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RESEARCH ARTICLE

The efficiency of urea-ammonium nitrate application in inter-rowfeedinginmaize cultivation

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Abstract

The issue of influence on the level of grain maize yield of different rates of application of Urea Ammonium Nitrate (UAN-32) in the BBCH 17-18 phase is highlighted. The fertilizer was applied by inter-row cultivation with a mounted cultivator IRIS-T. The most optimal rate of nitrogen fertilizer application during root application is N_{35}, in conditions of dark gray soil, on loess loam in the Polissya zone of Ukraine, against the background of applied nitrogen N_{98} in autumn and when sowing N_8 as part of a complex fertilizer (YaraMila 8-24-24). The application rate of UAN above N_{35} reduces grain yield and profitability. Applied during the growing season, the norms of N_{16}-N_{35} of nitrogen fertilizer contribute to an increase in the height, weight of the plant, leaf surface area and grain yield.

Keywords: fertilizer rates, nitrogen, yield, productivity, corn, inter-row cultivation, UAN (Urea Ammonium Nitrate).

Introduction

Nitrogen application is one of the key points in the grain maize fertilization system. Numerous works of researchers give examples of the use of nitrogen fertilizers in different forms, at different times, and methods of application (Kharchenko et al., 2021a; Simon et al., 2022). But there are still discussions about the rapid availability of ammonium and nitrate nitrogen to the plant (Lopushniak et al., 2021). A number of scientists talk about the significant impact on the development of maize is the application of nitrogen fertilizer in pre-sowing tillage (Zakharchenko et al., 2023a). There is also information about the positive effect of nitrogen application in the composition of pre-sowing complex fertilizer for the optimal beginning of the growing season and the biological cycle. But in the fertilization system, the importance of foliar feeding and, in recent times, also root nutrition is distinguished. It is known that the maize plant has critical phases of development and at this time the signs of physiological starvation for certain nutrients, in particular, nitrogen, are too acute (Zakharchenko et al., 2023b; Zhang et al., 2023). Therefore, nitrogen application during the growing season is carried out mainly in the BBCH 13-17 phases. The nitrogen supply of the plant also depends on the type of soil (Zanella et al., 2022), place in the crop rotation (Mishchenko et al., 2019; Ivanov et al., 2019;

Palamarchuk et al., 2021a), weather and climatic conditions (Kharchenko et al., 2021b) the location of the field/plant on the ground (Dindaroglu et al., 2021), and the tillage system.

The application of nitrogen fertilizers affects the increase in plant height, leaf surface area, chlorophyll content, plant weight, grain weight per cob and, accordingly, a higher yield. The quality of the grain also depends on the application of nitrogen fertilizers.

The desire for super-high grain yields leads to the use of high doses of nitrogen, especially during fertigation, but this can cause nitrogen losses in the form of nitrates or nitrogen gases. The addition of urease inhibitors significantly reduces ammonia evaporation. Application of UAN, together with nitrification inhibitors and urease, increases the available nitrogen content for the plant and reduces the loss of nitrate nitrogen. Both UAN alone and in combination with the above-mentioned compounds, there is an increase in the nitrogen content in the grain, in general the grain yield (Palamarchuk et al., 2018; Ren et al., 2023). But there are other opinions that it is better not to mix UAN with inhibitors (Li et al., 2023).

Materials and Methods

The research was carried out in production conditions on the territory of the farm of LLC "State Enterprise "Zernyatko" of the Koryukiv district of the Chernihiv region. The geographical coordinates of the location of the plots are 51.549364,32.375249. The field is dominated by dark gray podzolic medium-loamy soil on loess loam. Total humus content is 3.05 % (according to Tyurin), pHKCl 5.04, pHH_2O 5.76, NO_3+NH_4+12.6 mg kg^{-1} (very low), mobile phosphorus 77.8 mg kg-1 according to Machygin (medium level), exchangeable potassium 49.5 mg/kg according to Kirsanov (medium level), sulfur content 15.95 mg kg^{-1} (very high), exchangeable calcium 5.99 mg-eq/100 g according to Schollenberg (medium), magnesium 1.01 mEq/100 g according to Scholenberg (medium). The content of microelements is low: zinc 1.32 mg kg^{-1}, copper 0.13 mg kg^{-1}, manganese 6.38 mg kg^{-1} (atomic absorption spectrometry method), boron 0.19 mg kg^{-1} (hot water determination). Since the soil pH is slightly acidic, there is a decrease in the level of absorption of phosphorus, potassium, nitrogen and these microelements. Liming has not been carried out for twenty years. The area of the accounting plot is 50 m2 with the three replications. The research was conducted in 2021-2022. The predecessor of maize in field crop rotation is sunflower. UAN-32 was used in inter-row fertilization in the development phase of BBCH 17-18 maize. Inter-row fertilization was carried out by the IRIS-T mounted unit in combination with the John Deere 6135 tractor. The Pioner 8816 maize hybrid was used in the experiment, the results of the experiment were recorded after threshing each plot and weighing threshed crop on truck scales. Moisture during harvesting was 22%-23% and was converted to 14% moisture when calculating the crop.

