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EFFECT OF FERTILIZATION AND LIMING ON GRAIN MAIZE PRODUCTIVITY IN THE SHORT-TERM CROP ROTATIONS ON SODDY-PODZOLIC SOIL

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The research results on the influence of doses and forms of limestone ameliorants and fertilization on the maize productivity in the Western Polissia were shown. The ameliorants application on the background of mineral fertilizers increased the indicators of the yield structure and plant survivability. We have obtained the highest results due to the application of dolomite meal with 1.5 doses based on the hydrolytic acidity, namely, plant density before harvesting was 62.4 ths. pcs/ha, plant height – 229 cm, ear weight – 223 g, the grain yield per ear was 79.7 %.

The limestone ameliorants and fertilizers application also had a positive effect on the yield and protein content of maize grain. According to the obtained data, it was found that the protein content in the grain increased by 1.82–2.89 % in variants with melioration on the background of $N_{120}P_{90}K_{120}$ compared to the control, and was to 9.4–10.5 %. The maximum protein content (10.5 %) was obtained due to applying a 1.0 dose of dolomite meal on the background of mineral fertilization with the addition of sulfur S_{40} and foliar dressing with Nutrivant Plus Cereals micronutrient fertilizer (2 kg/ha). The highest yield of 9.04 t/ha was formed by the combined use of 1.5 dose of dolomite meal by the hydrolytic acidity and the recommended rate of mineral fertilizers ($N_{120}P_{90}K_{120}$). The increase in the maize yield to control (without fertilizers) was 4.99 t/ha, and to the background ($N_{120}P_{90}K_{120}$) – 3.98 t/ha. The grain yield of maize increased by 10.3 % due to the application of sulfur fertilizer (S_{40}) and two-time foliar fertilization with Nutrivant Plus Cereals micronutrient fertilizer (2 kg/ha).

The analysis of economic efficiency showed that the cultivation of grain maize was unprofitable at the $N_{120}P_{90}K_{120}$ application without soil liming; while when applying chemical ameliorants, in particular different doses of dolomite meal, on a similar background fertilizer the maize cultivation was profitable (in the range of 6174–16024 UAH/ha).

***Keywords**: chemical ameliorants, rates, fertilizers, yield, maize.*

The problem of soil fertility remains extremely urgent in modern agriculture. Over the past two decades, the Polissia region of Ukraine has followed a steady trend toward a decrease in the use of organic and mineral fertilizers, limestone ameliorants in the agriculture. This leads to a violation of the ecological balance between the basic elements of plant nutrition, a negative balance of soil organic matter, increasing the area of acidic soils. At an acidity of pH = 5.5 (slightly acid reaction of soil), plants can assimilate no more than 70 % of nitrogen and potassium available in the soil, up to 50 % of calcium and magnesium and only 10% of phosphorus. When acidity is higher (pH value is lower), the adsorption level of nutrients by plants is further reduced, i.e. the efficiency of the fertilizer applied is practically reduced to zero [1, 2].

In view of this, the sod-podzolic soils of Western Polissia, which are characterized by a low level of natural fertility and an acid reaction of the soil solution, need special attention [3]. Acidity is the result of a multi-year process of washing down of calcium and magnesium from the soil and soil enrichment with hydrogen ion - the primary source of acidic reaction of the soil.

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It is known that the soil solution reaction is one of the main indicators of soil fertility level for almost all agricultural crops, since it is an integral indicator of the whole complex of its properties: the content of mobile forms of nutrients and trace elements available to plants, mobility of aluminum, which at accumulation in large quantities (especially on strongly and moderately acidic soils) can negatively affect the growth and development of most crops, and decrease yield by 20–50 % [4, 5].

A characteristic feature of acidic soils is the suppression of microbiological activity in the topsoil, the accumulation of mobile forms of aluminum, iron and manganese harmful to plants, deterioration of physical parameters, poor nutritional regime. Plants growing on acidic soils are more affected by diseases, heavy metals and nitrates get into the grain. As a result of the free aluminum action on the root system, the drought resistance of plants reduces. The specific weed infestation of the fields increases on acidic soils, as most weeds can tolerate acidic environments [6, 7].

About 1.4 million hectares of arable land in Western Polissya have high acidity of the soil solution and their area is constantly increasing due to the insufficient lime application. This reduces the yield of all crops, but above all competitive, as a result, the overall efficiency of agriculture in the region significantly reduces. One such crop is maize, which is sensitive to the acidity of the soil solution and responds well to liming. Depending on the type of soil, the pH should be 6.2–7.0 (lower for light granulometric composition, 6.5 for loamy composition). On acidic soils, liming is a reliable measure to prevent damage to maize by wireworms [8, 9].

