The effect of No-till technology on the mineral nitrogen content in the Lower Don Chernozem

Anna Medvedeva[1,•], *Olga* Buryukova[1], *Yaroslav* Ilchenko[1], *Tatyana* Minkina[1], *Roman* Kamenev[2], and *Coşkun* Gülser[3]

[1] Southern Federal University, Stachki Ave, 194/1, Rostov-on-Don, 344090, Russia
[2]Don State Agrarian University, Krivoshlykova St., 24, Rostov Region, Oktyabrsky District, Persianovsky Village, 346493, Russia
[3]Ondokuz Mayis University, 55139, Samsun, Turkey

Abstract. The paper presents the results of a five-year study of the impact of various agricultural technologies (No-till, minimum and traditional using moldboard ploughing) on the content of mineral nitrogen in Haplic Chernozem in southern zone of Rostov Region. It has been revealed that the content of ammonium and nitrate nitrogen in the winter wheat areas cultivated by various agricultural technologies does not significantly change in samples collected both in spring and in summer. However, the content of nitrate nitrogen under resource-saving technologies (both minimum and No-till) has been higher than under ploughing throughout the whole period of study. The trend identified has not been mathematically confirmed. Nevertheless, the impact of No-till technology on the intensity of ammonification and nitrification should not be unequivocally denied, since a significant amount of mineral nitrogen is extracted by crops, and their crop yields under minimum and zero tillage was higher, than when ploughing was applied.

1 Introduction

Soil is one of the most important natural resources. It performs vital biogeocenotic functions. High soil fertility is the basis for the existence of the civilization on our planet. Providing the population with high-quality and environmentally friendly food requires an active nutrient balance in ecosystems, optimization of the biological cycle of substances of the pedosphere [1]. Agriculture uses the soil as a substrate to produce crops through the application of mineral fertilizers and significantly limits its ecological function in the biosphere, disrupting the vegetation cover, reducing the humus content, and significantly
polluting with pesticides, heavy metals, oil and other substances.

The most important element of the technology that affects soil fertility and crop yields is the primary soil cultivation, which has a wide range of methods from traditional ploughing to No-till technique with many options for boardless cultivation and various minimization conditions. Traditional cultivation methods, as a rule, have an adverse effect on the long-term soil productivity due to erosion, loss of organic matter and increase soil degradation risk [2,

• Corresponding author: medvedeva.estelior@yandex.ru

3]. Nowadays no tillage-seeding technique - No-till has been widely recognized to be the highest level of minimizing tillage and seeding.

Many studies find that the use of No-till can improve the agrophysical, physicochemical and biological properties of soils by optimizing the structure of the soil and reducing the risk of erosion processes [4, 5].

Available research on the dynamics of mobile nitrogen accumulation depending on the primary cultivation method shows that replacing ploughing with other methods gives ambiguous results. Thus, Kiryushin and Zabolotsky [6, 7] pointed out a steady decreasing tendency in the nitrate nitrogen content when flat cutting and minimum tillage were applied. It was associated with the presence of crop residues in the upper soil layer that slow down soil heating and promote the immobilization of available nitrogen by microorganisms. A number of researchers point out that no significant differences in nitrate nitrogen content in the meter soil layer under deep soil loosening and No-till techniques have been established [8, 9].

As reported by Novikova [10] flat-cutting and No-till methods contributed to an increase in nitrate nitrogen content, compared with ploughing. Apparently, such disagreement is associated primarily with differences in soil properties, environmental conditions, and features of agricultural practices.

The purpose of the study was to investigate the content of mineral nitrogen in Haplic Chernozem when No-till technique was used under insufficient moisture conditions.

2 Materials and methods

The present studies were conducted in agrocenoses of the steppe zone in the European part of southern Russia. This zone is characterized by a continental climate, unstable and insufficient moisture. Annual precipitation is 410-460 mm, HTC = 0.7-0.76, the average annual temperature is 8.7-9.5 degrees, the sum of temperatures for the active growing season is higher than 3400 degrees. Groundwater is 7-10 m below the ground surface. The formation of high yields of field crops in these landscapes depends primarily on the state of the water conditions, as well as on the conditions of mineral nutrition. The object of study was Haplic Chernozem calcareous heavy loamy formed on loess loam.

