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MINERAL FERTILIZATION - AN IMPORTANT FACTOR IN OBTAINING MAIZE HARVESTS

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Abstract

Fertilization is a basic technological element of modern agriculture. The complex process of absorption of nutrients is dependent on a number of biotic and abiotic factors and the interaction between them. The research aimed to establish a rational system of fertilization, with low impact on the environment and identifying the optimal fertilization variant, to obtained satisfactory maize yield. The experiment was conducted between 2018-2021 at Agricultural Research and Development Station Turda (ARDS Turda). The experimental factors: factor A - climatic conditions in the experimental years (2018; 2019; 2020; 2021); factor B - nitrogen doses, with five graduations (N_0; N_{50}; N_{100}; N_{150}; N_{200} kg/ha a.s.); factor C - phosphorus doses, with five graduations (P_0; P_{40}; P_{80}; P_{120}; P_{160} kg/ha a.s.). The biological material was represented by Turda 332 hybrid. In addition to the climatic factor, a significant contribution to the increase in maize yield was made by the doses of fertilizers, especially those with nitrogen, the highest yields being recorded in the variants where was applying more than 150 kg/ha a.s. N respectively 120 kg/ha a.s.

***Key words**: maize, mineral fertilization, climatic factors, yield.*

INTRODUCTION

Maize is an important food crop, which contributes significantly to food security and, like any other crop, needs optimal environmental and nutritional conditions, available as needed, to achieve satisfactory yields.

Crop yield depends on many environmental factors (Ranjan et al., 2006; Espósito et al., 2009), such as temperature, precipitation, soil type, soil tillage system and soil moisture respectively whose effects are difficult to predict (Marin et al., 2012; Rusu, 2014).

Agrochemical optimization of the soil-plant system is the essential alternative to achieve high, quality, stable yields and is achieved through the rational and balanced application of fertilizers, differentiated and integrated, with sustainability according to crop requirements and effective soil input (Rusu, 2021), fertilizers playing an important role in increasing by up to 32-50% for crop yield (Ma et al., 2002).

The fertility of the land is constantly declining. Globally, 62% of soil surface area has low or very low fertility, 27% have moderate fertility and only 11% high fertility. The situation in our country on these issues is somewhat different, so 52% of the arable land has a low or very low fertility, 20.7% moderate fertility and 27.3% are considered soils with a very high fertility (Deac et al., 2017).

Removal of nutrients from the soil by their absorption into the plant, by leaching or other processes related to the natural dynamics of soils, they then reduce the nutrient content and a gradual decline in soil fertility (Lupu, 2018).

More than 50% of the administered nitrogen is not recovered by plants (Lassaletta, 2014), due to this low rate of nitrogen recovery by plants, a large amount of unused nitrogen is released, leading to a number of environmental problems (Zhu and Chen, 2002).

The judicious use of these fertilizers is necessary in the current context of climate change, nitrogen oxide emissions being one of the factors contributing to the destruction of the ozone layer (Ramos, 1996).

But with all the negative effects on the biosphere, Nitrogen fertilizers remain the main source of agricultural production to meet the food needs of the population.

In plant cultivation technologies, the importance of fertilization is undeniable, and the results obtained through research and agricultural practice have highlighted the influence of this technological link on the quantitative side, qualitative and economic aspects of the resulting crops (Lupu, 2014; Černý et al., 2010).

Providing adequate nutrient intake improves soil fertility, fertilizers are currently the most useful means of growth and maintaining soil nutrient levels (Smil, 1999).

Maize is known to have high requirements for nutrient and the climatic conditions during the growing season, crop yields being influenced by weather and agrotechnical conditions, yield variability being large and difficult to predict (Doré et al., 1998).

The aim of this study was to examine how the application of nitrogen fertilizers and phosphorus affect maize yield.

MATERIALS AND METHODS

The research have been developed during 2018-2021, at the Agricultural Research and Development Station (ARDS) Turda, on a type soil chernozem.

