NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 38, 2021
Print ISSN 1222–4227; Online ISSN 2067–5720

LONG TERM NITROGEN AND PHOSPHORUS FERTILIZATION INFLUENCE UPON SOIL

Nicoleta Mărin[1], Cornelia Lupu[2], Mihaela Șerban[3], Claudia Preda[1*]

[1]National Research and Development Institute for Soil Science, Agro-Chemistry and Environment - ICPA Bucharest, 61 Mărăşti Blvd., Bucharest, Sector 1, Romania

[2]Agricultural Research Station Secuieni, 617415 Secuieni, Neamţ County, Romania

[3]National Agricultural Research and Development Institute Fundulea, 915200 Fundulea, Călăraşi County, Romania

[*]Corresponding author. E-mail: claudia.balaceanu@icpa.ro

ABSTRACT

The paper presents the results obtained in the SCDA Secuieni long term experimental field. The effect of long term (42 years) nitrogen and phosphorus fertilization upon soil fertility and yield was followed up with 0, 40, 80, 120, and 160 kg N/ha and 0, 40, 80, 120, 160 kg P/ha doses. Long term fertilization led to a statistically significant increase of grain yield. Maize grain yield increased from 5,569 kg/ha in the unfertilized control to 9,805 kg/ha in the $N_{160}P_{160}$ fertilized variants. Each kilogram of phosphorus brought a 6.78 kg maize grain gain, and for each kilogram of nitrogen a 15.28 kg grain increase was obtained. Phosphorus long term fertilization significantly increased the total and mobile soil phosphorus content: from 0.0160% in the unfertilized control to 0.094% in the variants fertilized with 160 kg P/ha, respectively from 8 mg P_{AL}/kg in the unfertilized control to 144 mg P_{AL}/kg in the variants fertilized with 160 kg P/ha, and didn't significantly change total and mobile potassium level. No significant humus and nitrogen levels modifications occurred under the influence of nitrogen and phosphorus long term fertilization.

Keywords: long-term experiments, nitrogen, phosphorus, potassium, heavy metals.

INTRODUCTION

Mineral fertilizers researches showed that the results don't highlight statistically significant modifications of the soil physical, chemical, and biological characteristics in the short term experiments, due to soil resilience, except for the excessive fertilizer doses and in the case of sandy soils. As results begun to appear that highlighted negative modifications of the soil physical, chemical, and biologic characteristics following long term use of mineral fertilizers, Cristian Hera decided the organization of a unitary network of long term experiments in different pedo-climatic conditions, with the same mineral fertilizers doses. Sixteen such experimental fields were organized as early as 1975, some of them still running, more or less altered by the brutal changes occurred after 1990 when the research network of the Academy for Agricultural and Forrest Sciences underwent many changes as a result of severe funding cut down.

Not coincidentally a reduction of main field crops yields was noticed in the 1990-2000 period, with 2.4% for corn, 15% for wheat, 26.2% for barley, 26.5% for sunflower, 10% for sugar beet, and 18% for potatoes, as research activities diminished. The mineral fertilizers inputs also diminished, 3-4 times the nitrogen and phosphorus ones, and 10 times the potassium ones, down to 50% of the world average and 5-10 times less than in the European Union countries, as did the organic fertilizers inputs (swine and cattle numbers decreased three times, so the manure quantities diminished accordingly), which led to soil supply depletion of the main nutrition elements in the 1990-2000 period by 35% for humus, 35% for nitrogen, 29% for phosphorus, 37% for potassium and increased with 31% the extent of moderately and strongly acid surfaces (Dumitru, 2012).

Long term experiments are an ”open book”, a data ”mine” for studying the fertilizers effect upon different soil physical, chemical, and biological properties and of the

Received 7 January 2020; accepted 26 August 2020. First Online: August, 2020. DII 2067-5720 RAR 2021-1

manner in which it quantitatively and qualitatively influences yields, environment, and Romanian land fertility, in the present and in the future (Hera, 2004).

Ștefanic (1999) showed that any yield increase without the needed soil fertility state improvement or maintenance measures will lead to ”agricultural mining” which will deplete the soil in time, will ruin its structure and will lead to acidification and salinization.

As the need for food is continually growing, mineral fertilizers application became essential taking into account large yield gains and the need for new breeds to reach their yielding potential.

FAO (1999) assessed that fertilizers contribute 55-57% to average yield per hectare and with 30-31% to total crop growth. Lupu (2007) showed that fertilization contributes 40% of the crops total gain worldwide.

Shirazi et al. (2014) obtained the highest wheat yield following fertilization with 100 kg nitrogen/ha. The irrigation also had a significant effect upon yield and wheat growth parameters. Combining 200 mm irrigation and 120 kg N/ha, 80 kg P_2O_5/ha, 60 kg K_2O/ha, and 30 kg S/ha was the best treatment for wheat crop.

