizers on flax at a dose of N and P\textsubscript{2}O\textsubscript{5} - 60-90, K\textsubscript{2}O - 30, on average over two years with a yield at the control 0.89 t/ha, on the variant N\textsubscript{60} P\textsubscript{90} it was 1.73 t/ha, and on N\textsubscript{60} P\textsubscript{30} K\textsubscript{30} - 1.51 t/ha [5].

Khramtsov I.F. and Kuznetsova G.N. noted the varietal responsiveness of oilseed flax to mineral fertilizers in the conditions of the south of Western Siberia when they are cultivated on ordinary chernozems. In the experiment with application of fertilizers at a dose of N\textsubscript{30} P\textsubscript{60} K\textsubscript{60}, N\textsubscript{60} P\textsubscript{90} K\textsubscript{90}, N\textsubscript{90} P\textsubscript{120} K\textsubscript{20}, Legur, Isilkul and North varieties, showed the highest yield with N\textsubscript{60} P\textsubscript{90} K\textsubscript{90} applied, while the Falcon and N22768 formed the highest yield under the application of maximum doses of fertilizers. The yield increased depending on the variety, while a yield on control was 22-23.7 c/ha. With an increase in the dose to 23.6-26.3; 24.2-26.9 and 24.8-28 c/ha. Sokol and N22768 turned out to be more responsive [6].

Nitrogen fertilizers play a leading role in the fertilization system of oil flax on the soils highly supplied with phosphorus and potassium, which is typical of chernozems [7].

The introduction of resource-saving technologies in areas with unstable moisture using direct sowing caused a reduction in doses due to the application of fertilizers in a row with seeds and a decrease in the nitrogen dose. In addition, row spacings of 19-20 cm in modern complexes cause drying of the soil, competition of plants in a row with the formation of a small number of bolls. All of the above causes a low yield of flax.

The appearance on the market of liquid nitrogen and complex fertilizers, liquiizer aggregates, which allow them to be locally applied to the soil after sowing (or before sowing), makes it possible to solve the problem of optimizing flax nutrition, especially nitrogen.

The aim of the work was to study the effectiveness of the application of UAN-32, solid nitrogen and complex fertilizers in the cultivation of oilseed flax in the conditions of the moderately arid steppe of the Altai Territory.

2. Materials and Methods

Experiments with oil flax were carried out in 2017-2020, at the LLC "Orbita" farm located in the Mamontovsky and Kytmanovsky districts of the Altai Krai. The soils of the experimental plot - leached medium-thick low-humus medium loamy chernozems - were characterized by close to neutral pH\textsubscript{KCl}, low humus content, low N-NO\textsubscript{3} supply, high phosphorus and very high exchangeable potassium.

In 2017, the scheme of the experiment included options for the application of ammonium nitrate and its mixture with ammonium sulfate: N \textsubscript{24}; N \textsubscript{44}; N \textsubscript{6P} \textsubscript{26}; N \textsubscript{69}; N \textsubscript{69P} \textsubscript{26}.

In 2020, UAN-32 and diammophosca were applied: N \textsubscript{17P} \textsubscript{42}; N \textsubscript{38P} \textsubscript{42}; N \textsubscript{47P} \textsubscript{42} and N \textsubscript{59P} \textsubscript{42}.

The experiments were conducted against the background of the use of pesticides.

The Northern flax variety was cultivated with a potential seed yield of 23 kg/ha, formed under favorable weather conditions and the use of fertilizers.

Sowing was carried out with a John Deere 5430 seeder with a seeding rate of 50 kg/ha.

During the harvesting period, the number of balls per plant, the remaining density, seed yield, 1000 seed weight, protein and oil content were determined.

Analyses of quality indicators were carried out according to GOST standards: Protein-10846-91, Oil content-10857-64.

The reliability assessment was carried out by the method of variance analysis according to B.A. Dospekhov [8].
3. Results and Discussion

The weather conditions of 2017 were characterized by a lack of precipitation in June and July (5 mm fell in the 1st decade of July), which caused weak plant growth and, consequently, the formation of low productivity.

