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NITROGEN FERTILIZERS AND BIOECONOMIC AGRICULTURE – EXAMPLE ON WHEAT

MIHAI BERCA [1], VALENTINA-OFELIA ROBESCU [2], MIRCEA DUICĂ [3], ROXANA HOROIAŞ [4]

Abstract: *All the scenarios and models made up by the most titled scientists in biology, agriculture, geophysics, and human health prove that the four main resources of the existence of the biosphere are so polluted that it is a matter of time until a major collapse of human existence occurs. The problem is not that it will occur, but when it will occur, in what form and how great the losses will be. Among the many factors to be applied in agriculture in order to get food, the nitrogen fertilizers play an important part. Nitrogen fertilizer application has increased crop production by about 3-4 times, but at the same time it has reduced the content of heteropoly condensate humus by 3-4 times, especially in the countries of the Eastern Europe. Both European and world specialists have found that there is a large difference in the environmental (qualitative) behaviour between the two major fertilizers applied - ammonium nitrate and urea. The research carried out by us in the experimental field of Poroschia (Teleorman County) between 2014 and 2016 showed a significant difference in the organic and productive-qualitative behaviour in favour of the ammonium nitrate. In wheat crops, the ammonium nitrate is superior to urea, at the same applied dose, averaging 3.5-8.0 q/ha and with a protein content of 0.3-1.5%. The degree of absorption of ammonium nitrate is about 15-20% higher than that of urea. The volatilization degree of the two products is different, with a difference of 15-20% in favour of urea, which at the same time pollutes the air by about 15 t CO_2/ha and which leads to the warming of the atmosphere. Starting from here, we consider that ammonium nitrate, although not circumscribed to bioeconomic agriculture, is much closer to it than urea.*

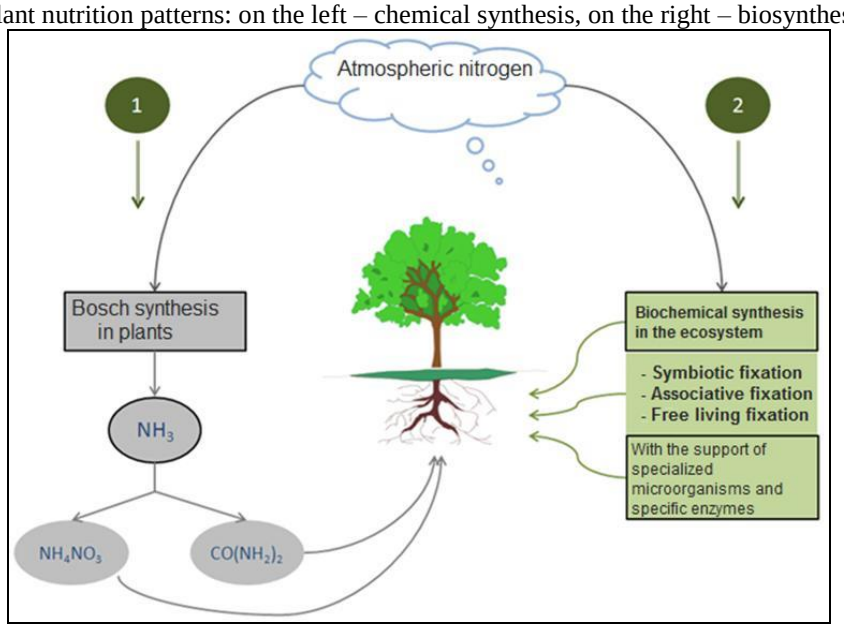
Keywords: *nitrogen fertilizers, wheat, bioeconomic models, bioeconomic agriculture*

Classification JEL: *Q10, Q16, Q57*

INTRODUCTION

The nitrogen nutrition of plants uses as source the atmospheric nitrogen, which can reach the plants according to Fig. 1.

