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SHORT COMMUNICATION

HOW FERTILISATION AFFECTS DISTRIBUTION OF CARBON AND NUTRIENTS IN VINEYARD SOIL?

VLADIMÍR ŠIMANSKÝ*, JÁN HORÁK, OTTO LOŽEK, JURAJ CHLPÍK

Slovak University of Agriculture in Nitra

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The effect of fertilisation on C and N, P, K nutrients distribution in the Rendzic Leptosol in locality Nitra-Dražovce was studied. We evaluated the following treatments of fertilisation: (1) G (non-fertilised), (2) FYM (farmyard manure – dose 40 t/ha), (3) G+NPK3 (grass + 3rd intensity of fertilisation for vineyards), and (4) G+NPK1 (grass + 1st intensity of fertilisation for vineyards). The soil samples were taken in spring during the years 2008–2015. Obtained results showed that the content of organic carbon (C_{org}) decreased in the following order: G+NPK1 > FYM > G > G+NPK3 and content of total nitrogen (N,) decreased in the following order: FYM > G+NPK3 > G+NPK1 > G. The application of NPK in the 1st intensity of fertilisation for vineyards and added FYM build up a C_{org} at an average rate of 370 and 229 mg/kg/year, respectively. On the other hand, contents of N_t due to fertilisation declined in FYM, G+NPK3 and G+NPK1 at an average rate of 53, 22 and 20 mg/kg/year, respectively. Available P and K contents were also increased after the fertilisation of FYM and NPK. Added fertilisers (G+NPK3) significantly build up a P at an average rate of 10.2 mg/kg/year.

Key words: farmyard manure, soil organic carbon, nitrogen, phosphorus, potassium, vineyard

In the future, due to the increase in human population sustainable land management based on extensive managements will be unlikely and fertilisation will be one of the most important factors affecting agricultural production (Roberts 2009). In present time, fertilisation has become a basis for modern agricultural production. It can be the major source of crop nutrients (mainly in soils with low production level) that take part in the metabolism of crops and is therefore closely associated with crop yield and quality (Gu *et al.* 2004). Fertilisation is one of the most important factors influencing the changes in soil chemical properties. It is well known that manures are a source of all-necessary macro- and micronutrients in available forms, thereby improving the soil properties (Abou El-Magd *et al.* 2005).

The main purpose of agricultural production is to obtain high crop yields and good quality. Many studies revealed the significant roles of fertiliser on crop production over the past several decades (Roberts 2009). Optimal supplies of inorganic fertiliser can achieve higher crop yields than the use of organic manure and do not reduce soil produc-

doc. Ing. Vladimír Šimanský, PhD. (* Corresponding author), Department of Soil Science, FAFR – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: Vladimir.Simansky@uniag.sk

Ing. Ján Horák, PhD., Department of Biometeorology and Hydrology, HLEF – SUA Nitra, 949 76 Nitra, Hospodárska 7, Slovak Republic. E-mail: Jan.Horak@uniag.sk

prof. Ing. Otto Ložek, CSc., Department of Agrochemistry and Plant Nutrition, FAFR – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: Otto.Ložek@uniag.sk

doc. Ing. Juraj Chlpík, PhD., Department of Soil Science, FAFR – SUA Nitra, 949 76 Nitra, Tr. A. Hlinku 2, Slovak Republic. E-mail: Juraj.Chlpik@uniag.sk

tivity (Kunzova & Hejcman 2009; Korsaeth 2012), however, only a unilateral addition of fertilisers can reduce soil fertility through the degradation of its physical properties (Šimanský & Bokor 2012). In present time, depending on the cropping system and soil fertility, N alone accounts for about a third of agricultural energy consumption and K and P typically account for 1.5–9% each (Ercoli *et al.* 1999). Achieving economically efficient agricultural production requires the monitoring of nutrients content in the soil and then modifying fertilisation (i.e., the content of nutrients) in the soil depending on the individual requirements of crops.

The aim of this study was to determine (1) how fertilisations influenced the distribution of carbon and nutrients in the soil over the period of 8 years (2) and which levels of fertilisation are better in response to improved soil supply.

An experiment of the different fertilisation in a productive vineyard, which started in 2006, is still ongoing at the locality of Nitra-Dražovcce (48°21'6.16"N; 18°3'37.33"E), and is located in the Nitra wine-growing area, where the climate is temperate. The mean annual rainfall is 550 mm and the mean annual temperature is $\geq 10^{\circ}$ C. The studies have been conducted in a complex of Rendzic Leptosol (WRB 2006) developed on limestone and dolomite and had the following characteristics: 57% sand, 33% silt, 10% clay, 7.18 pH (in 1 mol/dm³ KCl), 2.31% soil organic matter, 867 mg/kg total nitrogen, 99.3% base saturation, 99 mg/kg available P and 162 mg/kg available K in the year 2000. Before vineyard establishment the locality was abandoned, which resulted in prevailing grass growth. In 2000, the vines (*Vitis vinifera* L. cv. Chardonnay) were planted. A variety of grasses (*Lolium perenne* L. 50% + *Poa pratensis* L. 20% + *Festuca rubra* subsp. *commutata* Gaudin 25% + *Trifolium repens* L. 5%) were sown in 2003 in the interrows of the vines. In 2006, an experiment of the different fertilisation in a vineyard was carried out (Table 1). The experiment consisted of four replicates.

