Comparative Investigations on the Fertilizer Value of Certain Urea-Based Addition Compounds on Solonetz Soils

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At the turn of this century 'SIGMOND [11] already called attention to the importance of such nitrogenous fertilizers which could supply the nitrogen nutrient more slowly, approximately at the rate required by plants during the cropping season.

Nowadays, parallel with the considerable development of fertilizer producing industry, increasing interest is attached to highly concentrated materials, such as urea and its condensed compounds formed with various aldehydes. Urea-based addition compounds prepared with inorganic acids and salts are also known and used by the chemical industry for different purposes for a long time. Urea derivatives condensed with various aldehydes, their addition compounds prepared with mineral acids and salts, furthermore nitrogenous preparations reinforced with ionexchange resins may be considered as slowly and evenly acting, highly concentrated forms of nitrogenous fertilizers, able to meet continuously and steadily the nitrogen requirements of plants [1, 3, 5, 6, 8, 10].

The mobilization of plant nutrients at various rates and magnitudes may be achieved by changing the components and their proportions in the fertilizer mixtures and fertilizer preparations made by urea-based condensation and addition processes [3, 4, 6].

Procedures, producing, through the phase of policondensed ionexchanging urea compounds, on the one hand, and the concentrated nitrogenous fertilizers of different solubility, on the other hand, the multicomponent, combined fertilizers (carrying several nutritive elements) with retarded action, have been studied and tested in Hungary, too [3—7].

Up to the present time, of the urea-based fertilizer compounds the effectivity of urea nitrate has only been tested on a calcareous sandy soil in Hungary [7], while urea calcium nitrate and urea calcium sulphate have been applied on virgin grassland on meadow solonetz soil [2].

Significant increases of crop yields were obtained due to application of addition soil ameliorating fertilizers, but there was no considerable difference between the yield increases, as compared with the application of commonly used nitrogen fertilizers in the field experiments. However, application of urea nitrate on the sandy soils have resulted in a yearly increasing surplus of crop yields [7, 9].

Materials and methods

Fertilizers made in our Institute for experimental purposes, with the required content of active substances and of appropriate composition, were prepared as follows: on the one hand, the solution of synthetic aminoplast resins was mixed with various fertilizers, and the expected products were obtained by polimerization processes. On the other hand, urea and calcium nitrate were treated with mineral acids, until the preparations of required composition and nutrient ratios were obtained [3, 4, 6, 7]. The fertilizer value, application potential and the efficiency of these urea-based addition fertilizer products — their chemical characteristics are given in Table 1 — were studied both in pot culture and field experiments.

Table 1

Some chemical properties of urea-based addition compounds

Denomination	pH in 1% solution	Active substance				Acid content		Output
		Theoretical		Real		Theoretical	Real	
		N	P_2O_5	N	P_2O_5			
		%						
Urea nitrate $CO(NH_2)_2 \cdot HNO_3$	1.7–2.6	34	—	33.8	—	51.2_{HNO_3}	53	95.3
Urea calcium nitrate $CO(NH_2)_2 \cdot Ca(NO_3)_2$	5.8	25	—	23	—	— HNO_3	1.2	93.1
Urea calcium sulphate $CO(NH_2)_2 \cdot CaSO_4$	3.9	14.2	—	14.4	—	— H_2SO_4	14.6	83.8
Urea phosphate $CO(NH_2)_2 \cdot H_3PO_4$	2.3	17.7	33.8	16.3	44.5	$62.0_{H_3PO_4}$	67.5	86.9

The pot culture experiment was conducted with the appropriately prepared and treated air-dried soil collected from the 0—25 cm surface layer of a strongly compacted, heavy meadow solonetz, having unfavourable water regime.

The pH_{H_2O} of the soil was 6.6; humus content: 3.59 per cent; total nitrogen content: 0.23 per cent; exchangeable sodium content (expressed in the percentage of "S"-value): 36.31 per cent. In the 1 : 5 water extract the chloride and sodium ions were predominant, although the salt content of the soil solution was not significant. Each pot was filled with 6 kg of soil. The following treatments were compared in four replications:

1. Untreated control.
2. Limestone powder (0.99 g Ca/pot);
3. Superphosphate (1.13 g P_2O_5 and 0.72 g Ca/pot);
4. Salt of Pét (ammonium nitrate with 25 per cent of active substances, 0.56 g N and 0.12 g Ca/pot);
5. Ammonium nitrate (0.56 g N/pot);
6. Calcium nitrate (0.56 g N and 0.99 g Ca/pot);

7. Urea (0.56 g N/pot);
8. Urea nitrate (0.56 g N/pot);
9. Urea calcium nitrate (0.56 g N and 0.19 g Ca/pot);
10. Urea calcium sulphate (0.56 g N and 0.21 g Ca/pot);
11. Urea phosphate (0.56 g N and 1.13 g P_2O_5/pot);
12. Urea + superphosphate (0.56 g N, 1.13 g P_2O_5 and 0.72 g Ca/pot).