The conducted experiment is a three-factor one, and the surface of an experimental plot is 48 m^2. During the experiment, the sowing of maize was done by machine MT 6 - Maschio Gaspardo. The sowing density was 65,000 plants/ha and the seed incorporation depth was 5 cm. The pre-maize plant was winter wheat. The biological material was the maize hybrid Turda 332, created at ARDS Turda.

A three-factor experiment was organized to meet the proposed objectives, with the following graduations: factor A - climatic conditions in the experimental years: 2018; 2019; 2020; 2021; factor B - nitrogen doses, with five graduations: N_0; N_{50}; N_{100}; N_{150}; N_{200} kg/ha a.s.; factor C - phosphorus doses (P_2O_5), with five graduations: P_0; P_{40}; P_{80}; P_{120}; P_{160} kg/ha active substance. From the interaction of nitrogen and phosphorus factors resulted 25 experimental variants, placed in the field according to the method of subdivided plots, arranged in six repetitions. Phosphorus fertilization was done in the fall before plowing the land by turning the furrow and nitrogen was applied in the spring, before the processing of germination bed. The production data obtained were statistically processed by analyzing the variance (PoliFact, 2015) and setting LSD (5%, 1%, 0.1%).

The climatic conditions of the four experimental years were different, with variations in average temperatures from one month to the next, with average annual temperatures higher than the multiannual average of 65 years, all four years being thermally characterized as warm.

In 2018, the average monthly and decadal temperatures recorded higher values than the average of 65 years, monthly deviations ranging from 0.6°C in July until 5.3°C in April. From a thermal point of view, in 2019, there were increases in the average monthly temperature in the months of the growing season compared to the multiannual average, except in May, when a negative deviation of 1.4°C. In 2020, as in the previous year, there have been increases in the average monthly temperature over the 5 months, except for May, when the negative deviation was 1.3°C. Months at the beginning of the growing season, since 2021, they have been colder, with deviations of -2.2°C, respectively -0.9°C compared to the multiannual average, negatively influencing the emergence and development of that period (Table 1).

The amount of decadent rainfall has varied significantly each year, with a significant deficit in the spring of 2018 and 2020, corresponding to the sowing-sunrise period and in June-July 2019, when the maize crop has the highest requirements for nutrient and water consumption (Table 2).

Although the lack of rainfall during the growing season of the crop is an important factor in achieving the harvest, the water supply from the soil is still, acquired as a result of previous quantitative rains, can support the crop in order to overcome water stress, especially in conditions where there is no high evapotranspiration, especially due to high temperatures

Table 1. The average air temperature (°C) during the 2018-2021 period at Turda

Experimental year	**Average air temperature (°C)**						
	Month/Decade	April	May	June	July	August	September
2018	Decade I	12.4	19.6	20.5	18.5	23.2	19.6
	Decade II	16.6	15.6	20.5	20.5	22.3	18.8
	Decade III	17.0	20.7	17.5	22.0	21.6	11.5
	Monthly average	15.3	18.7	19.4	20.4	22.3	16.7
	Average 65 years	10.0	15.0	18.0	19.8	19.5	15.2
	Deviation	5.3	3.7	1.4	0.6	2.8	1.5
2019	Decade I	11.9	10.8	19.7	21.2	20.6	20.4
	Decade II	9.5	14.6	23.6	17.4	22.2	16.5
	Decade III	12.6	15.2	22.1	22.4	23.5	14.4
	Monthly average	11.3	13.6	21.8	20.4	22.1	17.1
	Average 65 years	10.0	15.0	18.0	19.8	19.5	15.2
	Deviation	1.3	-1.4	3.8	0.6	2.6	1.9
2020	Decade I	8.7	12.1	17.4	20.9	22.9	19.1
	Decade II	11	16.5	19.2	18.4	20.6	19.3
	Decade III	11.1	12.5	20.8	21.1	21	15.1
	Monthly average	10.3	13.7	19.1	20.2	21.5	17.8
	Average 65 years	10.0	15.0	18.0	19.8	19.5	15.2
	Deviation	0.3	-1.3	1.1	0.4	2.0	2.6
2021	Decade I	5.9	12.8	16.9	21.6	21.5	15.9
	Decade II	7.8	14.3	18.6	24.0	21.2	17.1
	Decade III	9.8	15.1	23.9	22.4	16.7	12.1
	Monthly average	7.8	14.1	19.8	22.7	19.7	15.0
	Average 65 years	10.0	15.0	18.0	19.8	19.5	15.2
	Deviation	-2.2	-0.9	1.8	2.9	0.2	-0.2