According to the generalized data of scientific institutions, the increase in corn grain yield on limestone areas increases by 16–25 %, especially on strongly and moderately acidic soils. The soil environment is improving, bacteria and fungi that cause various diseases are being partially destroyed. In consequence of liming, there are numerous simultaneous changes in soil processes, which positively effected on nutrient adsorption and reduce the intake of toxic heavy metals into the plants [10]. The efficiency of mineral fertilizers increases by 20–40 %. Many publications are devoted to the problem of liming acid soils, in particular, researchers A. I. Siryi and V. H. Polevychenko offer the optimal intervals of pH values of the soil solution, at which the corn yield is reduced. When pH was less than 4.6, the grain yield reduces about 25 %, at 4.6–5.0 – by 16 %, 5.1–5.5 – by 9 %. It is possible to increase corn yield by agrochemical amelioration of acid soils [11].

Aim. To establish patterns of influence of varieties and doses of chemical ameliorants in combination with mineral fertilizers on the maize grain yield under the cultivation on sod-podzolic soil in the Western Polissia.

Materials and Methods. The Institute of Agriculture of Western Polissya NAAS has conducted in 2015, 2016 and 2018 stationary field trials in short-term crop rotation on sod-podzolic cohesive sandy soil. The research was carried out on three fields. The crop rotation included next crops: winter wheat, maize for grain, spring barley, winter rape. The sown area of plot was 99 m^2, the accounting area was 50 m^2, and the trial is repeated three times. The variant placement in the field trial was consistent. The technology of growing maize for grain is generally accepted for the Polissya. Protection from pests, diseases and weeds was carried by intensive technology.

Mineral fertilizers were applied according to the trial scheme. $N_{120}P_{90}K_{120}$ was applied in the form of ammonium nitrate, ammophos, and potassium chloride. Chemical ameliorants were applied before the stationary trial establishment according to the trial scheme.

Nitrogen (N_{30}), phosphorus-potassium and sulfur (S_{40}) fertilizers were applied under fall plowing, the rest of nitrogen fertilizers (N_{90}) – under pre-sowing cultivation. Foliar feeding of maize was carried out with microfertilizer Nutrivant Plus Cereals (2 kg/ha) in the 4–5 and 6–8 leaves stages.

The statistical processing the obtained research results were carried out with the Dospekhov's variance analysis method using Microsoft Office Excel, Statistica 5.0.

The research period (2015, 2016, and 2018) was characterized by an increase in the average monthly air temperature and sharp fluctuations in the amount and intensity of precipitation. Often the prolonged drought was changed by the rains, it was adversely affected the growth processes, development of maize plants and the formation of appropriate grain productivity.

Despite temperature and moisture supply fluctuations, the weather conditions of the Western region were close to the average long-term indicators, as a result, the relatively high yield of maize was produced on sod-podzolic cohesive sandy soil.

Results indicate that the maize grain yield on sod-podzolic cohesive sandy soil primarily depends on soil improvement. On average for three years of research, in the variants without fertilizers and chemical ameliorants, the level of grain yield was only 4.05 t/ha. This indicates that such soils are unsuitable for growing maize for grain and require a set of agrochemical measures to reduce acidity and to improve soil nutrition. (Table 1, Figure 1).

Application of mineral fertilizers of $N_{120}P_{90}K_{120}$ caused acidification of sod-podzolic soil to pH_{KCl} 4.32 (initial data pH_{KCl} – 4.57), however, the grain yield increased by 1.01 t/ha compared to the control (without fertilizers) which was 4.05 t/ha.

1. Maize yield depending on fertilizer and chemical ameliorants application, t/ha (average for 2015, 2016, 2018)

Variant	Grain yield	The increase in grain yield	
		control	back-ground
Without fertilizers (control)	4.05	–	–
$N_{120}P_{90}K_{120}$ (background)	5.06	1.01	–
Background + CaMg $(CO_3)_2$ (0.5 H_h)	6.73	2.68	1.67
Background + CaMg $(CO_3)_2$ (1.0 H_h)	7.53	3.48	2.47
Background + CaMg $(CO_3)_2$ (1.0 H_h) + S_{40}	7.92	3.87	2.86
Background + CaMg $(CO_3)_2$ (1.0 H_h) + S_{40} + microfertilizers	8.4	4.35	3.34
Background + CaMg $(CO_3)_2$ (1.5 H_h)	9.04	4.99	3.98
Background + $CaCO_3$ (1.0 H_h)	7.41	3.36	2.35
LSD_{05}	0.75–0.97		