MATERIAL AND METHODS

One of these long term experiments was organized by SCDA Secuieni, Neamţ County, in 1975. Soil type: haplic chernozem (soil types in this paper are defined according to WRB 2014). The average annual temperature is 8.8ºC, average rainfall is 545 mm, irregularly distributed along the vegetation season. From the pluviometry point of view 50% of the years are characterized as normal, 27.8% as droughty, and 22.2% as very droughty (Trotuș et al., 2017).

The experiment was organized in subdivided parcels, with two factors: phosphorus in 0, 40, 80, 120, and 160 kg/ha and nitrogen in 0, 40, 80, 120, and 160 kg/ha. The phosphorus need was ensured by superphosphate and the nitrogen one from ammonium nitrate. Soil samples were taken in 2018 from the 0-20 cm layer and maize yields of the Olt hybrid from 2017 are presented.

Soil analyses were performed by the following methods:

- humus - STAS 7184/21-82; by the wet oxidation method Walkley-Black modified by Gogoaşă;
- pH determined by potentiometry in aqueous suspension, soil:water ratio 1:2.5, with glass-calomel combined electrode;
- total nitrogen (N%): Kjeldahl method: digestion with H_2SO_4 at 350ºC, potassium sulphate and copper sulphate catalyst - SR ISO 11261:2000;
- accessible (mobile) phosphorus: extraction after Ègner-Riehm-Domingo, determined by colorimetry with molybdenum blue after reduction with ascorbic acid;
- accessible (mobile) potassium extraction after Ègner-Riehm-Domingo, determined by flame photometry;
- total phosphorus by colorimetry, ICPA Methodology (1986), Chapter 8, pct. 2;
- total potassium, ICPA Methodology (1986), Chapter 9.

RESULTS AND DISCUSSION

Long term (42 years) fertilization with different nitrogen and phosphorus doses highlighted a continuous, statistically significant, maize grain yield increase.

In the case of phosphorus fertilization statistically significant gains occurred starting with the 80 kg/ha dose, which provided a 9% distinctly significant yield gain. The 120 and 160 kg/ha doses yielded very significant yield gains (17-18%). Maize grain average yield gains were 6% in the 1994-2003 period, in the same experiment, for the application of 40 kg P/ha, 7% for the application of 80 kg P/ha, 10% following fertilization with 120 kg P/ha, and 11% after 160 kg P/ha fertilization. Nitrogen fertilization with 40, 80, 120, and 160 kg/ha led to yield increase of 10, 17, 22, and 25%, respectively (Lupu, 2007).

For the same nitrogen fertilizers doses (0, 40, 80, 120, 160 kg/ha) the yield gain was twice as compared to the same doses of phosphorus fertilizers. The highest yield

(9,805 kg/ha) was obtained in the variants fertilized with 160 kg P/ha + 160 kg N/ha. The lowest yield (5,569 kg/ha) was obtained in the unfertilized variants.

Yield gains for each kilogram of fertilizer active substance were lower when applying together phosphorus and nitrogen fertilizers.

Data of the Code of good agricultural practice appraise that for a ton of main crop and the corresponding quantity of secondary crop 27.5 kg N/ha, 12.5 kg P/ha, and 16.5 kg K/ha are extracted from soil.

At the maximum obtained yield (9,805 kg/ha), 269.6 kg N/ha, 122.6 kg P/ha, and 161.8 kg K/ha were extracted from soil. The average yield in the experiment was 7,593 kg/ha and 208.8 kg N/ha, 94.9 kg P/ha, and 125.3 kg K/ha were extracted from soil. Yield growth along with the fertilizers doses shows that the latter should be increased and potassium should be added, which totally lacked.

In the same experiment, in the 2007-2009 period, the average yield gains in the nitrogen fertilized variants were 12% following fertilization with 40 kg N/ha, 18% at 80 kg N/ha fertilization, 23% at fertilization with 120 kg N/ha, and 30% for 160 kg N/ha. In the same period, phosphorus fertilization led to 5% yield gain in the 40 kg P/ha fertilized variant, 9% by applying 80 kg P/ha, 13% in the variant fertilized with 120 kg P/ha, and 14% by fertilization with 160 kg P/ha (Lupu et al., 2012).

In wheat crops in the 2013-1025 period yield gains obtained following phosphorus fertilization were 7% by applying 40 kg P/ha, 12% at the 80 kg P/ha dose, 17% when applying a 120 kg P/ha dose, and 15% at the 160 kg P/ha dose. Nitrogen fertilization provided 14% gains at the 40 kg N/ha dose, 22% at the 80 kg N/ha doze, 28% for 120 kg N/ha, and 36% by fertilization with 160 kg N/ha (Lupu et al., 2016).

Long term (30 years) research carried out by Manna et al. (2007) at the Ranchi Agricultural University in India showed that soya yields decreased in the unfertilized control variants or fertilized only with N or NP and wheat yields decreased in the control variants and in the variants fertilized only with nitrogen. Yields increased in the NPK + manure and NPK + amendments variants. Three decades of continuous soya-wheat system cultivation highlighted a nitrogen and carbon active fractions significant loss in the unfertilized control and in the N or NP fertilized variants. Carbon and organic nitrogen of the particles were lower as the aggregate N and C decomposition rate grew, which lead to a lower nutritive elements supply capacity.