Table 2. The amount of precipitation (mm) during the 2018-2021 period at Turda

Experimental year	**The amount of precipitation (°C)**						
	Month/Decade	April	May	June	July	August	September
2018	Decade I	5.4	16.8	13.8	51.9	20.6	15.2
	Decade II	14.4	33.4	67.5	28.2	0.0	10.0
	Decade III	6.4	6.6	17.0	5.6	17.6	4.6
	Monthly average	26.2	56.8	98.3	85.7	38.2	29.8
	Average 65 years	45.6	69.4	84.6	78.0	56.1	42.4
	Deviation	-19.4	-12.6	13.7	7.7	-17.9	-12.6
2019	Decade I	3.8	34.8	30.6	7.6	59.6	0
	Decade II	34.8	38.8	5.6	25.2	3	0.4
	Decade III	24	78.8	32.6	2.2	1.2	19
	Monthly average	62.6	152.4	68.8	35	63.8	19.4
	Average 65 years	45.6	69.4	84.6	78.0	56.1	42.4
	Deviation	17.0	83.0	-15.8	-43.0	7.7	-23.0
2020	Decade I	0	10.2	16	23	3.6	6.6
	Decade II	0.8	11.2	115	51.6	53.6	0
	Decade III	17	23	35.6	12.2	0.8	50.8
	Monthly average	17.8	44.4	166.6	86.8	58	57.4
	Average 65 years	45.6	69.4	84.6	78.0	56.1	42.4
	Deviation	-27.8	-25.0	82.0	8.8	1.9	15.0
2021	Decade I	8.1	4.4	7.2	56.7	7.4	1.5
	Decade II	18.5	32.2	25.6	63.9	7.5	11.0
	Decade III	11.8	44.2	12.2	2.5	38.0	26.6
	Monthly average	38.4	80.8	45.0	123.1	52.9	39.1
	Average 65 years	45.6	69.4	84.6	78.0	56.1	42.4
	Deviation	-7.2	11.4	-39.6	45.1	-3.2	-3.3

RESULTS AND DISCUSSIONS

The analysis of variance reflects very well the very significant influence of fertilizer doses and climatic conditions in the production of maize. The significance of the F test reflects a very significant involvement of the studied factors in the realization of maize crops. The analysis of the variance shows that the highest share in the formation of production has nitrogen doses, phosphorus doses and climatic conditions (Table 3).

Climatic conditions also play a very important role in the production, being the decisive factor in the formation of crops, especially in the conditions in which the water coming from the precipitations is the main source of water that the culture uses during all the vegetation period. Maize production shows increased variability in terms of results obtained during the four years of experimentation, the dependence of the culture on the climatic conditions being reflected in the average productions made during the period 2018-2021 presented in Table 4.

The favorable climate conditions of 2021 have brought an increase in the harvest of 249 kg/ha, with a very significant difference from the average of the years (control).

The use of nutrients by maize depends very much on the humidity conditions and especially on the distribution of precipitation during the growing season. The period when maize consumes large amounts of nutrients coincides with the period when it also consumes large amounts of water (Haș, 2004), therefore it is very important that by the beginning of the grain formation the plants benefit from sufficient humidity and temperatures below 30°C.

Lack of precipitation in important phenophases leads to significant decreases in production, especially when is correlated with high temperatures, the lowest production of the four years studied being recorded in the year 2018, with a difference of 259 kg/ha in a negative way compared to the average of the years(control). Although at the beginning of the growing season the maize crop suffered due to thermal and water stress, however, the optimal conditions in the following period made the production obtained in the year 2021 to increase compared to the average.