The increase in pH_{KCl} to 5.42 (initial pH_{KCl} – 4.35) was accompanied by an increase in maize yield when applied against the background of dolomite meal, even in small doses (0.5 H_h), the increase in grain yield was 2.68 and 1.67 t/ha according to control and chemical ameliorants (background). The maize yield increased due to further neutralization of soil acidity. When soil acidity changed to pH_{KCl} 5.73–6.40, the increase in grain yield on the background of $N_{120}P_{90}K_{120}$ was 1.67–3.98 t/ha.

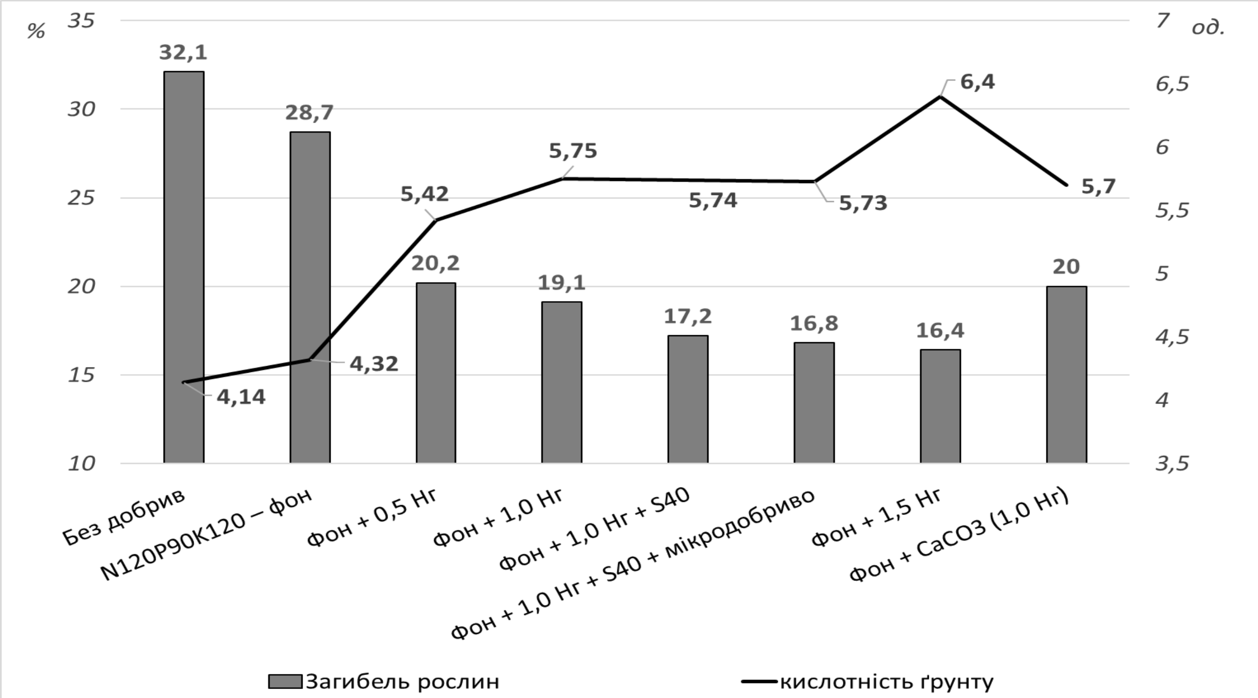
According to research, there is a close direct relationship between grain yield and soil pHCl, the correlation coefficient corresponds to a high level (r = 0.84).

Depending on application of fertilizer and different doses of ameliorants, maize grain yield increased from 5.06 to 9.04 t/ha, i.e. 1.2–2.2 times compared to the control. A significant increase in grain yield (1.67–3.98 t/ha) was ensured by ameliorant application on the background of $N_{120}P_{90}K_{120}$.

Over the years of research, the highest grain yield (9.04 t/ha) was observed when applying 1.5 doses of dolomite meal on the background of $N_{120}P_{90}K_{120}$.