The fertilizers were weighed out separately for each pot and were incorporated with the whole of soil in each pot. 19 pregerminated seeds of Sudan grass were sown per pot. Two cuts were harvested during the cropping season.

The field experiment was carried out on a solodized meadow solonetz soil with a heavy mechanical composition, formed on loess-like calcareous clay turning into steppe formation under irrigated conditions. The top soil had a pH_{H_2O} of 6.5, humus content of 3.98 per cent, exchangeable sodium+potassium content of 11.4 per cent, expressed in percentage of "S"-value. The B horizon of this soil displayed the typical properties of a meadow solonetz. With depth its pH increased up to 7.3, while the exchangeable sodium+potassium content up to 20.5 per cent. The effervescence with dilute hydrochloric acid appeared at a depth of 70 cm, while the depth of the water table was 450 cm. The field experiment was conducted on a virgin grassland and the following treatments were applied:

1. Untreated control.
2. Limestone powder (315 kg Ca/ha);
3. Calcium nitrate (180 kg N and 315 kg Ca/ha);
4. Ammonium nitrate (180 kg N/ha);
5. Urea calcium nitrate (180 kg N and 62 kg Ca/ha);
6. Urea calcium sulphate (180 kg N and 67.6 kg Ca/ha).

The experiment had a Latin-square layout and was conducted in six replications. Three cuts were harvested during the cropping season.

In both experiments the green mass yields obtained in each treatment were weighed and subsequently their absolute dry-matter-, N-, P_2O_5-, K_2O- and CaO contents were determined. Calculations were done concerning the nutrient amounts extracted by crops and the recovery rate of nutrients. All the data were statistically evaluated by analysis of variance.

Results and discussion

Yield data converted into 86 per cent dry-matter level are presented in Table 2. From these results it may be seen that superphosphate applied separately significantly increased the yield of Sudan grass. The application of various N sources, such as salt of Pét, ammonium nitrate, calcium nitrate and urea resulted in considerable yield surplus (74—106 per cent), as compared to the yield of the control plot. However, there was no reliable difference among the yields obtained by the various N fertilizers.

Due to the influence of different urea-based addition compounds, with the exception of urea calcium nitrate, the obtained yield increases of dry matter were ranging from 21.8 to 28.2 g per pot. No such great difference appeared between the crop yields of pots if nitrogen and phosphorus were

applied in separate compounds, i.e. in the form of urea and superphosphate; if, however, these nutrient elements were applied in chemical combination, like urea phosphate, the latter exerted a somewhat greater (53.5 g per pot) effect.

When evaluating the yields of three cuts in the field experiment, it can be stated that due to the influence of various nitrogenous fertilizers applied in an amount corresponding to a rate of 180 kg N (active substance) per hectare, significant surplus yields (from 3920 to 5120 kg) were achieved, which had been realized predominantly during the formation of the first cut.

Table 2

Yields as influenced by the treatments
(Data converted into 86% of dry matter content)

Treatments	Pot culture experiment Sudan grass			Field experiment Grassland		
	g/pot	D	%	kg/ha	D	%
1. Untreated	25.3	—	100.0	5.650	—	100.0
2. Limestone-powder	25.7	0.4	101.6	6.340	690	112.0
3. Superphosphate	39.1	13.8	154.5	—	—	—
4. Salt of Pét	45.5	20.2	179.8	—	—	—
5. Ammonium nitrate	52.3	27.0	206.7	9.900	4.240	174.9
6. Calcium nitrate	46.2	20.9	182.6	10.780	5.120	190.4
7. Urea	44.1	18.8	174.3	—	—	—
8. Urea nitrate	50.9	25.6	201.2	—	—	—
9. Urea calcium nitrate	38.3	13.0	151.4	10.560	4.900	186.6
10. Urea calcium sulphate	47.1	21.8	186.2	9.580	3.920	169.2
11. Urea phosphate	53.5	28.2	211.5	—	—	—
12. Urea + superphosphate	49.8	24.5	196.8	—	—	—
$LSD_{5\%}$	10.7	10.7	42.3	1.340	1.340	23.7

No reliable difference could be demonstrated between the yield increasing effects of ammonium nitrate, calcium nitrate, urea calcium nitrate and urea calcium sulphate, although the yield increases obtained with calcium nitrate proved to be consequently the greatest. Application of small doses of limestone powder increased the hay-yield of the grassland by 690 kg per hectare.

