

The effect of the nitrification inhibitor 3,4 dimethylpyrazole phosphate on the productivity of winter oil seed rape at different rates of nitrogen fertilizers

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Objective. *To determine the effect of the use of nitrification inhibitor (NI) 3,4 dimethylpyrazole phosphate at different rates of nitrogen fertilizers in combination with urea-ammonia mixture (UAN-32) on the yield of winter rape seeds. To determine the difference in the yield of winter rape under the condition of using different rates of UAN-32 with and without the addition of NI. **Methods.** Field (stationary experiment); laboratory (agrochemical analysis of soil and plant samples); analytical (systematic analysis of long-term results of field experiment and meteorological observations); mathematical and statistical; correlation and regression analysis; mathematical modeling and empirical generalization of established regularities. **Results.** It was confirmed that the use of nitrification inhibitor (NI) together with UAN-32 significantly affected the yield of winter rape. On average, for 3 years of research in 2018, 2020 and 2021, at the same rate of nitrogen fertilization, the variant Control+N₁₃₀ with the use of NI showed an increase in yield by 0.37 t/ha or 13.3% compared to the variant Control+N₁₃₀ without the use of NI, and the variant with a reduced rate of nitrogen fertilizers Control+N₁₂₀ with the use of NI compared to the variant with an increased rate of nitrogen fertilizers Control+N₁₃₀ but without the use of NI also recorded an increase in yield of 0.27 t/ha or 9.7%. **Conclusions.** It was found that the increase in yield on the variants Control+N₁₂₀ and Control+N₁₃₀ using a nitrification inhibitor (NI) compared to the control N₁₀P₃₀K₄₀ (Control) was 0.58-0.68 t/ha (23.4-27.4%), and on the variants Control+N₁₂₀ and Control+N₁₃₀ using NI compared to the variant Control+N₁₃₀ but*

without using NI, an increase in yield was found in the range of 0.27-0.37 t/ha (9.7-13.3%) for 3 years of research in 2018, 2020 and 2021.

Keywords: nitrogen nutrition, yield, nitrogen losses, ammonium and nitrate nitrogen, urea-ammonia mixture, nitrification.

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Nitrogen inhibitors are a class of agrochemicals used to reduce nitrogen losses in agricultural systems. These inhibitors slow down the conversion of nitrogen forms that are susceptible to loss, such as nitrates, and instead promote the retention of nitrogen in the soil where it can be taken up by plants [1]. These inhibitors help to increase the efficiency of nitrogen use in plants, which leads not only to higher crop yields but also to improved soil quality [2, 3]. It has also been proven that the use of nitrogen inhibitors can reduce greenhouse gas emissions in agricultural systems by reducing the release of nitrous oxide, which is a harmful greenhouse gas produced during nitrification and denitrification [2, 4-6].

The nitrification inhibitor under study, 3,4-dimethylpyrazole phosphate, was developed by the German chemical concern BASF in 1994-1999 from products of the pyrazole group. The main characteristics of this nitrification inhibitor are that it has no negative effect on soil fertility, has no intermediate toxic components in the inhibition process and does not create a toxic effect on plants and living organisms, is easy to use, leads to increased plant nitrogen uptake from fertilizers and soil, and reduces nitrogen losses due to reduced levels of leaching and denitrification (gaseous losses) [7, 8-10].

The use of nitrogen inhibitors is strictly regulated by regulatory agencies in many countries, with specific limits on use, application rates and frequency of application [11]. The nitrification inhibitor 3,4-dimethylpyrazole phosphate is also regulated. According to the decision of the European Union Regulatory Commission No. 1257/2014 amending Regulation (EC) No. 2003/2003 of the European Parliament and of the Council as regards fertilizers and amending Annexes I and IV of 24 November 2014, the rate of use of 3,4-dimethylpyrazole phosphate (EC No. 424-640-9) is set at a minimum of 0.8% and a maximum of 1.6% [12].

The purpose of the research is to study the effect of the nitrification inhibitor 3,4-dimethylpyrazole phosphate (NI) applied together with UAN-32 (urea-ammonia mixture) on the yield of winter rape seeds over 3 years of research in 2018, 2020 and 2021.