Fig. 1. Nitrogen plant nutrition patterns: on the left – chemical synthesis, on the right – biosynthesis (original)



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The difference between the two models of nutrition lies in the fact that the first one is extremely polluting and very expensive (Lacroix, 1995). However, it has the advantage of rapid results, frequently required by plant nutrition. The major environmental disadvantage of using Model 1 is the rapid destruction of humus, the acceleration of global warming and the destruction of the planet's bioeconomic potential (Raggam, 2009). With all the benefits of using the synthetic fertilizers, they are nowadays regarded as a less necessary evil (Berca et al., 2015). There are two major reasons behind the difficulties of implementing the bioeconomic Model 2:

1) The resilience of the world's political factors, which support by all means the economy that is based on hydrocarbons;
2) The insignificant profits brought by it, transforms this excellent bioeconomic model that derives from nature, into one which is scarcely used in food production.

Under these circumstances, some questions come up: "How do we approach the bioeconomic model of agriculture by using the nitrogen fertilizers manufactured through industrial synthesis?", "How much closer are we and is it worth the effort?".

The studies conducted by Lammel and Brentrup (2003), by ADA (2015, 2016) and by YARA GmbH & Co. KB (2011) have highlighted that the forms of nitrogen of the ammonium nitrate and urea have different behaviors in agricultural crops. At the same dose of nitrogen, the ammonium nitrate proved to be superior to urea, both in terms of production levels and environmental relations. Research has been carried out in universities and departments in Germany, France, England and other countries (Lesouder, 2014).

In the modern intensive agriculture, the amount of fertilizer to be applied is 150 to 200 kg N for a yield of 7-9 t wheat/ha. According to DEFRA (2003-2005) and EMEP (2007) data, with their use, the air pollutant nitrogen losses averaged 3% for ammonium nitrate, 14% for nitrogen solutions and 22% for urea (applied on agricultural land).

Once in the air by volatilization, the nitrogen is transformed into NO_x (nitrogen oxides), which pollute the atmosphere 296 times more than CO_2, with all the resulting consequences for the global warming phenomenon. At global level, the agricultural nitrogen pollution of the atmosphere reaches 20-25% (Berca, 2011).

MATERIALS AND METHODS

The research was conducted in the field and in the laboratory and had the following goals:

1) Comparison of the various forms of nitrogen (NH_4NO_3 and CO (NH_2), as well as nitrogen (ammonium and urea) solutions on wheat yields and their quality (protein content) to two premium wheat varieties – Arnold and Adesso.
2) Comparison of the ecological and bio-economic effects, as well as the choice of the fertilizer that offers the best results of production, quality and ecological parameters. It is the one that comes closest to the desired goal in bio-organic farming.

The research was carried out on 3.7% humus soil, located on the Burns Platform in the 2014-2015 and 2015-2016 agricultural years. Climatic, the years have been thermally moderated, alternating the periods of drought with rain in the summer, due to the drought (in the soil).

Plots of 5000 m^2 were built for each treatment. The observations and determinations were made using various methods.

The method of measuring volatility, urea loss is proposed by Marshall and DeBell (1980) and perfected by San C.K. (1986). The determination with 20 cm diameter PVC tubes, which were filled with surfaces of absorbent material to retain the volatile N, which in turn was measured (Cancellier et al., 2016), it was carried out in the open field, on a circular surface, using a semi-open absorbent. N_2H_4 is captured and then evaluated in ammonia, thus calculating the loss.

The absorption recovery of the potentially lost nitrogen was achieved at 95-97% (San, C.K., 1986). The results are presented as a percentage of the total amount of applied urea, expressed in kg/ha SC nitrogen. The process started from dry urea, with the parameters from the table below (Table 1).