The soil on which the experiment was placed had a moderately acid reaction.

Long term (42 years) nitrogen and phosphorus fertilization influence upon soil pH is presented in Figures 1a, 1b, and 1c. The data show that phosphorus fertilization with 0, 40, 80, 120 and 160 kg/ha did not lead to soil pH statistically significant modifications (Figure 1a).

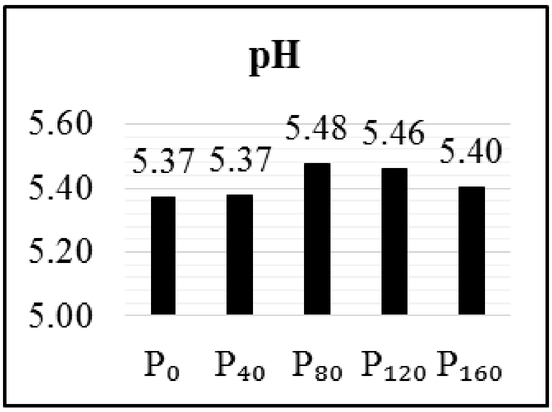

Figure 1a. The influence of long term phosphorus fertilization upon soil pH

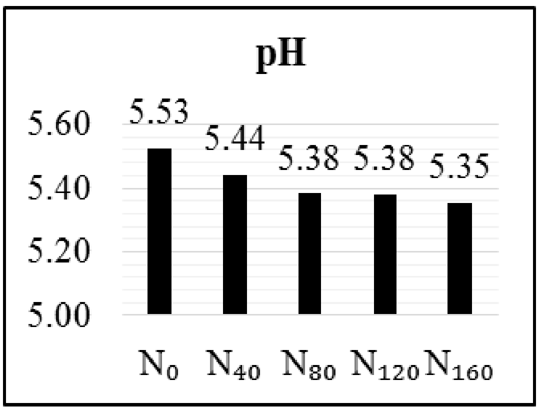

Figure 1b. The influence of long term nitrogen fertilization upon soil pH

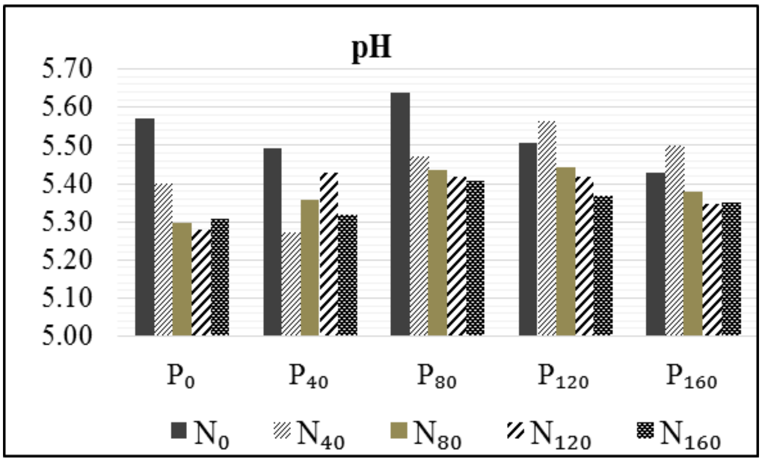

Figure 1c. The influence of long term nitrogen and phosphorus fertilization upon soil pH

Superphosphates (simple and concentrated) can determine temporary sporadic effects of soil acidification through the incongruent solubilization phenomenon of the mono-substituted phosphate they contain, from which disubstituted calcium phosphate and phosphoric acid result. The acidity thus generated is neutralized in time by reactions with the soil hydrated sesquioxides, so that simple (17-20% P_2O_5) and concentrated (34-44% P_2O_5) superphosphates don't sustainably modify soil reaction. The superphosphates bases (Ca, Mg) input also contribute as does the slightly soil T value increase effect through phosphoric acid ions adsorption on soil particles (Borlan, 1998).

Studies carried out by Curtin et al. (2007) offered data regarding the strong and stable association between carbon bound sulphur and organic nitrogen in soil and the organic matter light fraction. Two factors can be singularized as contributing to the soil organic sulphur increase induced by the superphosphate alone.

Carbon bound sulphur increased at the same time with total nitrogen. Nitrogen increase can be mainly attributed to superphosphate supply which controls clover growth resulting in nitrogen rich organic matter input in soil. Secondly, sulphur from superphosphate produced the increase of hydro iodic acid reduced sulphur, although it was a small organic sulphur component, especially in the case of organic matter light fraction.

Long term nitrogen fertilization with doses higher than 80 kg/ha led to a soil statistically significant acidification (Figure 1b).

Nitrogen application together with phosphorus led to a soil acidification tendency but the values were not significant (Figure 1c).