The growing season of 2020 was also characterized by a shortage of precipitation – 67% of the norm fell in the 3rd decade of May, 1st and 3rd decades of July with a higher number of temperatures at 192.5 °C more than the norm.

Considering that oilseed flax is very demanding on moisture availability, starting from the "herringbone" phase to the formation of balls, the years of research in general were unfavorable for obtaining high productivity of flax seeds, however, the use of fertilizers contributed to an increase in yield and quality indicators.

In earlier experiments in the cultivation of flax on grain predecessors, it was found that the application of azophoska during sowing in doses of 1-1.5 c/ha provided an increase in yield from 7.3 to 9.1-9.3 c/ha, combination of 1, 5 c/ha of azophoska with 0.25 c/ha of NH₄NO₃ increased yield to 11.1 c/ha, and the application of 2 c/ha of azophoska with 0.25 c/ha of NH₄NO₃ to 12.8 c ha [9]. Even the application of 1.5 c/ha of azofoski with 0.5 c/ha of NH₄NO₃ in an average of 2 years with repeated sowing of flax provided an increase in yield by 2.4 c/ha or 24%.

Table 1 shows the results of the influence of different combinations of fertilizers (UAN-32, ammonium nitrate, ammonium sulfate and ammophos) on the elements of the yield structure, the yield value and quality indicators.

Table 1. Efficiency of UAN-32 and solid mineral fertilizers (2017).

| №  | Variant    | Density, pcs/ p.m | Number of balls | Yield, c/ha | Increase c/ha | 1000 kernel weight, g | % of oil | Oil output, c/ha | % of protein | Protein output c/ha |
|----|------------|-------------------|-----------------|-------------|--------------|-----------------------|----------|------------------|--------------|-------------------|
| 1  | Control    | 51                | 14.0            | 11.2        | -            | 3.57                  | 41.6     | 4.65             | 25.1         | 2.8               |
| 2  | N₂₄        | 58                | 19.6            | 12.9        | 1.7          | 3.62                  | 43.6     | 5.62             | 21.7         | 2.8               |
| 3  | N₄₄S₂₄    | 52                | 19.5            | 13.0        | 1.8          | 3.71                  | 44.0     | 5.72             | 26.8         | 3.48              |
| 4  | N₄₆P₂₆    | 62                | 15.4            | 12.3        | 1.1          | 3.55                  | 42.9     | 5.27             | 19.8         | 2.43              |
| 5  | N₆₃        | 56                | 16.5            | 15.2        | 4.0          | 3.65                  | 41.0     | 6.23             | 31.8         | 4.83              |
| 6  | N₆₉P₂₆    | 62                | 17.2            | 17.3        | 6.1          | 3.60                  | 43.6     | 7.54             | 25.2         | 4.35              |

The least significant difference 0.5, c/ha 0.75

According to the obtained data, the plant density was in the range of 32-62 pcs/p.m with 51 - at the control. The low density according to variant N₄₄ is explained by the introduction of ammonium sulfate into the fertilizer, which, with low moisture availability, creates an increased concentration of soil solution. On fertilized variants, more bolls were formed per plant - 15.4 - 19.6 pcs. at 14.0 - on the control.

Due to the aridity of the growing season, a relatively low seed yield was formed: 11.2-17.3 c/ha with 11.2 on the control. At the same time, ammonium nitrate (N₂₄) and a mixture of it with ammophos (N₄₄ S₂₄) provided an increase in yield by 1.7 – 1.8 c/ha or 15.2 – 16.1%. The introduction of 0.5 c/ha of ammonophos during sowing contributed least of all to an increase in yield, which is explained by a low dose of nitrogen (N₄₆P₂₆) - the increase is 1.1 c/ha or 9.8%. An increase in the nitrogen dose to 63 kg with the introduction of UAN-32 - 150 l/ha provided an increase of 4 c/ha or an increase in yield by 1.36 times. The addition of 0.5 c/ha of ammophos to UAN-32 N₆₉P₂₆ during sowing increased the yield by 1.54 times and made it possible to obtain the largest increase of 6.1 c/ha.