Materials and methods of research. The research was carried out at the research station of “Druzhba Nova” LLC in Varvynskyi district, Chernihiv region (a branch of the Kernel agricultural holding). The soil of the experimental plot is typical low-humus black soil, the arable layer of which is characterised by the following main indicators: humus content - 3.4%, pH neutral and close to neutral - 5.7-7.0, mobile phosphorus content - high and very high - 15.4-26.3 mg/100 g of soil, exchangeable potassium - medium to high - 7.1-16.2 mg/100 g of soil, and the content of easily hydrolyzed nitrogen is increased to high – 5,7-7,9 mg/100 g of soil. The research was conducted according to the scheme of a one-factor experiment. The sown area of the experimental plot was 0.6 hectares, the alternation of variants was sequential. The field experiments were laid out and carried out according to the methodology of field experiments (Dospikhov B.A., 1985). Harvest accounting was carried out by continuous harvesting and weighing of the bunker mass from each plot with subsequent recalculation to standard moisture and weediness according to DSTU 2240-93 in 3 replicates. Mathematical and statistical data were calculated using the Agrostat software and information system.

To calculate the rate of use of the nitrification inhibitor 3,4-dimethylpyrazole phosphate on UAN-32, it was taken into account that 78 kg of ammonium nitrogen NH_4^+ and 156 kg of amide nitrogen NH_2^- are required to be inhibited per 1000 kg of available UAN-32, which gives a total of 234 kg of ammonium nitrogen NH_4^+ and amide nitrogen NH_2^- , i.e. the total nitrogen to be inhibited. In accordance with the regulation, the minimum rate of the inhibitor 3,4-dimethylpyrazole phosphate was used at 0.8% (234 kg of nitrogen. 0.8% = 1.87 kg), so 1.87 kg of NI was required at 100% concentration. The fertilizer with a concentration of 24.9% was used, so the rate of 1.87 kg of DMPP with 100% concentration should be converted to a concentration of 24.9% ($1.87 \text{ kg}/24.9\% = 7.51 \text{ kg}$ of fertilizer with a concentration of 24.9% per 1000 kg of UAN-32). Since the NI is a liquid with a density of 1.07 kg/l, for ease of use in the field, it should be converted to l/ha ($7.51 \text{ kg}/1.07 \text{ kg/l} = 7.02 \text{ l}$ of NI per 1000 kg of UAN-32). The rate of use of the nitrification inhibitor 3,4 dimethylpyrazole phosphate on UAN-32 is 7.02 litres per 1000 kg of UAN-32. According to the above calculation, the calculated rate of NI for UAN-32 with a rate of 300 kg/ha was 2.11 l/ha at the rate of UAN-32, 350 kg/ha - 2.45 l/ha.

The following variants were used in the experiment with the application of appropriate fertiliser rates:

Control - N₁₀P₃₀K₄₀, granular fertilizer NPK 7-20-28 was applied at a rate of 150 kg/ha for sowing.

Control + N₁₂₀ + NI was additionally applied with granular ammonium sulphate at a rate of 100 kg/ha on permafrost soil and UAN-32 at a rate of 300 kg/ha with the addition of NI in the spring after the vegetation recovery.

Control + N₁₃₀ + NI was additionally applied with granular ammonium sulphate at a rate of 100 kg/ha on frozen soil and UAN-32 at a rate of 350 kg/ha with the addition of NI in the spring after the vegetation recovery.

Control + N₁₃₀ was additionally applied with granular ammonium sulphate at a rate of 100 kg/ha on frozen soil and UAN-32 at a rate of 350 kg/ha without the addition of NI in the spring after the vegetation recovery.

Research results. Starting from the moment of spring vegetation renewal, rapeseed becomes extremely demanding to nitrogen nutrition. The reason for this is the active process of restoring the vegetative mass damaged in winter and the need to build up a new leaf apparatus for further growth and development. The main problem for this crop is that the process of nitrogen assimilation is active and requires constant availability up to the budding and flowering stages.