The soil acidification effect is only explained by base depletion. This takes place through the increased base consumption by the higher yields and by leaching in the profile of the anions which accompany fertilizers nutrition elements (HCO_3^-, Cl^-, SO_4^{2-}) or form in the soil by nutrition cations transformation (for instance, NH_4 → NO_3^- → NO_2^-).

Only the fertilizers that determine substantial yield gains but don't contain bases themselves while the anions they contain are not at all adsorbed (Cl^-, NO_2^-, HCO_3^-) or are slightly adsorbed in soil (SO_4^{2-}) cause a definite debasification of the soil ploughed layer (Borlan, 1998).

Borza et al. (2001) noticed the same acidification process following nitrogen fertilization in a long term (20 years) experiment placed on the Făget - Lugoj Albic Luvisol in which the same nitrogen and phosphorus fertilizers doses were applied.

Long term (26 years) researches carried out on the Suceava Chernozem on which 0, 40, 80, 120 and 160 kg P_2O_5/ha and 0, 50, 100, 150 and 200 kg N/ha doses were applied led to the following modifications in soil:

- Soil acidification as pH values decreased with 1.02-0.86 units;

- Hydrolytic acidity increase with 3.12-3.84 me/100 g soil;
- Exchangeable bases sum decrease with 2.6-3.0 me/100 g soil;
- Base saturation percentage decrease with 9-11%;
- Exchangeable aluminum content increase (Ciobanu, 2001).

Fertilization with nitrogen and phosphorus, in 40, 80, 120 and 160 kg/ha for 42 years did not lead to statistically significant modifications of the soil humus level (Figures 2a, 2b and 2c).

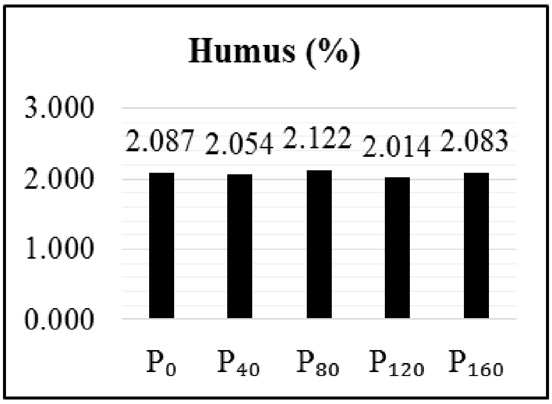

Figure 2a. Phosphorus long term fertilization influence upon humus content

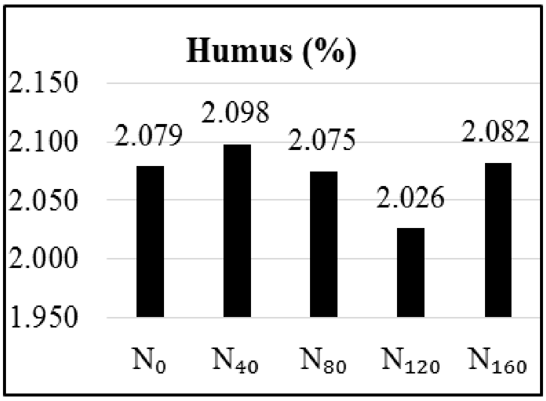

Figure 2b. Nitrogen long term fertilization influence upon humus content

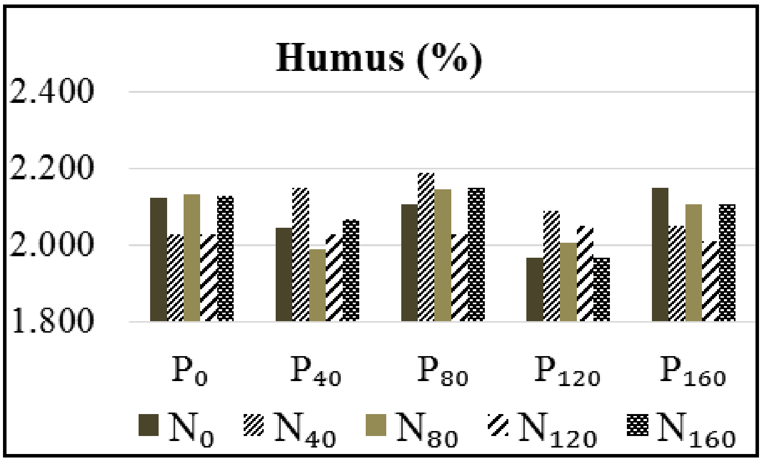

Figure 2c. Nitrogen and phosphorus long term fertilization influence upon humus content

Hai et al. (2010) discovered that no statistically significant modifications of the soil organic carbon and total nitrogen contents were noticed after 26 years of NPK fertilization.

The soil total nitrogen values were not statistically modified following long term nitrogen and phosphorus mineral fertilization.

Kaur et al. (2008) found out that fertilization with only nitrogen led to the soil microbial biomass carbon content decrease after a number of years. Microbial biomass decrease can be the consequence of the acidifying effect of the nitrogen fertilizers that were applied as urea only which probably leads to unfavorable conditions occurrence for many microorganisms types, such as bacteria and actinomycetes.