Table 1. Some characteristics as seen comparatively between ammonium nitrate and urea

Product / Parameters	Urea	Ammonium nitrate	Specifications	Evaluation
Density (kg/m3)	770 kg/m^3	900 kg/m^3	The granules are heavy; as a result, the dispersion distance is also great.	Nitrogen benefit
Average grain diameter (mm)	2.9 mm	3.5 mm	The diameter of the granules is high + increasing the spreading distance	Nitrogen benefit
Hardness / roughness (do N)	2.5 do N	>4 do N	Hardness is great - the fertilizer does not produce dust.	Nitrogen benefit
Regularity of physical characteristics	– –	+ +	Regular presentation - application is adjusted with precision.	Nitrogen benefit
Nitrogen content	46.63	33.50	Larger amount of nitrogen, lower transport costs	Urea benefit

Urea has a 15% lower density than ammonium nitrate and a 17% smaller size range of granules than the ones of ammonium nitrate. Hence, the different volatilization in the mentioned soil conditions, which were detailed in Berca (2017) works. In order not to interfere with the nitrogen fixation association consisting of *Azospirillum brasilense* and wheat, the two forms of the nitrogen fertilizers were applied in the spring, after having reached 6.5°C in the soil. Moreover, irrespective of the nitrogen doses used, the fertilizers were applied only once.

The doses used, in kg / ha for the three types of nutrients: nitrogen, urea (32% N, LU* type) and the nitrate solution, were as follows: 0, 40, 80, 120, 160 and 200 kg / ha. Thus, nutrition of nitrogen for about 8000 kg of wheat per hectare was provided, including the 14% protein.

Two premium wheat varieties (Adesso and Arnold) were used. Based on the material synthesis needs, only the average of the varieties and the average of the years have been used. In order to compare the volatilization at higher temperatures, these doses were also applied to black soil in the summer. Moreover, the harvesting was carried out on random plots, a total of five, of 10 m^2 each, with a special harvester for small plots.

The calculations and the presentation of the results were carried out by the dispersion analysis (of variance). The calculation of correlations in 2D and 3D systems was also used. It was aimed at observing:

→ the level of wheat yields in relation to the doses applied;
→ the level of protein content;
→ the total amount of nitrogen lost through volatilization, for the three forms of fertilizer;
→ the ecological and economic effects generated by the volatilization loss of nitrogen in the form of NH_3.

RESULTS AND DISCUSSIONS

In Fig. 2 it has been proposed to demonstrate to what extent the three forms of nitrogen used in doses from 40 to 200 kg/ha influence the overall production and especially at each dose.

Under the circumstances of the Alexandria chernozem and the climatic conditions of the agricultural years of 2014-2015 and 2015-2016, on average for the two studied varieties, it is demonstrated that:

a) The maximum yield is achieved at 160 kg N/ha;

* LU-type nitrogenous solutions are in the form of colourless to yellow liquid and contain 32% N: 7.75% NH4 +, 7.75% NO3 and the remaining urea, all in aqueous solution.

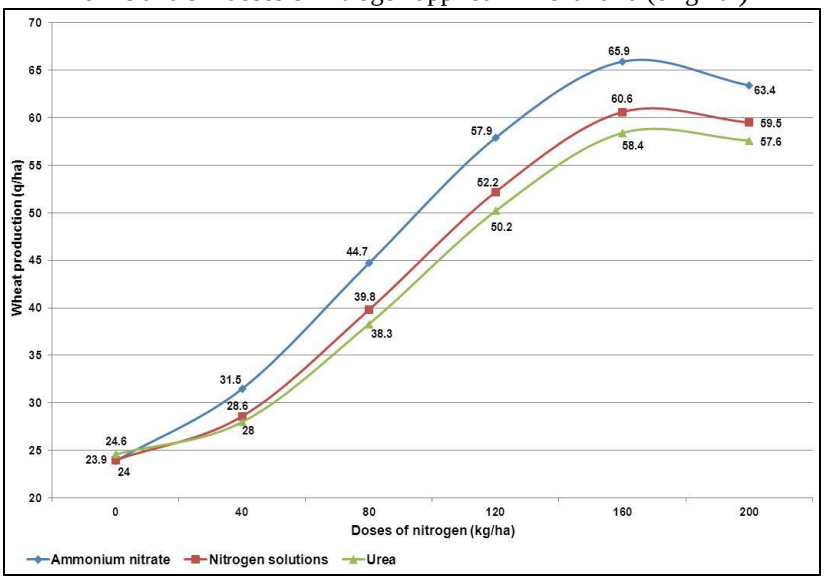
b) There is a significant production difference of more than 6 q/ha between the ammonium nitrate and the nitrogenous solutions and of 7.5 q/ha between the ammonium nitrate and the urea at the maximum yield dose of 160 kg N/ha.