1. Yield of winter rape depending on the use of different rates of nitrogen fertilizers with the addition of a nitrification inhibitor (2018-2021), t/ha

Variant	Yield, t/ha			Average yield, t/ha
	2018	2020	2021	
N ₁₀ P ₃₀ K ₄₀ (Control)	3,12	2,21	2,11	2,48
Control+N ₁₂₀ +NI	3,70	2,79	2,70	3,06
Control+N ₁₃₀ +NI	3,85	2,98	2,66	3,16
Control+N ₁₃₀	3,45	2,31	2,60	2,79
LSD ₀₅	0,312	0,266	0,363	–

To achieve optimal yields, it is important to pay attention not only to the selection of the right form of nitrogen for the plant, but also to the optimal distribution of the nutrient throughout the critical period of its assimilation. The best option for achieving optimal growth and development of a given crop and obtaining high yields in the future is to use a nitrification inhibitor in combination with UAN, as it is the nitrification inhibitor that can ensure uniform nitrogen uptake by the plant during the

critical period and at the same time significantly reduce nitrogen losses from the soil, keeping it only for the needs of the crop.

According to the research results (Table 1), the yield of winter rape varied depending on the years of research. Thus, the yield of winter rape in all experimental variants was higher in 2018 (3.12-3.85 t/ha). Yields in 2020 and 2021 were relatively at the same level (2.21-2.98 t/ha and 2.11-2.7 t/ha), respectively. The average yield of winter rape in all experimental variants in 2018-2021 ranged from 2.11-3.85 t/ha. The yield of winter rape in the control variant, control ($N_{10}P_{30}K_{40}$), in 2018-2021 was the lowest – 2.11-3.12 t/ha, which averaged 2.48 t/ha for 3 years. The yield in the variant Control+ N_{130} without NI during the years of research was in the range of 2.31-3.45 t/ha, with an average of 2.79 t/ha for 3 years. The yield in the variants, Control+ N_{120} and Control+ N_{130} with NI, in 2018-2021 was the highest compared to other variants of the experiment – 2.7-3.7 t/ha and 2.66-3.85 t/ha, which averaged 3.06 t/ha and 3.16 t/ha, respectively. The highest yield was in the variant Control + N_{130} with NI for 2 years of research (2018 and 2020). In 2018, the yield increase was 0.73 t/ha compared to the control variant ($N_{10}P_{30}K_{40}$), 0.4 t/ha compared to the variant Control+ N_{130} without NI and an increase of 0.15 t/ha compared to the variant Control+ N_{120} with NI. In 2020, a similar trend was observed and the yield increase was 0.77 t/ha, 0.67 and 0.19 t/ha, respectively. With an increase in nitrogen rates from N_{120} to N_{130} (which corresponds to an increase in UAN-32 rates from 300 kg/ha to 350 kg/ha), the highest yields were not always formed with the nitrification inhibitor. Thus, in 2021, the best result was in the variant Control + N_{120} with NI, the yield was 2.7 t/ha. The increase was 0.59 t/ha compared to the control variant, Control ($N_{10}P_{30}K_{40}$), 0.1 t/ha compared to the variant Control+ N_{130} without NI and 0.4 t/ha compared to the variant Control+ N_{130} with NI, given that the rate of UAN-32 in the latter was 50 kg/ha higher (350 kg/ha versus 300 kg/ha of UAN-32) plus NI in both variants. The LSD_{05} in 2018 was 0.312 t/ha, in 2020 – 0.266 t/ha and in 2021 – 0.363 t/ha. The levels of LSD_{05} by years were lower than the yield increase, which indicates that in the experiment the yield increase exceeds the potential error of the experiment.

The average yield of winter rape in 2018-2021 was 2.48 t/ha in the control variant $N_{10}P_{30}K_{40}$ (Control), 3.06 t/ha in the variant Control+ N_{120} with NI, 2.79 t/ha in the variant Control+ N_{130} without NI, the highest average yield – 3.16 t/ha was in the variant Control+ N_{130} with NI (Table 2). Thus, using NI together with the norm of nitrogen in N_{130} , the final result was an increase in yield of 0.648 t/ha compared to the control

variant N₁₀P₃₀K₄₀ (Control), an increase of 0.37 t/ha - compared to the variant Control+ N₁₃₀ without NI, and a slight increase in yield of 0.1 t/ha - compared to the variant Control+ N₁₂₀ with NI.