Long term (42 years) fertilization with 40-160 kg/ha phosphorus doses led to very significant increase of the soil total phosphorus level (Figure 3a). Nitrogen application along with phosphorus raised the yield but did not lead to soil total phosphorus significant accumulations (Figure 3c). Fertilization with only nitrogen did not lead to statistically significant modifications of soil total phosphorus level (Figure 3b).

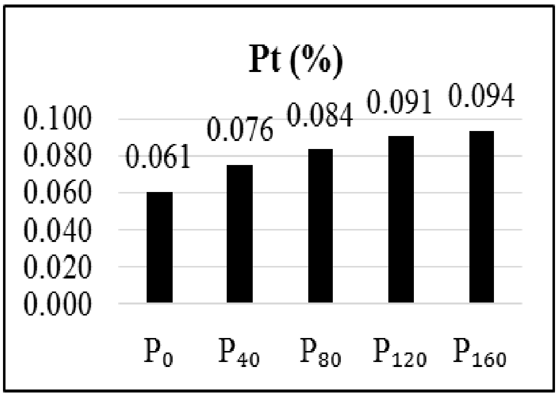

Figure 3a. Phosphorus long term fertilization influence upon total phosphorus content

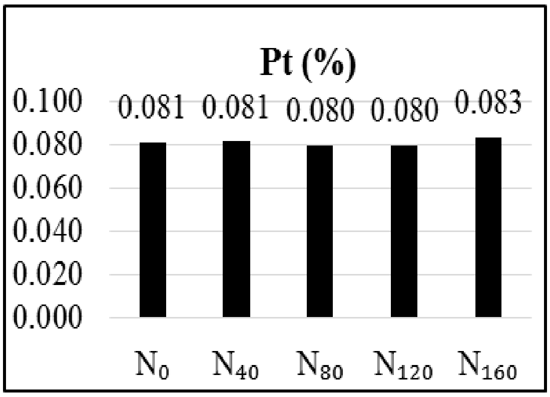

Figure 3b. Nitrogen long term fertilization influence upon total phosphorus content

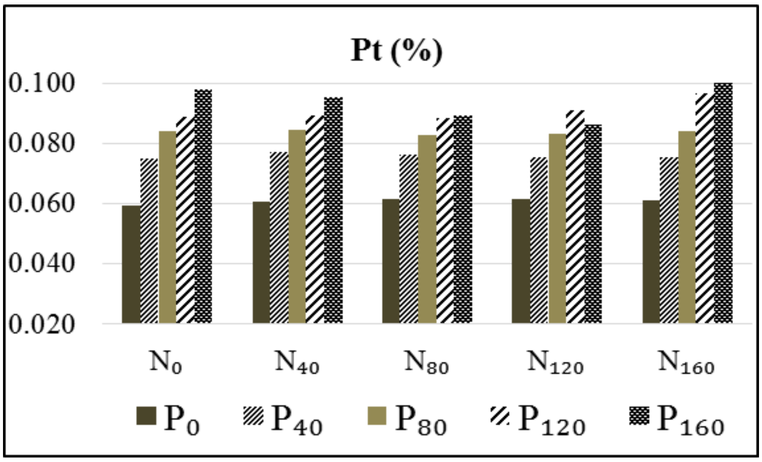

Figure 3c. Nitrogen and phosphorus long term fertilization influence upon total phosphorus content

Soil mobile phosphorus level significantly increased as the phosphorus dose increased (Figure 4a). Nitrogen fertilization didn't statistically significantly increase the soil mobile phosphorus level (Figure 4b). The joint application of phosphorus and nitrogen did not lead to statistically significant modifications of the soil mobile phosphorus level (Figure 4c).

The soil mobile phosphorus level grew from very low (4-8 mg/kg) in the variants fertilized with 40 kg/ha phosphorus to very high (more than 72 mg/kg) in the variants that received 80 kg P/ha. Nitrogen doses increase actuated the mobile phosphorus intake. The minimum phosphorus dose is 80 kg/ha, but the recommended one in the long run on a N_{120}-N_{160} fertilization background is 120 kg/ha.

The experiments organized by Borza et al. (2001) on the Sânandrei Luvic Phaeozem - Chromic Luvisol showed that the mobile phosphorus level increased from 7 to 58 mg/kg by 100 kg P/ha fertilization for 25 years.