Our research confirms the results obtained in Germany, France and England, with the specification that at approximately equal doses of nitrogen (153-182 kg/ha), in our studies the difference in favour of the ammonium nitrate is double to the above-mentioned experiences, by comparison with both urea and solutions of ammonium nitrate and urea. Production increases obtained at doses of 160 kg N / ha are:

→ 42.3 q/ha in the case of ammonium nitrate,
→ 36.7 q/ha in the case of nitrogen solutions,
→ 34.4 q/ha in the case of urea,
→ 26.4 kg/1 kg N in the case of ammonium nitrate,
→ 22.9 kg/1 kg N in the case of nitrogen solutions,
→ 21.5 kg/1 kg N in the case of urea.

This proves that each kg of nitrogen additionally obtains 4.9 kg of grains in the case of the application of ammonium nitrate as compared to urea. The calculations show that in order to obtain the same wheat yields, the amount of urea should be increased by 14 x 1.4 = 20 kg/ha. According to other authors, this figure would be of 40 kg/ha (DEFRA).

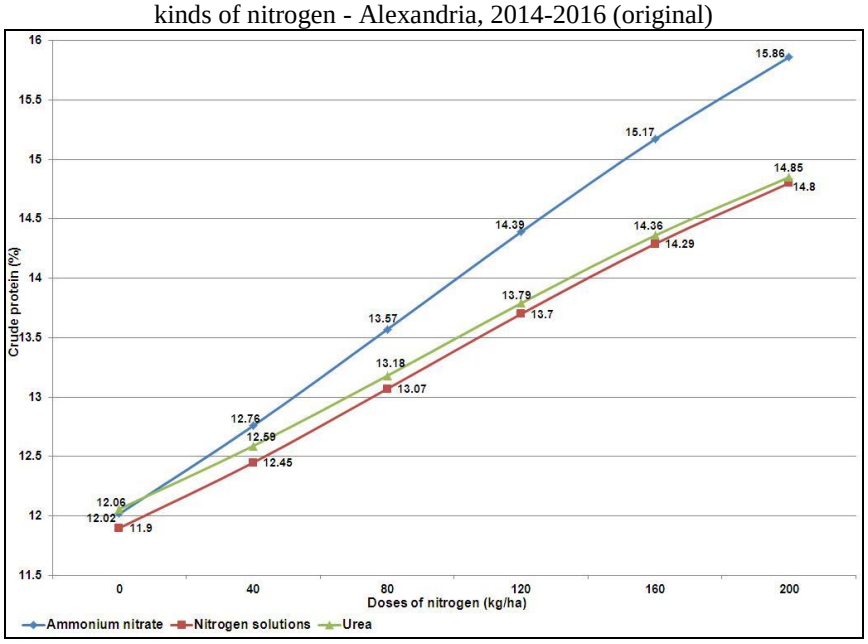
Fig. 2. Production of wheat (the average for two varieties) in the period 2014-2016 (average) according to the three forms and six doses of nitrogen applied – Alexandria (original)



It is difficult to recommend the exclusive application of ammonium nitrate fertilizers on a global or European scale, as long as 80% of global nitrogen fertilizers are produced in the form of urea. In this case, the recommendations of the Brazilian researchers (Cancellier et al., 2016) would be the introduction of an anti-volatilization stabilizer into urea to reduce the losses below or at the level of the ammonium nitrate.