The scheme of the experiment is as follows:

1. Control (without inter-row fertilization UAN).
2. Inter-row fertilization UAN-32 50 l ha-1 N16.
3. Inter-row fertilization UAN-32 80 l ha^{-1} $N_{25.6}$.
4. Inter-row fertilization UAN-32 110 l ha^{-1} with N_{35}.
5. Inter-row fertilization UAN-32 140 l ha^{-1} $N_{44.8}$.

Biometric indicators, namely the measurement of plant height and leaf surface area, were carried out in the phase of milky ripeness of the plant. The leaf surface area was determined by measuring the length and width of the leaf and multiplying by a conversion factor of 0.67. The results of the analysis were calculated statistically using Agrostat program.

The main cultivation of the field was carried out in a complex with the application of nitrogen fertilizer with a unit for the application of anhydrous ammonia 120 kg ha^{-1} to a depth of 20 cm-22 cm. Sowing of maize was carried out on April 20-25, 2021-2022 with a norm of 75 000 plants ha-1 to a depth of 3 cm-4 cm. Sowing was carried out with a Kinze 3600 tilled sixteen-row seeder, with a row spacing of 70 cm. Along with sowing, Yara Mila 8-24-24 complex fertilizer was applied at a rate of 100 kg ha^{-1} in physical weight.

Results and Discussion

Tab. 1 shows the results of measuring the height of the plant and the leaf surface area in the phase of milky-wax ripeness. As you can see, the plants react to the applied fertilizer and with an increase in the nitrogen rate in the UAN, the height of the plant increases. This is a proven fact of the effect of nitrogen on plants. There is a significant difference between the variants and a direct correlation with the increase in the norm. The results of determining the leaf surface area of the maize plant depending on the applied doses of UAN in inter-row cultivation also confirm our previous statements and the stable conclusions of agrochemists that nitrogen fertilizers have a significant impact on the above-ground mass, on the development of photosynthetic potential that can maximize the use of solar energy.

Table 1. **Biometric indicators of maize plants (average for 2021-2022)**

Variant	Plant height, cm	Leaf surface area, thousand m^2 ha^{-1}
1. Control (without applying UAN to inter-row cultivation)	246.7	46.8
2. UAN-N_{16}	250.2	47.2
3. UAN-$N_{25.6}$	252.4	47.4
4. UAN-N_{35}	254.1	47.5
5. UAN-N_{48}	256.5	47.8
LSD_{05}	0.9	0.3

Since the application of UAN was carried out in the root zone in the phase of 7-8 leaves, there was no difference in the dates of the onset of the phase of 11 leaves, panicle ejection, milky and wax ripeness and is not given in the article.

Scientists of Vinnytsia National Agrarian University also emphasize that foliar and root fertilization of maize affect not only the height of the plant and the area of the leaf apparatus, but also the height of the cob attachment, the length of the cob leg, and the number of cob wrappers (Palamarchuk & Solomon, 2021b). Scientists also note that the effect of fertilizer has a different effect on maize hybrids with different FAO, in them it was the early-ripening hybrid that had the highest response to the applied fertilizers – Ecolist, Rostok, Vympel.

In some cases, the biometric indicators may be lower than at the control. For example, if the research is aimed at studying the effects of soil pollutants on plant growth, development and grain yield. Scientists of the National Scientific Center "Institute of Agriculture of the National Academy of Agrarian Sciences of Ukraine" (Korsun et al., 2016) note that when polluted, all parameters of the photosynthetic potential of the plant decrease by 5, 10 and 100 times.

Tab. 2 shows the weight of the leaf-stem mass of one maize plant and the weight of grain from the cob as one of the important elements of nitrogen fertilizer application efficiency. It is the ratio of the main and by-products that reflects the effect of the applied fertilizer and other factors influencing the yield of the crop. (Tab. 2).

Table 2. **Structural elements of maize plant yield**

Experiment Option	Weight of leaf-stem mass and cobs of 1 plant, kg	Grain weight per cob, kg	Yield, t ha^{-1}
1. Control (without applying UAN to inter-row cultivation)	0.435	0.131	12.82
2. UAN-N_{16}	0.491	0.142	13.21
3. UAN-$N_{25.6}$	0.515	0.152	13.42
4. UAN-N_{35}	0.529	0.164	13.66
5. UAN-N_{48}	0.545	0.162	13.60
LSD_{05}	0.013	0.012	0.25

The weight of the leaf-stem mass together with the cobs is 0.435 kg-0.545 kg and is directly proportional to the applied UAN rate. We cannot say the same about the mass of grain on the cob. There is a significant difference between the variants, with the exception of a UAN of 110 kg ha^{-1} and a UAN of 140 kg ha^{-1}, between which there is no difference. That is, with the acquisition of a greater weight of the leaf-stem mass, the weight of the grain from the cob decreased.