It should be noted that when we compared the effect of dolomite and limestone meal on the maize yield, we found that the application of 1.0 dose of ameliorants on the background of $N_{120}P_{90}K_{120}$ caused an increase in grain, 2.47 and 2.35 t/ha, respectively. And in a case of application only mineral fertilizers, yield was 5.06 t/ha. When dolomite meal was applied, which include magnesium, there was an improvement in plant nutrition with this element, and hence, grain yield increased to 2 % compared to variant with liming.

When applying one dose of $CaMg(CO_3)_2$ on the background of $N_{120}P_{90}K_{120}$ in combination with sulfur fertilizer (S40) and two foliar fertilization with microfertilizer Nutrivant Plus Cereals (2 kg/ha), the grain yield of corn increased by 2.86–3.34 t/ha.



Note: for variant 3-7 - dolomite meal ($CaMg(CO_3)_2$)

Figure 1. Soil acidity and maize plant death depending on fertilizer and chemical ameliorants application (average for 2015, 2016, 2018)

When we used no fertilizers and ameliorants, the grain yield obtained on acidic soil was low due to significant death of maize plants (32.1 %), in addition, the weight of one ear was insignificant – 151 g, and grain yield per the ear was 71.1 %. Applying the full dose of $N_{120}P_{90}K_{120}$ fertilizers led to an increase in the weight of one ear to 174 g and grain yield per the ear to 75.3 %. Plant death due to soil acidification in this variant was 28.7 % (Figure 2).

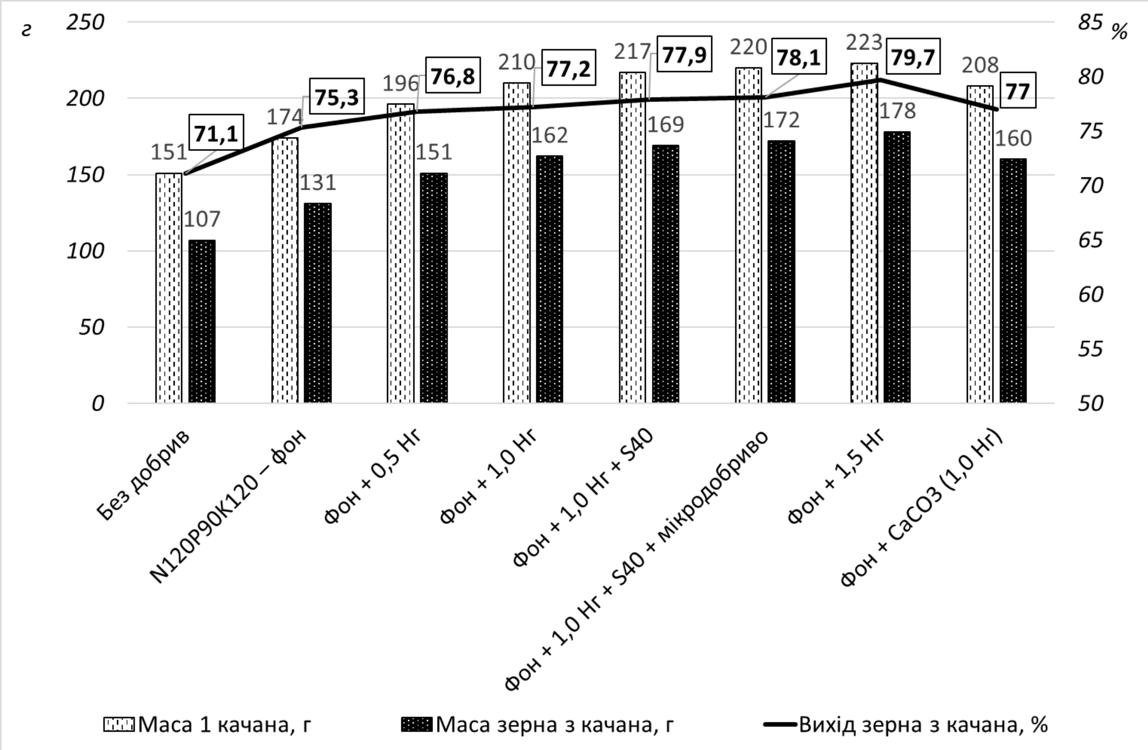
The ameliorants application on the fertilizer background increased the indicators of yield structure and the plant survivability. The application of dolomite meal in 1.5 doses by hydrolytic acidity provided the best results: ear weight – 223 g, grain yield per ear – 79.7 %. In this variant, during the growing season, from germination to harvest, the level of plant death was the lowest – 16.4 %. Application of lime at 1.0 dose by hydrolytic acidity provided slightly lower indicators of yield structure than in a similar variant with dolomite meal ($CaMg(CO_3)_2$). Plant death in these variants was low and ranged of 19.1–20.0 %.