Due to the dry conditions during the period of seed formation, the thousand-kernel weight was very low - 3.55-3.71 g with 3.57 g in the control. It was the highest 3.7 g on variant N₄₄ S₂₄, which is due...
to the low density and the introduction of sulfur (S24) into the fertilizer. According to the variants with the use of UAN-32, it was 3.6-3.65 g.

The level of oil content varied from 41 to 49% with 41.6% at the control. With the application of ammonium nitrate with ammonium sulfate and 150 l/ha of UAN-32 with 0.5 c/ha of ammophos during sowing, it was higher - 43.6-44%. Also, the introduction of one UAN-32 with a significant increase in yield (up to 15.2 c/ha) provides a high oil output - 6.23 c/ha, with its content of 41%. Both ammonium nitrate and its mixture with ammonium sulfate, with a relatively low increase of 1.7-1.8 c/ha, contributed to the formation of a high oil content of 43.6-44% and an oil output of 5.62-5.72 c/ha, which is 0.97-1.07 c/ha more than on the control. The most significant output was provided by the combination of UAN-32 with ammophos (N60 P26) - 7.54 c/ha, which was 1.62 times higher than the control.

The protein content in all variants was in the range of 19.8-31.8% with 25.0% on the control. The lowest content was obtained in the variant with the application of one ammophos (19.8), and the highest (31.8%) in the variant with the UAN-32 only. There was a relatively high amount of protein in flax seeds on the variant with application of ammonium nitrate with ammonium sulfate. There is a pattern of the effect of the nitrogen dose in the fertilizer - the higher it is, the more protein accumulates. The effect of sulfur in the composition of a mixture of ammonium nitrate with ammonium sulfate is noticeable. Changes in the quality indicators of flax seeds in arid conditions on leached chernozems in the moderately arid steppe of the Altai Territory show high efficiency of the application of UAN-32 in a dose of 150 l/ha and its combined use with 0.5 c/ha of ammophos.

In the conditions of 2020, in the experiment with the application of different doses of UAN-32 and 0.8 c/ha of diammophos under arid conditions of the 2nd decade of July and almost the whole of August at a density of 59-69 pcs./p.m., a low number of balls of 9.6-14.3 pcs. were formed with 11 pcs. on the control. Below the control – 9.6 - 10.8 pcs. they were formed according to variants N59 P42 and N17 P42, which is associated with density, especially according to N17 P42, where it was the largest (Table 2).

| n/a | Variant | density, pcs/ p.m | number of balls | Yield, c/ha | Increase c/ha % | thousand-kernel weight, g | % of oil | oil output, c/ha | protein content, % | Protein output, c/ha |
|----|---------|------------------|----------------|-------------|-----------------|-------------------------|---------|----------------|---------------------|---------------------|
| 1  | control | 59               | 11.0           | 10.8        | -               | 6.65                    | 42.9    | 4.6           | 16.4                | 1.77                |
| 2  | N30     | 59               | 13.5           | 12.4        | 1.6             | 14.8                    | 7.04    | 40.3          | 5.0                 | 15.8                |
| 3  | N17P42  | 69               | 10.8           | 13.1        | 2.3             | 21.3                    | 7.41    | 44.6          | 5.8                 | 14.7                |
| 4  | N38P42  | 52               | 14.6           | 14.0        | 3.2             | 29.6                    | 7.9     | 44.1          | 6.2                 | 19.2                |
| 5  | N59P42  | 63               | 14.3           | 14.1        | 3.3             | 30.5                    | 7.8     | 43.4          | 6.1                 | 17.1                |
| 6  | N59P42  | 66               | 9.6            | 14.8        | 4.0             | 37.0                    | 7.6     | 43.7          | 6.5                 | 15.5                |

The least significant difference 0.5, c/ha 0.9

Taking into account the density, the number of balls and the greater fulfillment of seeds under the influence of fertilizers, a higher yield was obtained: 12.4-14.8 c/ha versus 10.8 c/ha on the control variant. The increase was 14.8-37%. At the same time, with an increase in the nitrogen dose, it increased from 21.3% for the N17P42 variant to 29.6-37% for the combinations, where the nitrogen dose increased to 38-59 kg/ha. The highest increase was formed according to the variant N59 P42.