A comparative analysis of the intensity of ammonification and nitrification processes in the soil under various agricultural technologies (traditional, minimum and No-till) has been carried out for 5 years (2013 - 2017) in Peschanokopsky district of Rostov Region. The traditional technology has been used in the study area for more than 50 years, minimal - since 2000, No-till has been applied since 2008. The reference plot was the virgin area.

The ammonium nitrogen content was determined according to GOST 26489 in the edition of the Central Scientific Research Institute of Agricultural Chemistry. The method is based on preparing a complex compound by the interaction of ammonium chloride with Nessler's reagent in an alkaline medium and its subsequent photocolorimetry (wavelength 400-440 nm, soil:solution ratio 1:30). Nitrate nitrogen was determined according to the Grandval-Lajoux method. The method involves the interaction of nitrates with disulfophenolic acid with subsequent formation of trinitrophenol that causes solution colour change to yellow when placed in alkali due to the formation of potassium (KOH) or sodium (NaOH) salts, their amount being equivalent to the nitrate content, followed by photocolorimetry (wavelength 400-440 nm, soil:solution ratio 1:5).

Mathematical processing of the results was carried out by correlation analysis and ANOVA methods using the STATISTICA 10 software package.

3 Results and discission

On average the content of ammonium nitrogen in the 0-20 cm layer has been ranging from 16.8 - 19.8 mg/kg throughout the period of study (Figure 1). Down the profile there has been a uniform decrease in the amount of ammonium. Over the years of research the trend identified has continued.

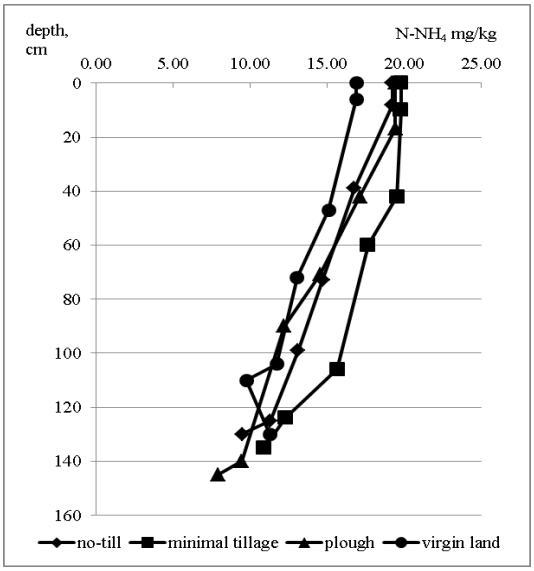


Fig. 1. The average depth-wise distribution of ammonia nitrogen in Haplic Chernozem over the years of research, mg/kg of soil.

The results obtained indicate that the intensity of ammonification when using various cultivation methods is almost the same (Figure 2).