Soil samples were collected in all treatments from two depths: 1. 0–30 cm and 2. 30–60 cm, every spring. Soil samples were analysed for: the organic carbon content (C_{org}) by the wet combustion method according to Tyurin (Dziadowiec & Gonet 1999), total nitrogen content (N_t) according to Kjeldahl (Fiala *et al.* 1999), available phosphorus and potassium according to Mehlich III. (Mehlich 1984).

Treatments were compared on the basis of data collected during the years 2008–2015. The Statgraphics Centurion XV.I statistical package was used. A multifactor ANOVA model was used for individual treatment comparisons at $P \leq 0.05$, with the separation of the means by the *LSD* multiple-range test. In individual treatments of fertilisation, the correlations between C_{org} and N_t contents were then determined. The linear model was used to evaluate the trends of C_{org} , N_t , P and K due to fertilisation during the period of 8 years.

Table 1

The investigated treatments in vineyard (Nitra-Dražovce)

Treatment	Description
Control (G)	Sown grass in the rows and between vine rows, without fertilisation.
Farmyard manure (FYM)	Medium tilth to the depth 0.25 m with ploughed farmyard manure (FYM) in a dose of 40 t/ha and intensive cultivation between vine rows during growing season.
Doses of NPK fertilisers in 3 rd intensity for vineyards (G+NPK3)	This means: 120 kg/ha N, 55 kg/ha P and 195 kg/ha K (Fecenko & Ložek 2000). The dose of nutrients was divided: 2/3 applied into the soil in the spring (bud burst – on March) and 1/3 in flowering (on May). The grass was sown in and between the vine rows.
Doses of NPK fertilisers in 1 st intensity for vineyards (G+NPK1)	This means: 80 kg/ha N, 35 kg/ha P and 135 kg/ha K (Fecenko & Ložek 2000). The dose of nutrients was divided: 1/2 applied into the soil in the spring (bud burst – on March) and 1/2 in flowering (on May). The grass was sown in and between the vine rows.

The contents of C_{org} were higher by 4 and 5% in FYM and G+NPK1, respectively, compared with G. Opposite, C_{org} content was lower by 4% in G+NPK3 than G. These findings are consistent with already published results of this experiment (Šimanský et al. 2013). A significant part of the organic carbon is associated with the stable fraction of organic matter and it has been turned over thousands of times over the years (Semenov et al. 2013). The content of N₊ decreased in the following order: FYM > G+NPK3 > G+NPK1 > G. The nitrogen soil content was strictly related to C_{org} and varied more in response to organic material supply than to mineral N rates or to the kind of N fertiliser (Triberti et al. 2008), however, in our case Corr contents did not correlate with N, in all treatments of fertilisation (FYM: r = 0.492, P > 0.05, n = 8; G+NPK3: r = 0.032, P > 0.05, n = 8; G+NPK1: r = 0.279, P > 0.05, n = 8). C_{org} and N_t contents varied by the addition of fertilisation, but without statistical significance (Table 2). However, the significant effect of soil depth on the content of selected soil parameters was observed. The average difference between the first (0-30 cm) and the second (30-60 cm) soil depth under vineyard was in C_{org} 7.1 g/kg and in N_t content 364 mg/kg. The application of NPK in 1st intensity of fertilisation for

vineyards significantly build up a $\mathrm{C}_{_{\mathrm{org}}}$ at an average rate of 370 mg/kg/year and added FYM at 40 t/ha build up a $C_{_{OTP}}$ at an average rate of 229 mg/kg/year, however, without any statistical significance. The dose of NPK in 1st intensity of fertilisation for vineyards can positively affect an increase of C_{org} in water-stable microaggregates (Šimanský & Polláková 2012). As presented by Marscher (2011), the addition of organic manure increases soil microbial activity, which may increase the content of soil organic matter after decomposing it. On the other hand, the application of NPK in 3rd intensity of fertilisation for vineyards caused a C_{org} decline at an average rate of 40 mg/kg/year. Inorganic fertilisation alone proved to be unable to increase Corre concentration in the long term (Yang et al. 2003; Su et al. 2006). Šimanský and Tobiašová (2012) showed that higher doses of NPK fertilisers are responsible for the higher mineralisation rate of soil organic matter. It is obvious that the fertilisers applied to the soil can act diametrically opposite; the effect of their action depends on their dose, which confirmed the findings of several authors (Halvorson et al. 2002; Whalen & Chang 2002). The use of organic manure caused the fastest build up of the N in the soil, followed by crop residues (in our case grass biomass). These