The seed quality indicators have also changed: the thousand-kernel weight increased from 6.65 g to 7.04-7.9 g at different doses of UAN-32 with diammophos.

The oil content for the fertilized variants varied from 40.3 to 44.6% with 42.9% in the control. UAN-32 at a dose of 50 l/ha slightly reduced the oil content, which is due to the absence of
phosphorus in the composition of fertilizers, which affects fat metabolism. For the remaining variants of fertilizer combinations, the oil content was significantly higher than the control - 43.4-44.6%. The oil output increased compared to the control by 0.4-1.9 c/ha and the highest was 6.1-6.5 c/ha versus 4.6 c/ha at the control, it was obtained by applying UAN at doses of 50, 70 and 100 l/ha together with 0.8 c/ha of dammophos.

The amount of protein on the fertilized variants has changed in different ways: above the control, it was obtained by combinations of N_{38}P_{42} and N_{47}P_{42} – 17.1-19.2%. It was significantly lower than the control on the combination of N_{17}P_{42} with the lowest nitrogen content. However, the protein yield for all variants exceeded the control level from 1.77 to 1.89-2.69 c/ha and it was higher for combinations of UAN and dammophos - 2.29-2.69 c/ha. There is a tendency for a greater accumulation of oil on variants with the addition of phosphorus, with a lowering effect of the introduction of one UAN-32, while UAN-32 in combination with dammophos increases the amount of protein.

4. Conclusion

The results obtained allow us to say that in unfavorable years in terms of moisture supply, the application of UAN-32 at a dose of 70-180-150 l/ha, together with the pre-sowing application of ammophos and dammophos, provides according to options N_{69}P_{26}; N_{47}P_{42} and N_{59}P_{42} yield, respectively, 17.3 c/ha (4.47% increase), 14.1 c/ha (30.5% increase) and 14.8 c/ha (37% increase). Against the background of high availability of phosphorus and potassium, UAN-32 150 l/ha increased seed yield by 35.7% (an increase of 15.2 c/ha). The oil output increased, respectively, from 4.6-4.61 c/ha to 7.54; 6.1-6.5 c/ha, and protein from 2.8-1.77 to 4.35 and 2.29-2.41 c/ha.

The combination of UAN-32 with ammophos and dammophos provides the highest oil content of seeds, and an increase in the dose of nitrogen in combinations increases the content and yield of protein.

References

[1] Gainulin R M 2008 Let's revive oilseed flax Dostizheniya nauki i tekhniki APK [Achievements of science and technology of the agro-industrial complex] 5 37-38
[2] Vinogradov D V, Peregudov V I, Artemova N A and Polyakov A V 2010 The peculiarity of the formation of the productivity of oilseed flax at different levels of nutrition Agrohimicheskij vestnik [Agrochemical Bulletin] 3 23-24
[3] Vinogradov V D and Kuntsevich A A 2015 The influence of seeding rates and fertilizers on the productivity of oilseed flax Vestnik KrasGAU [Bulletin of KrasGAU] 6 182-186
[4] Kochkin A C and Esaulko A N 2010 Optimization of mineral nutrition of oilseed flax on leached chernozem Plodorodie [Fertility] 2 34-35
[5] Shumskaya A A, Ermokhin Yu I 2015 The effect of nitrogen fertilizers on the yield of oilseed flax on ordinary chernozem of the steppe zone of the Poltava district of the Omsk region pp 7-12
[6] Khramtsov I F, Kuznetsova G A 2004 Varietal responsiveness of oilseed flax to mineral fertilizers Agrohimiya [Agrochemistry] 10 33-37
[7] Antonova O I 2013 Oilseed flax: attitude to soils. Features of nutrition and fertilizers (Barnaul, AGAU) pp 58
[8] Dospelkov B A 1985 The methodology of the experimental case (M., Kolos) pp 453
[9] Antonova O I and Latartsev P Yu 2014 The effectiveness of the starter application of ammonium nitrate and azofoska for oilseed flax during its re-sowing Vestnik Altajskogo GAU [Bulletin of the Altai State Agrarian University] 116(6) 5-10