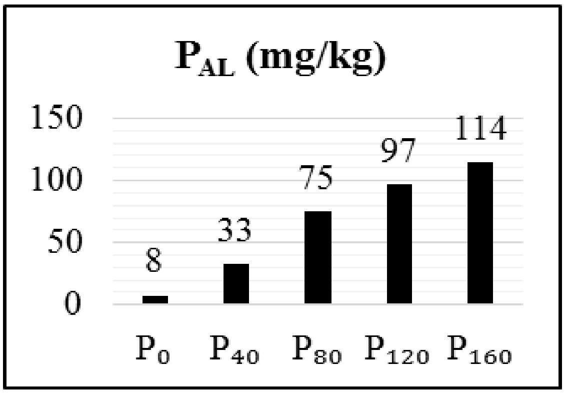

Figure 4a. Long term phosphorus fertilization influence upon mobile phosphorus content

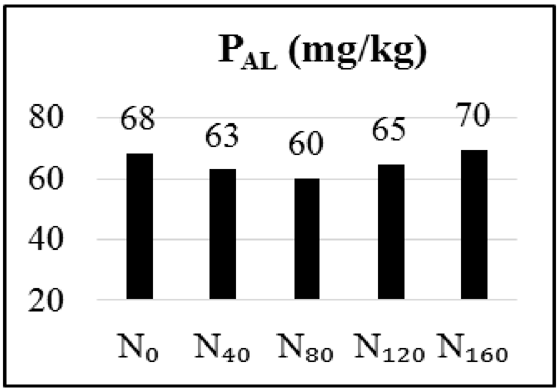

Figure 4b. Long term nitrogen fertilization influence upon mobile phosphorus content

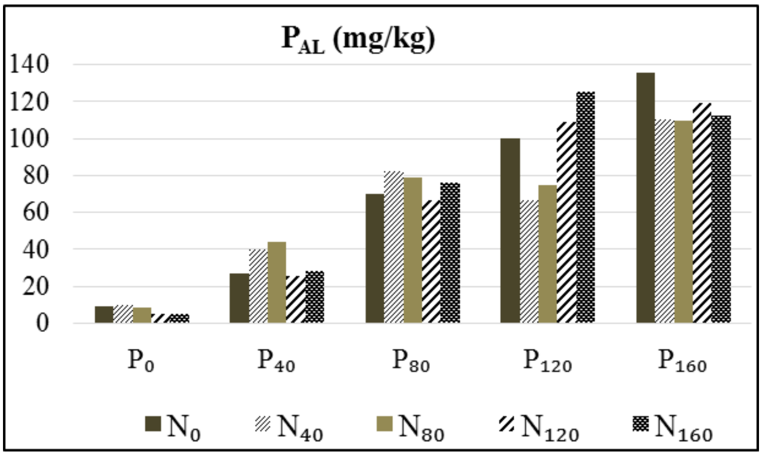

Figure 4c. Long term nitrogen and phosphorus fertilization influence upon mobile phosphorus content

The total and mobile potassium levels were not significantly modified following long time phosphorus, nitrogen, or phosphorus and nitrogen fertilization (Figures 5a, 5b, 5c, 6a, 6b, and 6c).

Mobile potassium supply was average and tended to decrease in the variants fertilized with large nitrogen and phosphorus doses. Minimum 40 kg/ha potassium doses have to be added to the fertilization formula to avoid the risk of soil mobile potassium level decrease even for a short time.

Mobile potassium level must not decrease below 130 mg/kg but must be higher than 200 mg/kg especially for industrial plants and in the variants fertilized with more than 120 kg P/ha and 160 kg N/ha.

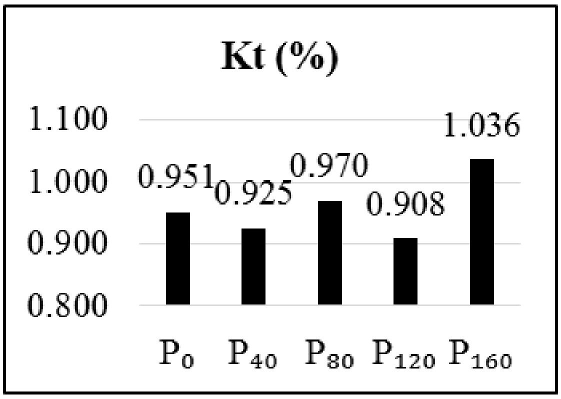

Figure 5a. Long term phosphorus fertilization influence upon total potassium content

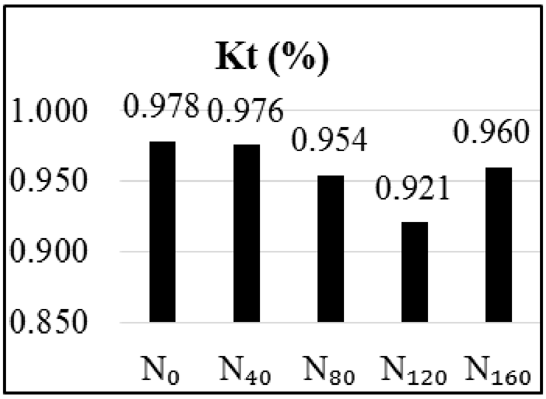

Figure 5b. Long term nitrogen fertilization influence upon total potassium content