Following the experiences made, Johnson și Raun (2003) states that the harvest can vary significantly from year to year even if the same N fertilizer is applied to the same area of land.

Table 3. Analysis of variance table

Source of variation	**Sum of square**	**Degree of freedom**	**Mean Square**	**F**
Y (Year)	26563680	3	8854560	51.00***
N (Nitrogen)	594975500	4	148743900	1728.22***
Y x N	26618270	12	2218190	25.77
P (Phosphorus)	163271500	4	40817870	535.87***
Y x P	10628630	12	885719	11.63
N x P	4123210	16	257701	3.38
Y x N x P	16721670	48	348368	4.57
Error Y	2604193	15	173613	
Error N	6885418	80	86068	
Error P	30468480	400	76171	
Total	842902460	99		

Table 4. The influence of climatic condition in experimental years on maize yield

Experimental years	**Yield (kg/ha)**	**Diference (kg/ha)**	**Duncan test**
Average years (control)	8296^{mt}	0	-
2018	8037^{000}	-259	A
2019	8145^{00}	-150	B
2020	8456**	160	C
2021	8545***	249	C
LSD (p 5%) 102 LSD (p 1%) 142 LSD (p 0.1%) 196			

Nitrogen demand for maize during the early vegetative stages is low, but it grows rapidly and remains elevated for several weeks. About half of the total nitrogen uptake by maize occurs when maize biomass is about a quarter of the maximum (Abendroth et al., 2011).

Nitrogen (N) is the most important element in the nutrition of a plant, being responsible for the processes of life, such as photosynthesis, growth and reproduction, vegetative and qualitative growth. One of the most important factors leading to poor recovery of nitrogen fertilizers is climatic conditions, drought, especially in spring, being in the first places in the top of the factors that intervene in the absorption of nutrients.

Nitrogen fertilization can also have long-term negative effects, especially when associated with temperature heating, by increasing evapotranspiration and limiting the water supply. The application of nitrogen fertilizers leads to a significant increase in production, of 1478 de kg/ha, with a very significant difference from the unfertilized control, since the application of a dose of 50 kg/ha a.s. N, growth that is maintained until the highest dose of applied nitrogen (200 kg/ha a.s. N) (Table 5).

Table 5. The influence of nitrogen doses on maize yield

Nitrogen doses	Yield (kg/ha)	Diference (kg/ha)	Duncan test
N_0 (control variant)	6529^{mt}	0	A
N_{50}	8007***	1478	B
N_{100}	8523***	1994	C
N_{150}	9085***	2556	D
N_{200}	9335***	2806	E
LSD (p 5%) 75	LSD (p 1%) 100	LSD (p 0.1%) 129	

Phosphorus (P) also plays a role in photosynthesis, plant growth, reproduction and respiration, being generally associated with cell division, root growth, flowering and maturatity of a culture.

The application of different doses of phosphorus brings an increase in production between 485 kg/ha and 1496 kg/ha, lower than the nitrogen mineral fertilizers, but statistically assured as very significant compared to the control variant to which no phosphorus was applied. (Table 6).

The application of phosphorus fertilizers on rich soils in this element can cause, by erosion, a eutrophication of fresh water. (Leinweber et al., 2002) and therefore it is important to take into study the soil content in macro and microelements before application.

Table 6. The influence of phosphorus doses on maize yield

Phosphorus doses	Yield (kg/ha)	Diference (kg/ha)	Duncan test
P_0 (control variant)	7494^{mt}	0	A
P_{40}	7978***	485	B
P_{80}	8359***	865	C
P_{120}	8658***	1164	D
P_{160}	8990***	1496	E
LSD (p 5%) 70	LSD (p 1%) 92	LSD (p 0.1%) 118	

From the analysis of the specificity of causal relationships and the influence of nitrogen and phosphorus doses, in the four years analyzed, by means of the corresponding response curves the important production differences which can be observed as a result of the application of NP mineral fertilizer can be observed, from low doses to doses of 160 kg/ha a.s. for Nitrogen and 120 kg/ha a.s. for Phosphorus.