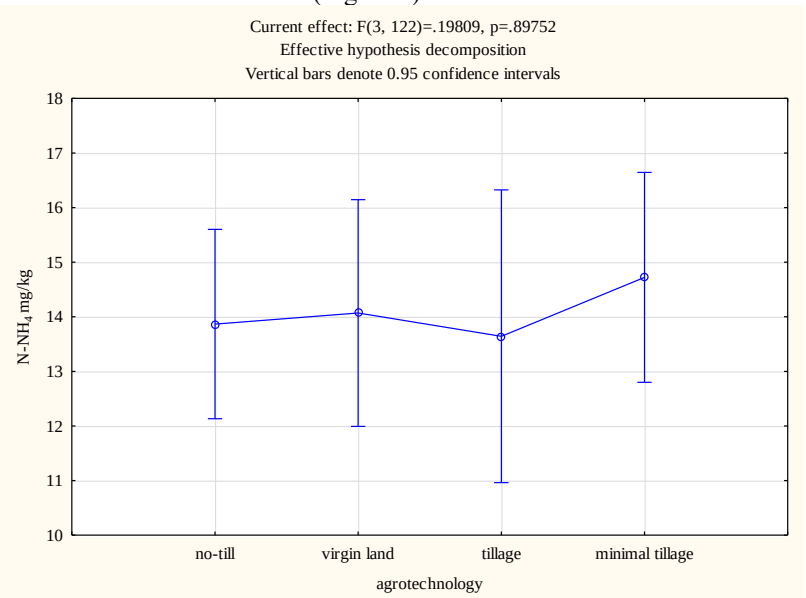
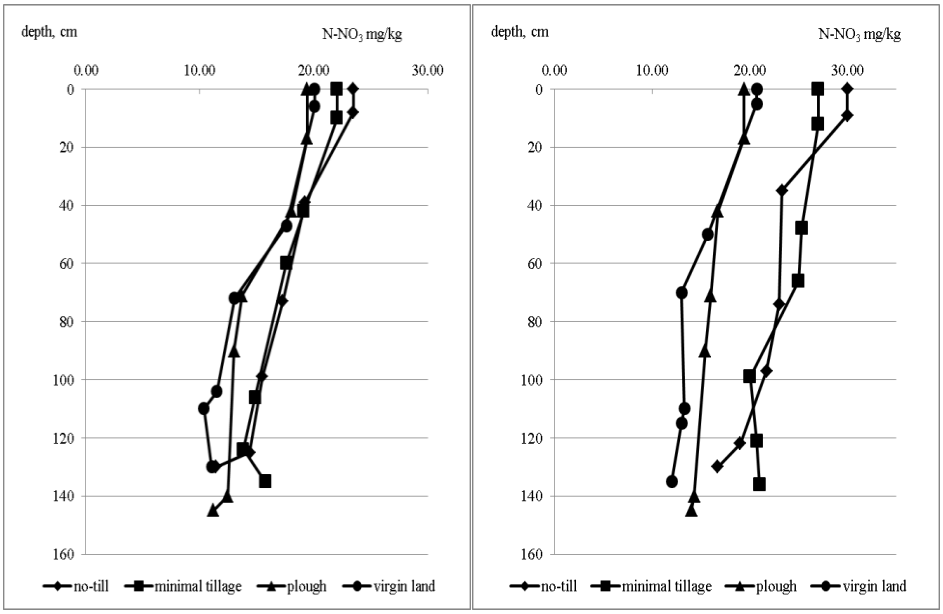


Fig. 2. The effect of the primary cultivation method on the content of ammonium nitrogen in Haplic Chernozem (average profile).

The ammonia form of nitrogen, having a number of advantages, cannot fully provide plants with nitrogen. There is much evidence that in many cases it is necessary to combine plant nutrition with ammonium and nitrate nitrogen. Soils in Rostov region are characterized with high biological activity, and, therefore, are able to produce nitrates in large quantities. It has been found that in most cases the nitrate form prevails over the ammonium ($N\text{-}NO_3/N\text{-}NH_4>1.0$), which is typical for the studied agrocenoses.

5-year average content of nitrate nitrogen in calcareous Haplic Chernozem of a virgin land has been 20.1 mg/kg (Figure 3 a).



a) b)

Fig. 3. Depth-wise distribution of nitrate nitrogen in Haplic Chernozem, mg/kg of soil (a) on average over the years of research; b) 2014 sampling).

Under No-till technique the level of nitrate nitrogen in the upper horizon increases to 23.5 mg/kg, whereas under minimal cultivation - up to 22.3 mg/kg. In case of ploughing the content of nitrate nitrogen (19.4 mg / kg) slightly decreased. The nature of nitrate nitrogen distribution along the chernozem profile was similar for all cultivation methods.