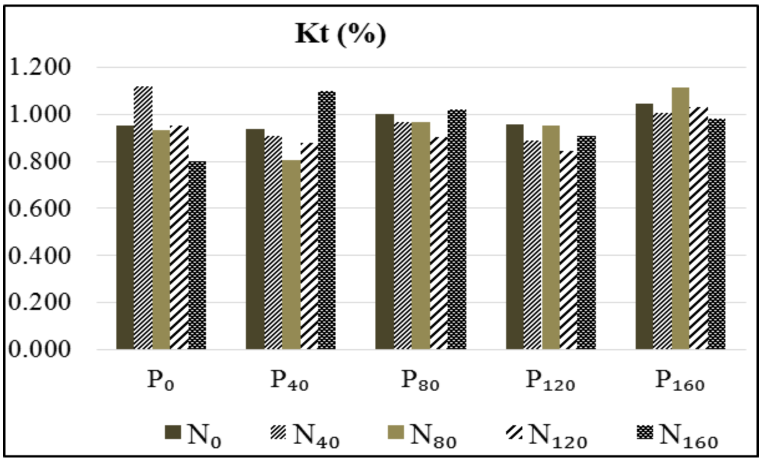

Figure 5c. Long term nitrogen and phosphorus fertilization influence upon total potassium content

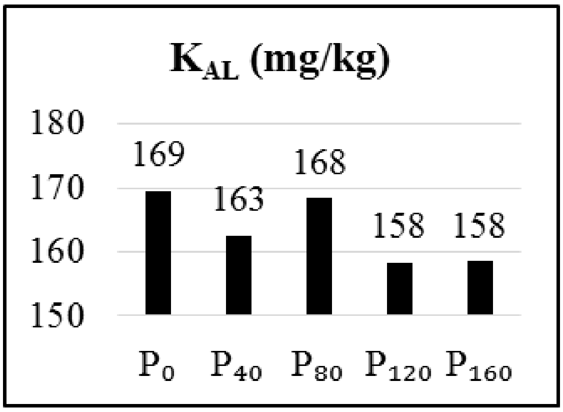

Figure 6a. Long term phosphorus fertilization influence upon mobile potassium content

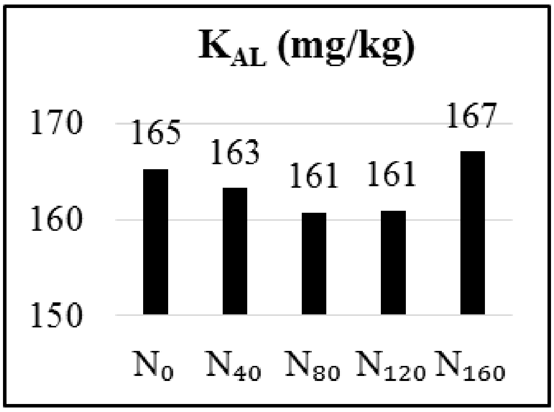

Figure 6b. Long term nitrogen fertilization influence upon mobile potassium content

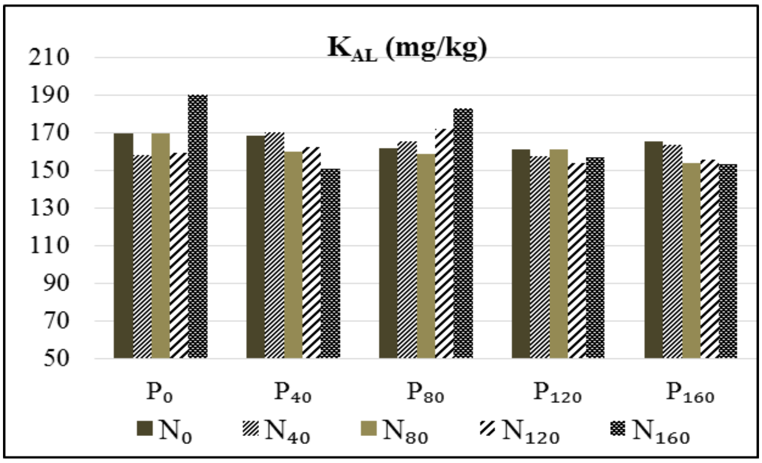

Figure 6c. Long term nitrogen and phosphorus fertilization influence upon mobile potassium content

Ştefănescu et al. (2001) found out that a tendency of soil mobile potassium level decrease occurs at high doses in NP long term experiments, especially in sugar beet and industrial crops harvested for garret or hay. Soil mobile potassium level increases when potassium is included in the fertilization formula.

CONCLUSIONS

1. Long term (42 years) fertilization with different nitrogen and phosphorus doses led to a continuous, statistically significant maize grain yield increase. The yield increased from 5,569 kg/ha in the unfertilized control to 9,805 kg/ha in the variants fertilized with

$N_{160}P_{160}$. Each kilogram of phosphorus brought a 6.78 kg maize grain gain and each kilogram of nitrogen brought a 15.28 maize grain gain.

2. Long term fertilization with 40-160 kg P/ha doses did not generate statistically significant soil pH changes.

3. Fertilization with 80-160 kg N/ha doses led to pH distinctly significant modifications. Nitrogen application along with phosphorus did not significantly modify soil reaction.

4. Long term phosphorus fertilization significantly increased the soil total and mobile phosphorus contents and did not significantly change the total and mobile potassium levels.