Although at the highest nitrogen thresholds (200 kg/ha a.s.) the highest productions are recorded every year (betwen 9118 and 9491 kg/ha), however, there is a capping of production after the dose of 150 kg/ha a.s. N (Figure 1).

In the case of phosphorus fertilization the situation is quite similar, except that in this case the response curves are not as pronounced as those of nitrogen.

The production results obtained from the application of phosphorus are between 8725 kg/ha and 9094 kg/ha when applying the maximum dose of phosphorus, with a rather small difference compared to the non-fertilized variant in all four years studied (Figure 2).

In the years 2020 and 2021, in the case of both nitrogen and phosphorus, the response curves are more flattened, the registered productions in the non-fertilized control variants starting from a higher valuation than those obtained in 2018 and 2019.

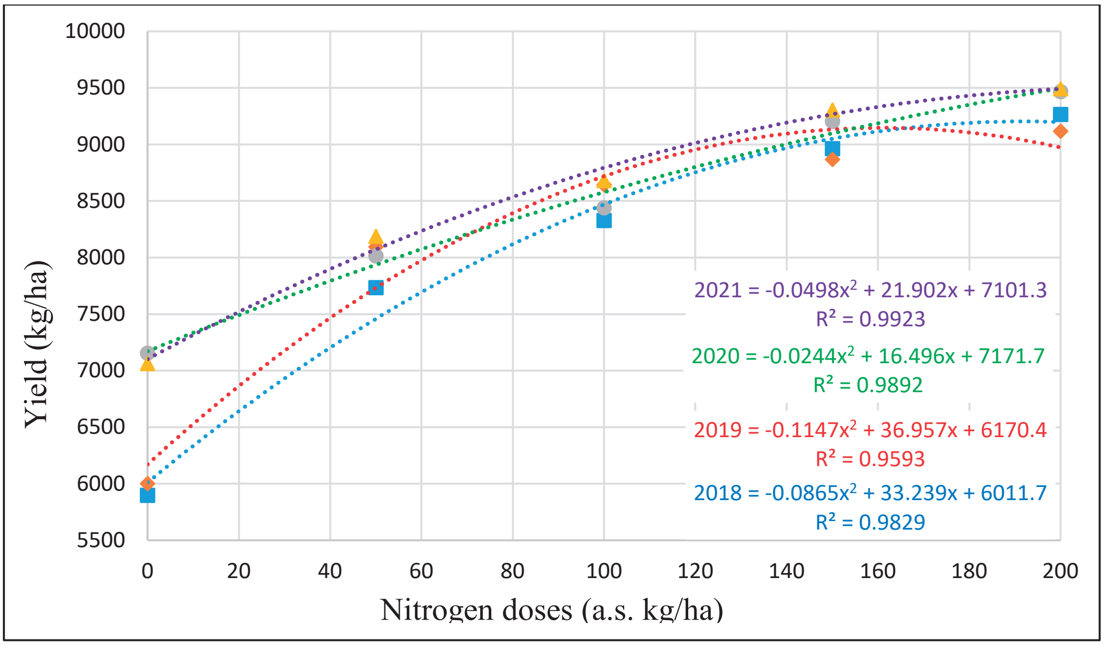

Figure 1. Relationship between nitrogen doses and production

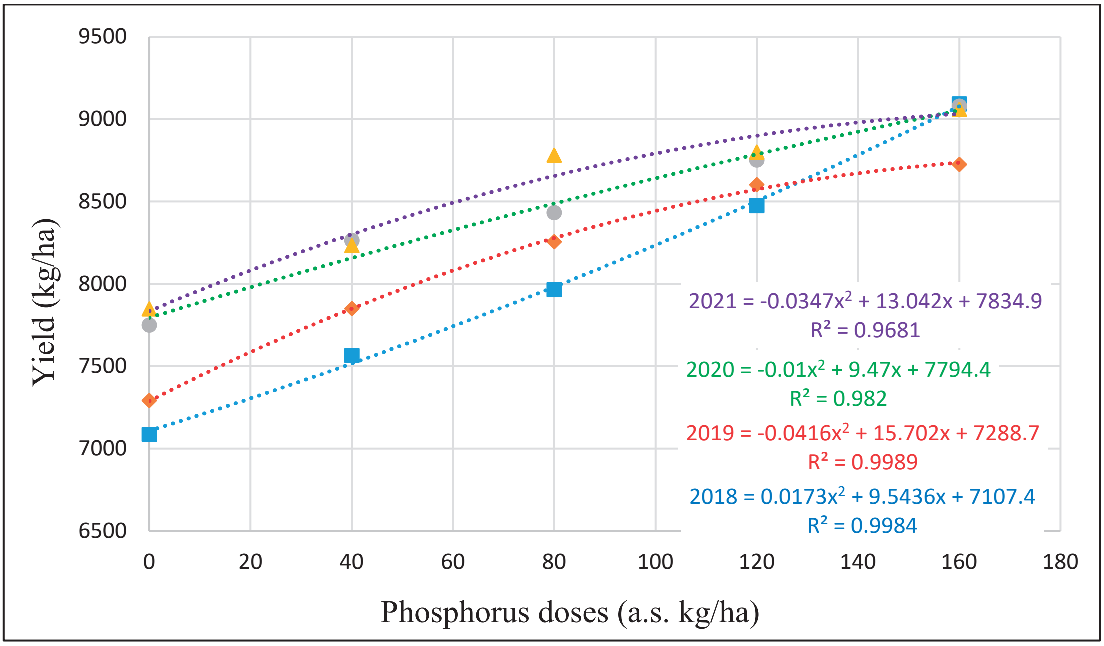

Figure 2. Relationship between phosphorus doses and production

Response curves at higher nitrogen depths are more pronounced than in the case of phosphorus, which suggests the importance of N fertilization of maize, in order to obtain superior productions, but higher maize yields cannot be obtained without the addition of phosphorus (Figures 3 and 4).