According to the study, we observe, as expected, that in the control area, the yield of grain maize is the lowest among other studied variants and amounts to 12.82 tha^{-1}. The reason is that no additional nitrogen rates were received in this area. The next plot with a root fertilization rate of 50 kg ha^{-1} of the physical weight of UAN fertilizer after harvesting and its calculation showed a yield of 13.21 t ha^{-1}, which is 0.39 tons more than in the control. The experimental plot with a fertilization rate of 80 kg ha^{-1} gave a yield of 13.42 t ha^{-1}, which is relatively higher than the previous one and gave an increase in yield relative to the control by 0.6 t ha^{-1}. The largest relative increase was given by the plot with the UAN application rate of 110 kg ha^{-1}–0.84 t. The experiment with the norm of 140 kg-1 ha of nitrogen fertilizer, although it showed an increase in yield, which was 0.78 t, did not continue the pattern of the experiment to increase the yield with an increase in the fertilizer rate. Thus, the study showed that an increase in the application rates of UAN in the root fertilization of maize is accompanied by an increase in yield, but stops increasing it after an increase in the application rate of more than 110 kg ha^{-1}. These results can be explained by physiological processes in plants, as well as by the rules of agriculture. Plants always absorb only those elements that are necessary for their life, and they do so only in the quantities they need. They are not able to replace some elements with others, since each plays its own role in biochemical processes. Turning to the rules of agriculture established by Justus Liebig, we find an explanation for the results of the experiment, namely, the law of optimum, which explains that the greatest yield can be obtained under conditions of optimal concentrations of elements available to plants. Because the closer the optimal concentration of all the necessary components for plants is, the more efficiently they are used, which is reflected in the increase in yield. Therefore, the rate of 110 kg ha^{-1} of UAN, which in terms of the active ingredient is 35 $kgha^{-1}$ of nitrogen, creates the most optimal concentration of elements necessary for maize plants. An increase in the rate to 140 $kgha^{-1}$, equivalent to 45 $kgha^{-1}$ of nitrogen for the active substance, led to a further decrease in yield, as the concentration shifted again.

In this experiment, it is also appropriate to talk about the principles of antagonism and synergy of ions. Antagonism can be explained by the decrease in yield gain after application of a rate greater than 110 kg ha^{-1}, since the excess of nitrogen compounds led to competition of elements when absorbed by the roots and led to a greater deficiency of others in plants. Also, at the norm that made it possible to obtain the highest yield, the phenomenon of synergy manifested itself, when, at optimal norms of the content of elements, they increased the effect of each other.

Such data confirm the work of a number of scientists. For example, in North Carolina, when UAN was applied at different doses from 39 kg ha^{-1} to 235 kg ha^{-1}, the yield increased significantly (Cahill et al., 2007). Chinese scientists investigated the effectiveness of adding phosphorus, magnesium and sulphur to UAN in the cultivation of grain maize in different doses and rates. The main factor influencing the effectiveness of a particular fertilizer was weather conditions. A good effect was obtained with pre-sowing application of urea mixture with phosphorus and then in top feeding together with sulfur, the increase in grain yield was 29%-35% (Li et al., 2021). Other scientists have also noted that the use of nitrogen in the cultivation of maize above 300 kg ha^{-1} is excessive and can lead to a decrease in the utilization rate of nitrogen and other elements and can cause environmental problems such as eutrophication of water bodies and global warming (Zhang et al., 2015; Good & Beatty, 2011).

The use of nitrogen fertilizers, in particular, urea ammonium nitrate, increases the yield of grain maize, but in a specific natural and climatic zone, it is necessary to select the appropriate scientifically based dose and timing of fertilizer application for the best effect and profitable economic efficiency.

Conclusions

The application of UAN has a positive effect on the height of maize plants and the area of the leaf surface. The level of exposure depends on the dose of nitrogen application. With an increase in the rate of nitrogen, the weight of the leaf-stem mass and grain increases. The introduction of urea ammonium nitrate with inter-row tillage in root fertilization in the phase of 7-8 leaves increases the yield of grain maize. The increase in yield increases approximately uniformly with an increase in the application rate of UAN, therefore, with limited resources, its application is also advisable, since it also brings additional income. In the conditions of dark gray forest soils of the Chernihiv Polyssia of Ukraine, it is recommended to use UAN-32 on maize crops with inter-row cultivation in the root application with rates of up to 110 kg ha-1 in the phase of 7-8 leaves to increase yield.

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