5. No significant soil humus and nitrogen levels modifications occurred under the influence of long term nitrogen and phosphorus fertilization.

REFERENCES

Borlan, Z., 1998. *Agrochemical characteristics progress prognosis and its correlation with agricultural soils amendment and fertilization need*. In: Romania Soils Quality State Monitoring, Vol. II, ICPA Bucharest. (In Romanian)

Borza, I., Țărău, D., Țîmbota, I., 2001. *Fertility evolution of luvisol albic pseudogleyed in the Lugoj-Făget depresion, as a result of long term mineral utilization*. Proceedings of International Symposium of CIEC “Role of Fertilizers in Sustainable Agriculture”, Aug. 21-22, Suceava 2000, AGRIS - Redacția Revistelor Agricole, Bucharest: 309-314.

Borza, I., Țîmbota, I., Țărău, D., Rogobete, Gh., Pușcă, I., 2001. *Modifications into the soil-plant system induces by mineral fertilization on argillic soils*. Proceedings of International Symposium of CIEC “Role of Fertilizers in Sustainable Agriculture”, Aug. 21-22, Suceava 2000, AGRIS - Redacția Revistelor Agricole, Bucharest: 461-466.

Ciobanu, I.V., 2001. *Modifications of some soil fertility features due to long term application of fertilizers on cernoziom soil*. Proceedings of International Symposium of CIEC “Role of Fertilizers in Sustainable Agriculture”, Aug. 21-22, Suceava 2000, AGRIS - Redacția Revistelor Agricole, Bucharest: 335-348.

Curtin, D., Beare, M.H., McCallum, F.M., 2007. *Sulphur in soil and light fraction organic matter as influenced by long-term application of superphosphate*. Soil Biology & Biochemistry, 29: 2547-2554.

Dumitru, M., 2012. *Agrochemistry. Present and ?*. In: Scientific papers ”Agrochemistry. Present and ? Reverential Session at the aniversary of 60 years of agrochemistry in Romania”, September 5, 2011, Bucharest. (In Romanian)

Hai, L., Li, X.G., Li, M.F., Suo, D.R., Guggenberger, G., 2010. *Long-term fertilization and manuring effects on physically-separated soil organic matter pool sunder a wheat-wheat-maize cropping system in an arid region in China*. Soil Biology & Biochemistry, 42: 253-259.

Hera, C., 2004. *Reply Address of Acad. Cristian Hera, at his 70 years Anniversary*. In: Academician Cristian Hera at 70 years, CERES Publishing House, Bucharest. (In Romanian)

Kaur, T., Brar, B.S., Dhillon, N.S., 2008. *Soil organic matter dynamics as affected by long term use of organic and inorganic fertilizers under maize-wheat cropping system*. Nutr. Cycl. Agroecosyst., 81: 50-69.

Lupu, C., 2007. *Influence of nitrogen and phosphorus fertilizers upon corn grain yield at SCDA Secuieni*. In: 45 year of scientific activity. Reverential volume, Ion Ionescu de la Brad Publishing House, Iași. (In Romanian)

Lupu, C., Naie, M., Pomohaci, T., 2012. *Effect of long term phosphorus and nitrogen fertilization upon corn grain yield at SCDA Secuieni*. An. INCDA Fundulea, Vol. LXXX: 151-161. (In Romanian)

Lupu, C., Pochișcanu, S.F., Naie, M., Buburuz, A.A., 2016. *Research regarding the long-term fertilization on the winter Yield at ARDS Secuieni*. Lucrări Științifice, Vol. 59(1), Seria Agronomie: 135-142.

Manna, M.C., Swarup, A., Wanjari, R.H., Mishra, B., Shahi, D.K., 2007. *Long-term fertilization, manure and liming effects on soil organic matter and crop yields*. Science Direct, Soil and Tillage Research, 94: 397-409.

Shirazi, S.M., Zardary, N.H., Ismail, Z., Othman, F., 2014. *Performance of wheat crop under different irrigation regimes and nitrogen levels. A field experiment*. JEPE, 15(3): 973.

Ștefanic, Gh., 1999. *Pedo-biologic research for sustainable agriculture*. In: Sustainable Efficient Agriculture, C. Hera (Coord.), Academy Publishing House: 261-264. (In Romanian)

Ștefănescu, D., Borlan, Z., Bogaci, R., Gavriluță, I., 2001. *Some aspects concerning effects of potassium fertilizers on mobile (K_{AL}) potasium content in the ploughed layer*. Proceedings of International Symposium of CIEC “Role of Fertilizers in Sustainable Agriculture”, Aug. 21-22, Suceava 2000, AGRIS - Redacția Revistelor Agricole, Bucharest: 489-495.

Trotuș, E., Naie, M., Isticioaia, S.-F., 2017. *Agricultural research and Development Station Secuieni*. Ion Ionescu de la Brad Publishing House, Iași. (In Romanian)

XXX FAO, 1999. *Fertilizer Strategies*. International Fertilizer Industry Association.