From the data referring to the nutrient content of the yields it can be seen that the applied nitrogenous fertilizers exerted an effect, first of all, on the nitrogen content of crops.

The data indicating the amounts of nutrients taken up by plants and thus extracted by the crops are shown on Figures 1, and 2. The Sudan grass yield of the control pot contained 0.39 g N per pot. Limestone powder did not essentially influence the nitrogen content, but the application of superphosphate increased it up to 0.45 g per pot. The effect of single nitrogenous fertilizers was significantly larger and the nitrogen content of the yields was as high as 0.74 – 0.82 g N per pot. Urea-based addition compounds achieved almost the same effect, the nitrogen amounts reached 0.73 – 0.85 g N per pot.

The application of nitrogenous fertilizers also affected the amounts of P_2O_5, K_2O and Ca taken up by plants. The level of P_2O_5 was 0.11 g in the control pot. Nitrogen treatments increased it up to 0.17 – 0.27 g P_2O_5 per pot.

The effect of applied superphosphate manifested itself in increasing the amount of absorbed P_2O_5, K_2O and CaO in the crop yields. The largest amount of P_2O_5- and K_2O was obtained by the urea phosphate and the combined treatments; in the latter urea and superphosphate were added separately.

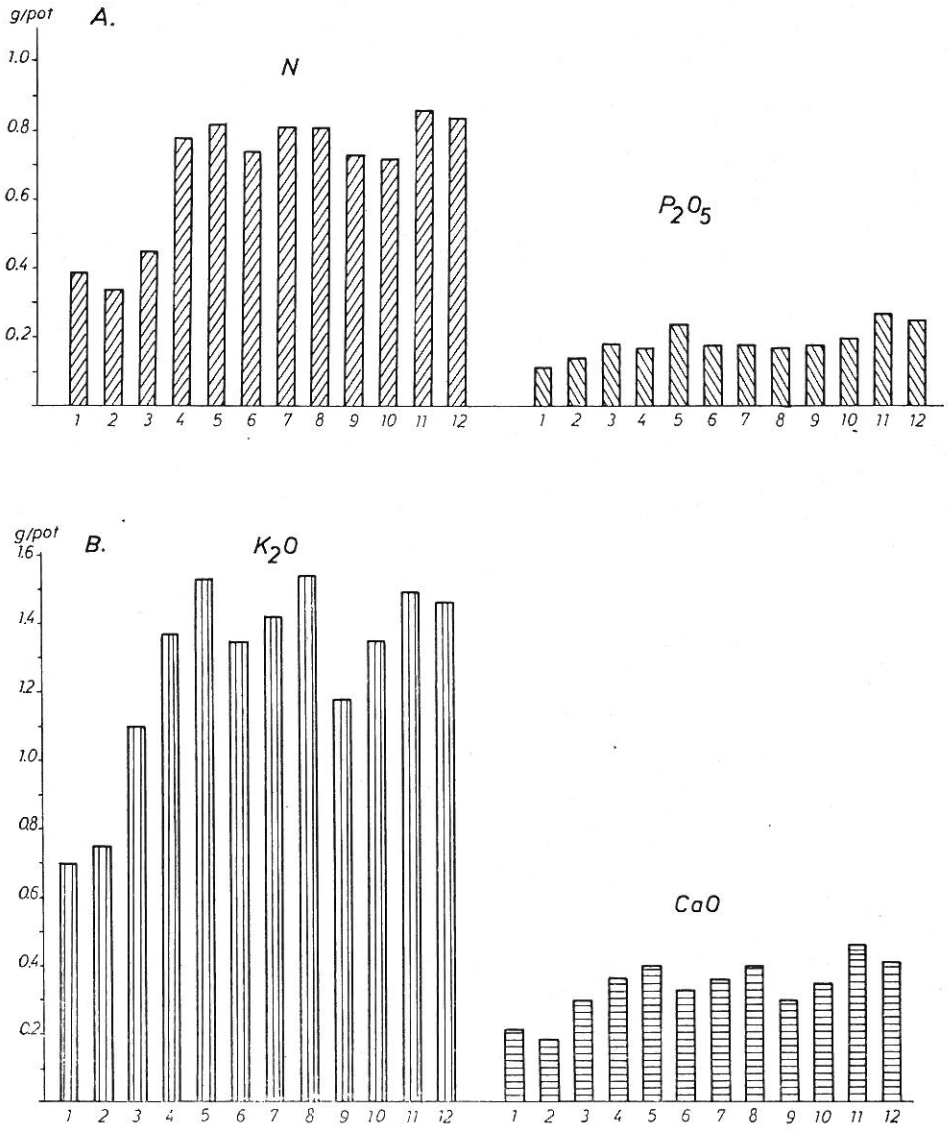

Fig. 1

Nutrient uptake by Sudan grass as influenced by different treatments in the pot culture experiment. Horizontal axis: No. of treatments