The content of nitrate nitrogen under resource-saving cultivation was slightly higher than in the virgin land and under ploughing. The maximum differences were recorded in 2014 during the summer period (August 5), with a significant lack of precipitation (Figure 3 b). The use of resource-saving cultivation in 2014 allowed to increase nitrate nitrogen content to 27.0-30.0 mg/kg (20.7 mg/kg in virgin land, and 19.4 mg/kg when ploughing was used).

Although, when comparing the results, the advantage of resource-saving cultivation over traditional ploughing seemed certain, the mathematical processing of the entire data obtained showed no significant effect of the cultivation method on nitrate nitrogen (Figure 4).

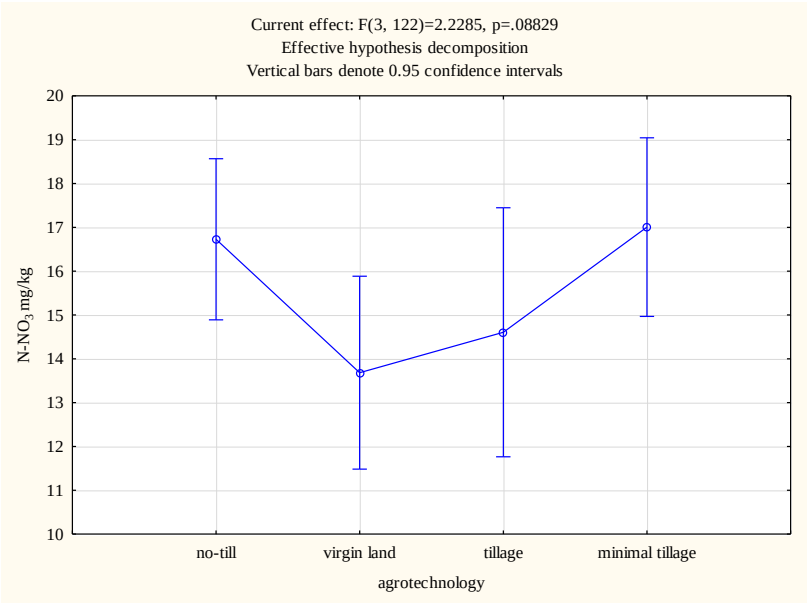


Fig. 4. The influence of the primary cultivation method on nitrate nitrogen content in Haplic Chernozem (average profile).

However, it is impossible to affirm categorically that there is no No-till effect on nitrate nitrogen accumulation, since its content also depends on plant absorption intensity during yield formation, and the crop yield with resource-saving cultivation was higher than when ploughing method was applied.

Malhi et al. [11] demonstrated that soil retained the smaller amount of mineral nitrogen at a depth of 0-10 and 20-30 cm when ploughing was used compared No-till method. It was concluded that reducing or even eliminating ploughing would improve N-reserve of the soil.

The results obtained are quite understandable, since nitrification intensity is mainly determined by soil hydrothermal conditions (moisture and aeration). It is well known that key conditions for nitrification to proceed intensively are favorable soil moisture of 60-70% of capillary moisture capacity, good aeration, and an optimal temperature of 25-32 ° C.

The depth and cultivation method significantly affect the water, temperature and microbial activity of the soil. Tereshchenko [12] found out that resource-saving technologies including No-till were responsible for a greater moisture accumulation in the soil, which led to a high intensity of biological processes.

Despite the fact that the rate of nitrification activity is very dynamic and depends on the agricultural technology used, fertilizers, meteorological conditions, Nieminen [13] pointed out a closer relationship between the content of organic matter and the nitrification in soils when No-till technique was used compared to conventional cultivation.

The major source of ammonia and nitrate nitrogen is the pool of organic matter and organic N-compounds. Therefore, the supply of plants with nitrogen depends on the rate of decomposition of soil organic matter to compounds assimilated by the plant. Our previous studies have shown that the humus content in Haplic Chernozem depends on the primary cultivation method [14]. Correlation analysis has revealed a close relationship between the content of ammonium and nitrates and the amount of humus.