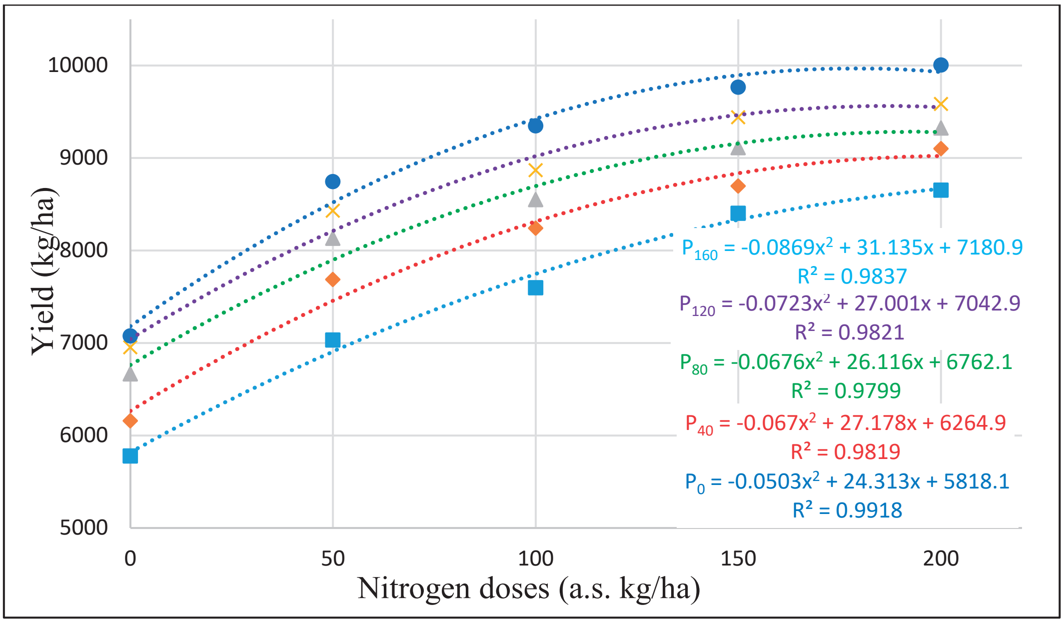

Figure 3. The influence of nitrogen doses on different phosphorus levels

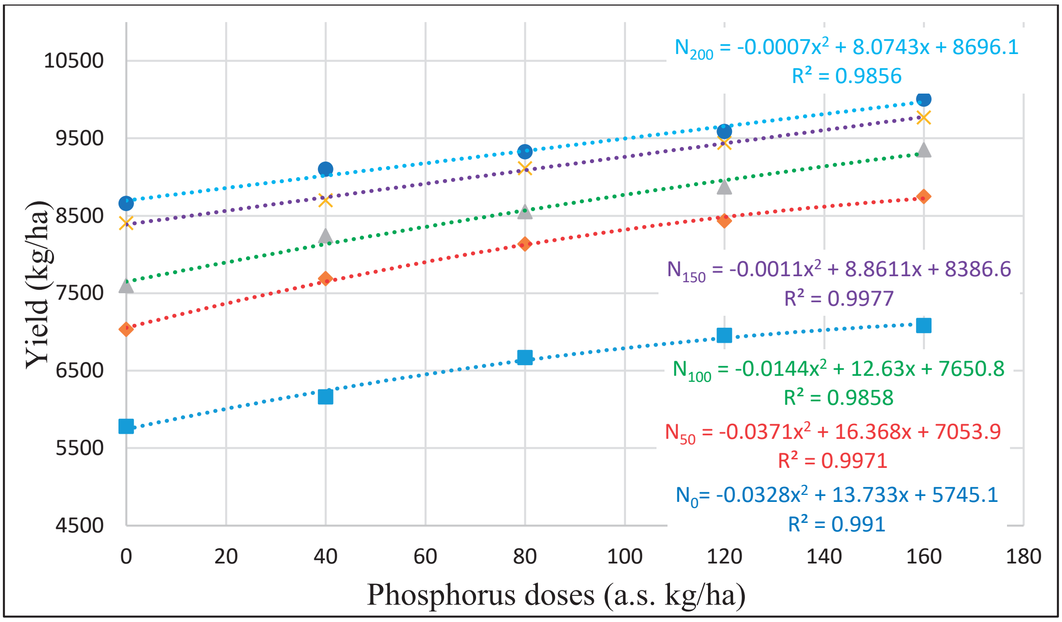

Figure 4. The influence of nitrogen doses on different phosphorus levels

CONCLUSIONS

The identification of the optimal doses of mineral fertilizers has a special importance in the efficiency of the harvests but also in the prevention of some secondary phenomena in time.
The strong influence of climatic conditions over the four years on maize production reflects a very pronounced inter-annual variability, which makes the adaptability of biological material to favorable and less favorable conditions an important factor in the stability of production.

Behavior of maize hybrid Turda in the four years, at different doses of nitrogen and phosphorus, indicates a rather high variability of its reaction to nitrogen and phosphorus fertilization, reaction resulting from differences in production between different doses of nitrogen and phosphorus.
Although the most significant maize production is obtained by applying the maximum doses of mineral fertilizers, at doses higher than 150 kg/ha a.s. N and 120 kg/ha a.s. P there is a less significant increase in production than in those fertilized with lower doses, where the

differences between doses are more pronounced.

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REFERENCES

Abendroth, L. J., Elmore, R. W., Boyer, M. J., Marlay S. K. (2011), Maize growth and development. PMR 1009. Iowa State Univ. Ext., Ames.

Černý, J., Balík, J., Kulhánek, M., Čásová, K., Nedvěd, V. (2010). Mineral and organic fertilization efficiency in long-term stationary experiments, *Plant Soil Environ*, 56, no.1: 28–36.