In the control pot the yield contained 0.70 g K_2O and 0.21 g CaO. Due to the effect of various nitrogenous fertilizers the K_2O and CaO contents of Sudan grass increased up to 1.18—1.54 g and 0.29—0.46 g per pot, respectively.

According to our data there was no essential difference between the effects of single nitrogen fertilizers and those of urea-based addition compounds in respect of the nutrient-output. The diagrams of Figure 2. indicate that the nutrient-outputs, with the exception of some deviations, display the same tendency as the hay surplus yields. Limestone powder increased the nutrient

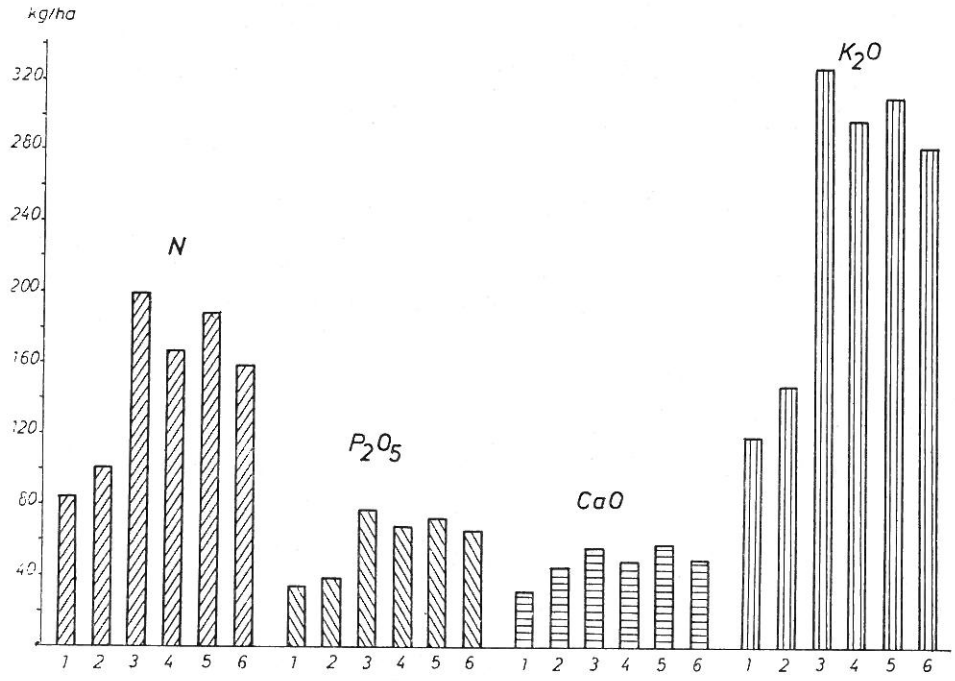

Fig. 2

Nutrient uptake by the mixed grass of pasture in the field experiment. Horizontal axis: No. of treatments

contents of yields to a lesser extent than the nitrogenous fertilizers did. The application of nitrogenous fertilizers resulted in a considerable increase in the amounts of N, P_2O_5, K_2O and CaO, taken up by crops. No essential difference could be observed among the efficiencies of various nitrogenous fertilizer treatments.

In the field experiment the highest nutrient-outputs, except the amount of CaO, resulted from the application of calcium nitrate.

Data regarding the apparent recovery of added nutrients are summarized in Table 3. In accordance with these figures the Ca-content of limestone powder was hardly utilized if at all. The recovery rate of the nutrient content of superphosphate added separately was 6.4% for phosphorus and 12.9% for Ca.