The research data indicate that plant survivability increased when soil acidity decreased on the fertilizer background of $N_{120}P_{90}K_{120}$.

When growing maize for grain, the chemical ameliorants application on the background of mineral fertilizers increased the plant density by 12.1–21.9 % and plant height by 9.9–51.6 % compared to the background ($N_{120}P_{90}K_{120}$), where they were 51.2 thousand plants/ha and 151 cm, respectively. Before grain harvest, the highest indicator of plant density was 62.4 thousand plants/ha and plant height – 229 cm under application of dolomite meal in 1.5 doses on the fertilizer background.

The lime ameliorants and fertilizers also positively influenced on the protein content of maize grain. According to the obtained data, it was found that the protein content increased by 1.82–2.89 % compared to the control and amounted to 9.4–10.5 %, when the chemical ameliorants were applied on the background $N_{120}P_{90}K_{120}$. The maximum protein content (10.5 %) in the grain were observed in the variant with 1.0 dose of dolomite meal on the mineral fertilizer background with S_{40} sulfur and foliar fertilization of plants with microfertilizer Nutrivant Plus Cereals (2 kg/ha).

Under market relations, the economic efficiency of maize cultivation for grain is a paramount importance and one of the most important indicators of crop competitiveness.



Note: for variant 3-7 - dolomite meal ($CaMg(CO_3)_2$)

Figure 2. The maize yield structure depending on application of fertilizers and chemical ameliorants (average for 2015, 2016, 2018)

Economically feasible variants of cultivation technology, which will ensure the return on resources spent with maximum efficiency, should be developed on the basis of evaluation of research results and comprehensive analysis of elements of the technological process. This will increase grain production, improve grain quality and reduce production costs.

2. Economic efficiency of grain maize cultivation depending on fertilizer and chemical ameliorants application (average for 2015, 2016, 2018)

Variant	The increase in yield, t/ha	The cost of liming and fertilizing, t/ha	Cost gain, UAH	Profit, UAH/ha
Without fertilizers (control)	–	–	–	–
$N_{120}P_{90}K_{120}$ (background)	1.01	6376	5050	-1326
Background + CaMg $(CO_3)_2$ (0.5 H_h)	2.68	7226	13400	6174
Background + CaMg $(CO_3)_2$ (1.0 H_h)	3.48	8076	17400	9324
Background + CaMg $(CO_3)_2$ (1.0 H_h) + S_{40}	3.87	9076	19350	10274
Background + CaMg $(CO_3)_2$ (1.0 H_h) + S_{40} + + microfertilizers	4.35	9292	21750	12458
Background + $CaMg(CO_3)_2$ (1.5 H_h)	4.99	8926	24950	16024
Background + $CaCO_3$ (1.0 H_h)	3.36	7276	16800	9524

It was clarified the economic efficiency of fertilization and liming crops in order to substantiate the most optimal combination of the studied agrotechnical measures.

The analysis of economic efficiency showed that when applying mineral fertilizers of $N_{120}P_{90}K_{120}$ without lime, growing maize for grain was unprofitable, while when chemical ameliorants including different doses of dolomite meal was applied on a similar fertilizer background caused a profit of 6174–16024 UAH/ha (Table 2).

The application of dolomite meal at a dose of 1.5 H_h on the background of $N_{120}P_{90}K_{120}$ was the most cost effective, profit was 16024 UAH/ha.

Conclusion

Researches have shown that the application of dolomite meal on sod-podzolic cohesive sandy soil in the Western Polissia on the mineral fertilizer background increased grain maize productivity. We obtained the highest grain yield (9.04 t/ha) by applying dolomite meal at a dose of 1.5 H_h on the background of the recommended dose of $N_{120}P_{90}K_{120}$. The increase in the yield of maize grain to control (without fertilizers) was 4.99 t/ha, and to background ($N_{120}P_{90}K_{120}$) – 3.98 t/ha. Application of sulfur fertilizers (S40) and two foliar fertilization of plants with microfertilizer Nutrivant Plus Cereals (2 kg/ha) on background of $N_{120}P_{90}K_{120}$ and application of 1.0 dose of dolomite meal in the 4–5 and 6–8 leaves stages increased grain yield by 10.3 %.

The application of dolomite meal at a dose of 1.5 H_h increased in pH_{KCl} by 1.93 units (initial pH_{KCl} 4.47).

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