Deac, V., Ignea. M., Ștefănescu, M. (2017). Rezultate ale cercetăriilor effectuate la SCDA Turda în domeniul folosirii rationale a îngrășămintelor în experiențele de lungă durată. Contribuții ale cercetării științifice la dezvoltarea agriculturii; Vol. VII, Volum omagial 60 ani SCDA Turda, 201-227, Turda, România.

Doré, T., Meynard, J. M., Sebillotte, M. (1998). The role of grain number, nitrogen nutrition and stem number in limiting pea crop (*Pisum sativum*) yields under agricultural conditions. *European Journal of Agronomy*, 8, 29-37.

Espósito, M. A., Alejandra, M. E., Pamela, C. V., López, L. D., Sebastián, A. F., Luis, C. E. (2009). Relationships among agronomic traits and seed yield in pea. *BAG J Basic Appl. Genet,* 20, 1.

Haş, I. (2004). *Particularităţi tehnologice pentru cultura porumbului în Transilvania*. Ed. Boema Turda, 21–45.

Johnson, G. V., Raun, W. R. (2003). Nitrogen response index as a guide to fertilizer management. *J. Plant Nutr.* 26, 249–262.

Lassaletta, L., Billen, G., Grizzetti, B., Anglade, J. and Garnier, J. (2014). 50 year trends in nitrogen use efficiency of world cropping systems: the relationship between yield and nitrogen input to cropland. *Environ. Res. Lett*., 1-10.

Leinweber, P, Turner, B. L, Meissner, R. (2002). Phosphorus. In: Haygarth P.M, Jarvis S.C, editors. Agriculture, hydrology and water quality. ch. 2. CAB International; Wallingford, UK, 29–55.

Leonte, A., Agapie, A., Pintilie, P. L. Druțu, A. C., Amarghioalei, G., Eșanu, S. (2021). Research regarding the influence of nitrogen and phosphorus fertilizers on winter wheat, in the pedoclimatic conditions in entral of Moldavia. *Life Science and Sustainable Development*, Vol. 2, No. 2, Lovrin, România.

Lupu, M., Druțu, C., Popa, L. D., Naie, M. (2014). Influence of chemical fertilizers application on autumn wheat yield in long-term experiences at Agricultural Research and Development Secuieni, Neamț county, România. *Cercetări Agronomice în Moldova*, Vol. XLVII, no. 3 (159), 27-38.

Lupu, M., Simona, F. I., Margareta, N. (2018). Study of nitrogen fertilization at maize crop in ARDS Secuieni conditions. *Lucrări Ştiinţifice*, Vol. 61(2), Seria Agronomie.

Ma, C., Yang, F., Gao, X., Chen, L. (2002). A historical review of China chemical fertilizers in last 100 years (in Chinese). *China AgroSciTech Press*, Beijing, China.

Marin, D. I., Rusu, T., Mihalache, M., Ilie, L., Bolohan C. (2012). Research on the influence of soil tillage system upon pea crop and some properties of reddish preluvosoil in the Moara Domneasca area. *Annals of the University of Craiova – Agriculture, Montanology, Cadastre Series*, 42(2), 487-490.

Ramos, C. B. (1996). Effect of agricultural practices on the nitrogen losses in the environment. Fertilizers and environment, Dordrecht, *The Netherlands Kluwer Academic Publishers*, 355–361.

Ranjan, S., Kumar, M., Pandey, S. S. (2006). Genetic variability in peas (*Pisum sativum* L.). *Legume Research*, 29: 311-312.

Rusu, T. (2014). Energy efficiency and soil conservation in conventional, minimum tillage and no-tillage. *International Soil and Water Conservation Research*, 2, 42-49.

Rusu, M. (2021). *Compendiu agrochimic*. Ed. AcademicPres, Cluj-Napoca.

Smil, V. (1999). Long-range perspectives on inorganic fertilizers in global agriculture. Travis P. Hignett lecture. IFDC, Florence, Italy.

Zhu, Z. L., Chen, D. L. (2002). Nitrogen fertilizer use in China-contributions to food production, impacts on the environment and best management strategies. *Nutr. Cycl. Agroecosyst*., 63, 117–127.