The quality of production, represented by the crude protein content, is shown in Fig. 3. The protein content, on average for the two wheat varieties, is continuously increasing from unbound to 200 kg N/ha (0 → 200). Both the slope and the growth angle are higher in the case of the ammonium nitrate. The three-dimensional model presented in the equation stated in the figure shows a very significant difference in protein content in favour of ammoniacal nitrogen, starting at a dose of 80 kg N/ha. From this dose, the differences are between 0.41-1% over the 80-200 kg N/ha range. At high dose, this means an extra of about 43 kg protein/ha, which is not supplied by the quantity of the fertilizer, but only by the fertilizer range (ammonium nitrate). On 1000 hectares of wheat, we will additionally have 4.3 t of protein, which is a very significant result.

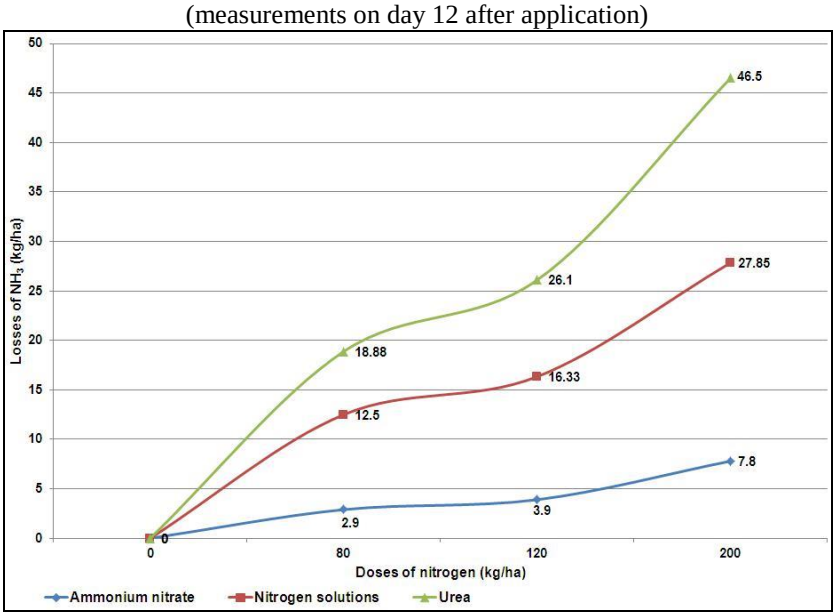
Fig. 3. Crude protein content for autumn wheat (an average for two varieties), dose-dependent and the three kinds of nitrogen - Alexandria, 2014-2016 (original)



The other two forms of nitrogen have a similar behaviour, their differences in protein content being permanently positive in favour of the nitrogen solutions when compared to urea, but statistically uninsured at the same time. Our data are confirmed by numerous researches made in the period 1999-2002 in the German Land of Rhineland-Palatinate (ADA, 2015), as well as in England (DEFRA) or France (YARA, 2011).

Why is this happening? Nitrogen volatilization is a cause. Perhaps the volatilization of nitrogen, especially in the case of urea, may be a cause, but not the only one (Fig. 4). Our measurements, performed according to the methodology, show that in the case of ammonium nitrate the maximum loss recorded was of 7.3 kg/ha at the maximum dose (200 kg N/ha), the model shows that for urea the maximum loss of NH_3 at the same dose was 45.8 kg / ha.