2. Yield of winter rape depending on the use of different rates of nitrogen fertilizers with the addition of a nitrification inhibitor (2018-2021), t/ha

Variant	Average yield, t/ha	+/- to control	
		t/ha	%
N ₁₀ P ₃₀ K ₄₀ (Control)	2,48	–	–
Control+N ₁₂₀ +IH	3,06	0,58	23,4
Control+N ₁₃₀ +IH	3,16	0,68	27,4
Control+N ₁₃₀	2,79	0,31	12,5

Analysing the data of average yield in comparison with the control variant N₁₀P₃₀K₄₀ (Control), a significant deviation in the yield increase in all variants of the experiment was noted. Thus, the increase in yield compared to the control variant N₁₀P₃₀K₄₀ (Control) in the variant Control+ N₁₂₀ with NI was 0.58 t/ha, or 23.4%, in the variants Control+ N₁₃₀ without NI and Control+ N₁₃₀ with NI – 0.31 t/ha and 0.68 t/ha, or 12.5% and 27.4%, respectively. In the variant Control+ N₁₃₀ with NI, the yield increase compared to the variant Control+ N₁₃₀ without NI was 0.37 t/ha, or 14.9%, in the variant with a reduced nitrogen rate Control+ N₁₂₀ with NI it was 0.1 t/ha, or 4.0%.

Conclusions.

Experimental studies have proved that the use of the nitrification inhibitor 3,4-dimethylpyrazole phosphate together with nitrogen fertilizers (in our case, when used in combination with UAN-32) is an effective agronomic measure that significantly affected the yield of winter rape during all 3 years of research (2018, 2020 and 2021). It was found that the yield in the variants with the use of NI compared to the control (N₁₀P₃₀K₄₀) increased by 0.58-0.68 t/ha (23.4-27.4%). On average, over 3 years of research (2018, 2020 and 2021), with the same rate of nitrogen fertiliser Control + N₁₃₀ in the variant with the use of NI, the yield of winter rape increased by 0.37 t/ha, or 14.9% compared to the variant where the same rate of nitrogen Control + N₁₃₀ was used without NI. In the variant with a reduced rate of nitrogen Control + N₁₂₀ with NI compared to the variant with an increased rate of Control + N₁₃₀, but without NI, the yield was 0.27 t/ha or 10.9% higher.

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The effect of the nitrification inhibitor 3,4 dimethylpyrazole phosphate on the yield of winter oil seed rape in combination with different rates of nitrogen fertilizers

Purpose: To determine the effect of nitrification inhibitor 3,4 dimethylpyrazole phosphate with different rates of nitrogen fertilizers in combination with UAN-32 solution on the yield of winter oil seed rape seeds. To define difference in yield of winter oil seed rape in terms of using different rates of UAH-32 solution with and without adding nitrification inhibitor. **Methods:** Field (stationary experiment); laboratory (agrochemical analysis of soil and plant samples); analytical (systematic analysis of long-term results of field experiments and meteorological observations); using mathematical and statistical methods, correlation and regression analysis, mathematical modeling and empirical generalization of established patterns). **Results:** It has been confirmed that the use of the nitrification inhibitor (NI) in combination with UAN-32 solution significantly affected the yield of winter oil seed rape. On average, over the 3 years of research in

2018, 2020 and 2021 under same rates of nitrogen fertilizers on variant Control+N₁₃₀ with NI shows yield increase on 0.37 t/ha or 13,3% in comparison with variant Control+N₁₃₀ without NI and on variant with reduced rate of nitrogen fertilizers Control+N₁₂₀ with using NI in comparison with increased rate of nitrogen fertilizer Control+N₁₃₀ but without NI was also detected yield increase on the level 0.27 t/ha or 9,7%. **Conclusions:** It has been determined that yield increase on the variants Control+N₁₂₀ and Control+N₁₃₀ with using NI in comparison with control N₁₀P₃₀K₄₀ (Control) was in the range 0.58-0.68 t/ha (23,4-27,4%) and on variants Control+N₁₂₀ and Control+N₁₃₀ with using NI in comparison with variant Control+N₁₃₀ but without using NI was determined yield increase in the range 0.27-0.32 t/ha (9,7-13,3%) during 3 years of research 2018, 2020 and 2021.

Key words: *nitrogen nutrition, yield, nitrogen loses, ammonium and nitrate nitrogen, urea-ammonia solution, nitrification.*

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***"Influence of nitrification inhibitor 3,4-dimethylpyrazole phosphate on the
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(S.V. Muntian)

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