Table 3

Apparent recovery percentage

Treatment	Pot culture experiment			Field experiment		
	N	P_2O_5	CaO	N	P_2O_5	CaO
Superphosphate	—	6.4	12.9	—	—	—
Salt of Pét	68.1	—	—	—	—	—
Ammonium nitrate	75.5	—	—	45.6	—	—
Calcium nitrate	61.4	—	13.4	64.5	—	7.8
Urea	73.3	—	—	—	—	—
Urea nitrate	73.7	—	—	—	—	—
Urea calcium nitrate	59.3	—	45.0	56.5	—	43.5
Urea calcium sulphate	58.9	—	22.5	41.2	—	26.6
Urea phosphate	80.1	14.7	—	—	—	—
Urea + superphosphate	78.5	13.0	27.7	—	—	—

In both pot culture and field experiments the active substances of nitrogenous fertilizers were taken up and utilized by plants in a considerable extent. Apparent recovery percentage of the active substance of the added nitrogen fertilizers was 58.9 – 80.1 per cent in the pot experiment, while in the field experiment this value represented 41.2 – 64.5 per cent. The least apparent recovery percentage of N, 58.9 – 59.3 per cent, was obtained with urea calcium nitrate and urea calcium sulphate, while the highest recovery rate was observed due to urea phosphate and to the combination treatment, where urea and superphosphate were added separately.

It is also evident from these data that in both experiments the Ca-content of urea calcium nitrate and urea calcium sulphate was utilized by plants in almost the same extent, 43.5 – 45.0 and 22.5 – 26.6 per cent, respectively.

The apparent recovery percentage of phosphorus, one of the active substances in the treatments with urea phosphate and urea+superphosphate was 13.0 – 14.7 per cent, while that of the calcium content of the combination treatment amounted to 27.7 per cent.

Summary

In the pot culture and field experiments the fertilizer value and the application potential of various urea-based addition compounds were investigated and compared with the yield increasing effect of single nitrogenous fertilizers having the same amount of active substance. The experiments were conducted on a grassland with a solodized meadow solonetz soil turning into steppe formation and on a heavy meadow solonetz soil being under agricultural use. Irrigation was applied according to the plant requirements.

On the bases of data obtained in pot culture and field experiments the following conclusions may be drawn:

1. The yields of virgin grassland, as well as of Sudan grass significantly increased due to the application of the urea-based addition fertilizer products;

2. of the single urea-based addition fertilizer preparations in the field experiment urea calcium nitrate, while in the pot culture experiment urea nitrate proved to be the most effective;

3. of the urea-based addition fertilizer compounds containing two kinds of plant nutrients urea phosphate gave the best results. Yield increase obtained by the application of urea phosphate surpassed by 15.1 per cent the increase effected by the NP-combination treatment, where nitrogen and phosphorus were applied separately in the forms of urea and superphosphate;

4. nitrogen uptake by plants was doubled by the application of various nitrogenous fertilizers. In this regard also urea phosphate gave the greatest surplus. Phosphorus applied in chemical combination with nitrogen further increased nitrogen uptake by crops;

5. the crop yields extracted the highest amounts of nutrients with the exception of the K_2O-output, when urea phosphate, an urea-based addition fertilizer preparation containing two kinds of essential plant nutrients, was applied. The highest amount of K_2O was obtained in the urea nitrate treatment;

6. the apparent recovery percentage of fertilizer nitrogen varied between 58.9–80.1 per cent in the pot culture experiment and was somewhat less, between 41.2 and 64.5 per cent, in the field experiment;

7. by incorporating phosphorus into the chemical combination of the urea-based addition fertilizer compounds the apparent recovery percentage of fertilizer phosphorus may be more than doubled, as compared with its application in the form of superphosphate;

8. the apparent recovery percentage of calcium applied in the form of limestone powder was 4.0 per cent, while in the case of urea calcium nitrate it amounted to 43.5–45.0 per cent. Consequently the incorporation of calcium into the chemical combination of the urea-based addition fertilizer compounds may be recommended for increasing the apparent recovery percentage of calcium. This way its utilization may be increased more than ten times;

9. although there was no significant difference between the yield increasing effects of single nitrogenous fertilizers and urea-based addition fertilizer compounds, the apparent recovery percentage of the different kinds of fertilizers showed considerable deviations. This deserves attention, especially from viewpoints of the economical use of fertilizers.

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