Fig. 4. Nitrogen losses (NH3) in wheat crops under fertilization with three fertilizer forms - Alexandria, 2014-2016 (measurements on day 12 after application)

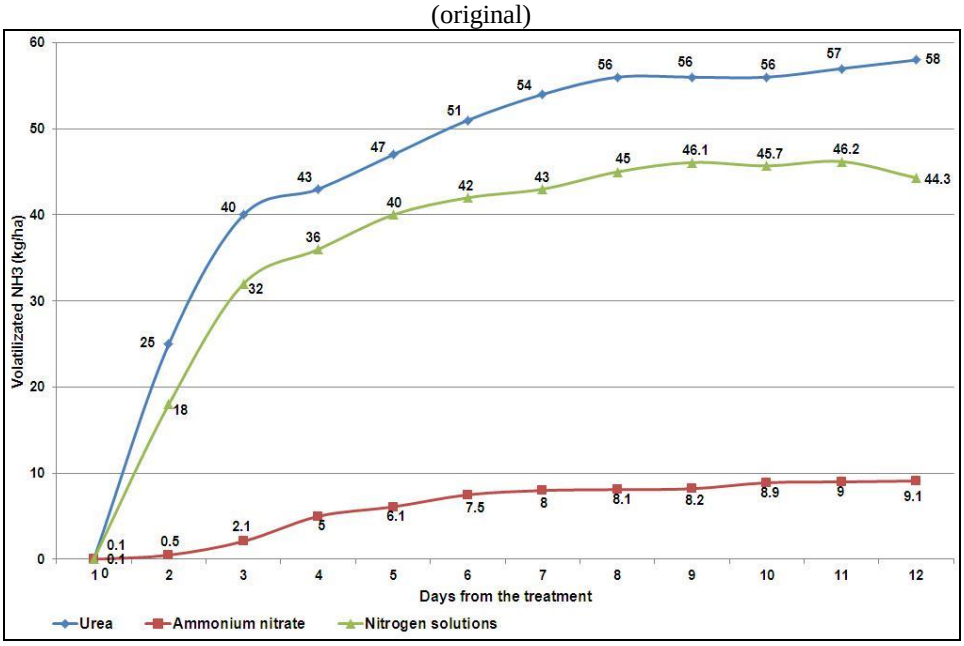


For all the nitrogen species applied, the increase in the loss was positively correlated with the applied dose due to the exposure of a larger quantity of fertilizer, the products being applied at the beginning of the vegetation period in the spring at 6-8° C in the soil on vegetation.

The nitrogen loss in the case of urea was 2.5 times higher at the 200 kg/ha dose compared to the one at 80 kg/ha. Similar reports are found in other assortments, but at much lower levels of losses.

The product volatilization model, shown in Fig. 5 demonstrates that the largest amount of nitrogen (NH_3) was gone within the first 5 days of application, namely 71% in the case of urea, 86% in the case of the nitrate solution, and 6-7% for ammonium nitrate.

Fig. 5. Nitrogen volatilization model, expressed in NH_3 kg/ha, for three fertilizer forms - Alexandria, 2014-2016 (original)



In the first 12 days of application, the volatilization was practically carried out, the rest of the nitrogen entering the nutritional circuit of wheat plants.

What happens to the volatilized nitrogen in the environment? If the ammonium nitrate does not raise very high pollution problems through volatilization, the urea, on the contrary, at a volatile loss of about 23% (see Figure 4) can lead to a loss of only 100 kg N/ha at a loss of 23 kg N/ha and at about 500,000 ha treated with urea in Romania with wheat only, it results that 11,500 t of nitrogen are released into the atmosphere.

Only wheat crop has a loss in value:

1) at 1 ha = 23 kg N x 2.17* x 1.52 lei/kg = 76 lei/ha = 17 €/ha;
2) Total for Romania = 500,000 ha x 76 lei/ha = 38,000,000 lei = 8.4 mil. €.

In a 1000 ha wheat farm where 160 kg N/ha is applied, the volatilization loss is:

1000 ha x 76 lei/ha x 1.6 = 121,600 lei = 27.326 €

The loss for the farmer is equivalent to 27,326/0.15 €/kg = 182 t = 182 kg/ha. It is a significant loss, which nobody wants but which is present anyway.