4 Conclusion

The supply of plants with nitrogen depends on the rate of decomposition of the soil organic matter to compounds assimilated by plants. Close relationships has been found between the intensity of ammonification and nitrification processes and humus accumulation (r=0.58; r=0.57, respectively, at p=0.05). The content of ammonia nitrogen does not significantly depend on the agricultural technology used, with all processing methods it was practically at the same level. Cultivation methods have showed no significant effect on nitrate nitrogen. However, the impact of resource-saving technologies on nitrogen mobilization in the soil should not be unequivocally denied. Mineral nitrogen is the major source of nitrogen for plants and has great effect on yield formation, and the yield with minimum and zero tillage was higher than when moldboard ploughing is used.

It should also be noted that under a favorable combination of agrometeorological conditions, differences in the intensity of ammonification and nitrification between the cultivation methods were smoothed out. Under a significant shortage of precipitation or plentiful precipitation and low temperatures, the positive effect of resource-saving cultivation manifested itself more clearly and contributed to a certain increase in the content of mineral nitrogen.

Thus, agrocenoses, characterized by a significant alienation of biomass, in the absence of special agricultural techniques for regulating soil fertility, are not able to maintain a sufficient level of nutrients. Therefore, the efficient use of agricultural land requires continuous improvement of technologies for increasing soil fertility and optimizing the mineral nutrition of plants. The use of No-till technology in conditions of insufficient moisture can improve nitrogen nutrition of plants.

The research was supported by the project of the Ministry of Science and Higher Education of the Russian Federation within the framework of the state task of the Southern Federal University for 2020-2022 (№ FENW-2020-0028)

References

1. V.G. Mineev, *Selected writings*, 601 (Moscow, 2005) (in Russian)
2. R.P. Mathew, Y. Feng, L. Githinji, R. Ankumah, K.S. Balkcom, Appl. Environ. Soil Sci., **2012,** 10 (2012) doi:10.1155/2012/548620
3. B.D. Soane, B.C. Ball, J. Arvidsson, G. Basch, F. Moreno, J. Roger-Estrade, Soil and Tillage Research, **118,** 66-87 (2012)
4. Y.P. Dang, H. Liu, L. Carvalhais, V. Rincon-Florez , M. Crawford, P.G. Dennis, M. Peer, P.M. Schenk, Soil and Tillage Research, **158,** 91–99 (2016) doi:10.1016/j.still.2015.12.007
5. J. Bareche, D. Plaza-Bonilla, C. Cantero-Martínez, J. Lampurlanés, J. Álvaro-Fuentes, Field Crops Research, **203,** 74–85 (2017) doi:10.1016/j.fcr.2016.12.008
6. V.I. Kiryushin, Agronomic soil science. 668 (2010) [In Russian]
7. V.V. Zabolotskikh, Siberian Bulletin of Agricultural Science, **1,** 95-98 (2013) (in Russian)
8. V.T. Maltsev, E.N. Dyachenko, Achievements of Science and Technology of AIC, **12**, 8-11 (2011) (in Russian)]
9. A.N. Vlasenko, N.G. Vlasenko, Agriculture, **3**, 17-19 (2016) (in Russian)
10. A.S. Novikova, V.T. Lobkov, *The influence of modern energy-saving technologies for soil treatment on agrochemical indicators of the soil. Innovative fundamental and applied research in the field of chemistry in agricultural production*, 8-12 (Orel, 2011) (in Russian)

11. S.S. Malhi, A. Légère, A. Vanasse, G. Parent, The J. of Agricultural Sc., **156**, 472–480 (2018) doi: 10.1017/S0021859618000448
12. V.V. Tereshchenko, O.A. Biryukova, D.V. Bozhkov, *Agrophysical properties of chernozem under various cultivation methods* (LAP, 2015) (In Russian)
13. J.K. Nieminen, P. Pohjola, Boreal Environ. Res, **19**, 257–266 (2014)
14. A.M. Medvedeva, O.A. Biryukova, Y.I. Ilchenko, A.V. Kucherenko, E.V. Kuchmenko, Successes in modern natural sciences, **1**, 29-34 (2018) (In Russian).