According to the graph in Figure 2, the loss of production may be much higher, reaching 800 kg/ha at 180 kg N/ha, i.e. 800 x 0.15 = 120 €/ha, losses that could get us out of the economic area of wheat crops.

But what happens to urea lost in the air? We have already shown that the loss occurs as ammonia (NH_3). This, in the presence of the air and water in the atmosphere, turns into oxides of nitrogen. The nitrous oxide (N_2O) dominates:

→molar mass of ammonia = 17.03;

→the molar mass of N_2O = 44.013.

$$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O$$ (Lippits et al., 2008)

* 2.17 = transformation coefficient from N to urea

Regardless of the chemical process, whether it is industrial or natural, the 4 molecules of ammonia result in 2 N_2O nitrous oxide molecules. Taking into account the molecular weight, the conversion ratio is $NH_3 \rightarrow N_2O = 1.29$. On the other hand, at the time of volatilization, urea is converted to ammonia in the presence of water and measured as such:

$$CH_4N_2O + H_2O \rightarrow 2NH_3 + CO_2 \text{ (Guwahati, 2012)}$$

This reaction takes place in the presence of the enzyme called urease, found in the upper layer of the soil. The fact that CO_2 results from conversion increases the degree of GHG pollution of the atmosphere.

One kg of ammonia (NH_3) will result in about 52 kg of N_2O, which equates to 52 x 296 = 15,392 kg of CO_2 in the atmosphere, and it is considered as GHG for each hectare where 180 kg of urea was applied as fertilizer without stabilizer. Nitrous oxide (N_2O) has a capacity of warming the atmosphere which is 296 times higher than the CO_2 (carbon dioxide).

In this way, it can be partly demonstrated why agriculture participates in GHGs with over 25%. The agriculture accounts for 94% of total ammonia losses, of which 20% come from the mineral fertilizers (Berca, 2017).

CONCLUSIONS

1) The studies conducted on the Burnas Plateau in the Alexandria area (Teleorman County) regarding the behaviour of the nitrogenous fertilizer varieties in the spring showed the following:
   a) The average harvests for the two premium wheat varieties (Adesso and Arnold) led to a maximum yield of 160 kg N/ha, 66 g/ha for ammonium nitrate and 58.4 g/ha for urea. A significant advantage for ammonium nitrate (+ 11%).
   b) The production quality, expressed as crude protein content, correlated positively with the application of nitrogen doses, reaching maximum at the highest dose (200 kg N/ha). The highest protein content (15.86%) is obtained with ammonium nitrate and the lowest with urea (14.8%). An advantage in favour of ammonium nitrate - 6.8% relative, which is a significant difference as well.
2) The lower wheat production and quality parameters in case of application of urea are due to the volatilization and the high nitrogen loss (NH_3) in this fertilizer. Volatility values of 46.8 kg N/ha are recorded at the application of 200 kg N/ha in the spring and 66 kg N/ha in summer applications. The climatic conditions in the summer were favourable for the volatilization (the drought after the application). The loss ratio was 1/6 for the spring applications and 1/6.2 for the summer applications. The nitrogen solutions have provided intermediate parameters, whilst those from the summer applications were approaching urea.
3) The economic losses from urea volatilization amount to 76 lei or 17 €/ha for every 200 kg N in all spring applications. Taking into account the two advantages, the economic losses for ammonium nitrate are at least 7 times lower.
4) According to our calculations, approximately 40 kg of ammonia resulting from the volatile loss of urea lead to the production of 15,392 kg/ha of wheat equivalent to GHG, adding very large amounts of GHGs into the atmosphere. Only the nitrogen fertilizers contribute by 20% to the ammonia pollution of the atmosphere.

The proposed solutions consist mainly of the use of ammonium nitrate in 2-3 rounds in order to avoid losses at maximum. Moreover, avoiding the use of non-stabilised urea against volatilization is a process harmful to the environment and the shift of the agriculture to the bioeconomic area.

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