during the years 2008–2015								
Fertilisation	C _{org}	N _t	P [mg/kg]	K [mg/kg]				
	[^{g/ k} g]	[IIIg/Kg]	[IIIg/Kg]	[IIIg/Kg]				
G	13.8ª	932ª	101ª	204ª				
FYM	14.3ª	1,034ª	109 ^a	233 ^{ab}				
G+NPK3	13.3ª	964ª	124ª	257 ^b				
G+NPK1	14.5ª	953ª	113ª	223 ^{ab}				
LSD _{0.05}	±1.41	±194	±54	±52				
Depth								
0–30 cm	17.5 ^b	1,153 ^b	162 ^b	313 ^b				
30–60 cm	10.4ª	789ª	78ª	145ª				
LSD _{0.05}	±0.99	±138	±38	±37				

Table 2

Statistical evaluation of C N. P and K distribution in the Rendzic Leptosol at depths 0-30 and 30-60 cm

Different letters between lines (a, b) indicate that treatment means are significantly different at $P \le 0.05$ according to LSD multiple-range test

G - control; FYM - farmyard manure; G+NPK3 - doses of NPK fertilisers in 3rd intensity for vineyards; G+NPK1 - doses of NPK fertilisers in 1st intensity for vineyards; C_{org} - soil organic carbon content; N_t - total nitrogen content; P - available phosphorus; K - available potassium

effects can be explained by the fact that the lower the stabilisation of organic matter (crop residues < manure), the higher the nitrogen release (Triberti *et al.* 2008). Opposite situations have been recorded (Table 3). Contents of N_t due to fertilisation decline in FYM, G+NPK3 and G+NPK1 at an average rate of 53, 22 and 20 mg/kg/year, respectively, which means the decrease of 31, 25 and 24% N_t in the soil, respectively, during the years 2008–2015.

The content of phosphorus in the soils of Slovakia ranges from 0.03 to 0.20% (Kováčik 2014). The majority of P is usually present in the soils as insoluble compounds of calcium, iron or aluminium with little or no solubility (Rahmatullah *et al.* 1994). There is a need to improve the availability of native soil P. In our study, available P contents were also increased after fertilisation of FYM and NPK (Table 2). In G, the average value of available P was lower by 8%, by 23% and by 12% than in FYM, in G+NPK3 and in G+NPK1, respectively.

The average contents of P were evaluated as a satisfactory in G and FYM and in treatments with added fertilisers in 1st and 3rd intensity for vineyards were evaluated as a good supply. It is reported that P sorption capacity of soils varies widely according to clay content, clay mineralogy, soil organic matter, exchangeable aluminium, iron, calcium concentrations and pH (Tisdale et al. 1993). In our case, the lowest accumulation of P was observed in soil under FYM. Organic manures after decomposition may also provide organic acids and increase P bioavailability after the dissolution of native and fixed P (Marschner 2011). Similarly, higher K pool was observed in the soil under the adequate supply of organic and inorganic fertilisers. The content of K increased in the following order: G < G+NPK1< FYM < G+NPK3. This result confirms the results of Aziz et al. (2010), who reported that manure application significantly increases soil K contents. On the basis of the calculated average linear trend we established the average annual changes

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Trends of C_{org} , N_t , P and K distribution in the Rendzic Leptosol at depth 0–60 cm ($y = C_{org}$, N_t , P and K distribution) with time (x = years) (n = 24)

Treatments	Equations	R ²	Trend	Probability				
C _{org}								
FYM	y = 0.0229x - 44.55	0.154	increase	n.s.				
G+NPK3	y = -0.0042x + 9.715	0.006	decrease	n.s.				
G+NPK1	y = 0.0371x - 73.27	0.276	increase	++				
N,								
FYM	y = -53.68x + 108987	0.311	decrease	++				
G+NPK3	y = -21.75x + 44715	0.047	decrease	n.s.				
G+NPK1	y = -20.14x + 41470	0.120	decrease	n.s.				
Р								
FYM	y = -1.79x + 3696	0.013	decrease	n.s.				
G+NPK3	y = 10.20x - 20386	0.209	increase	+				
G+NPK1	y = -0.59x + 1298	0.001	increase	n.s.				
K								
FYM	y = 4.25x - 8316	0.031	increase	n.s.				
G+NPK3	y = 6.89x - 13642	0.082	increase	n.s.				
G+NPK1	y = 15.42x - 30741	0.150	increase	n.s.				

G – control; FYM – farmyard manure; G+NPK3 – doses of NPK fertilizers in 3rd intensity for vineyards; G+NPK1 – doses of NPK fertilizers in 1st intensity for vineyards; C_{org} – soil organic carbon content; N_t – total nitrogen content; P – available phosphorus; K – available potassium; ⁺⁺P ≤ 0.01 ; ⁺P ≤ 0.05 ; n.s. – non-significant

in the content of P and K at a depth of 0–60 cm. Added fertilisers in the 3rd intensity of fertilisation for vineyards significantly build up a P at an average rate of 10.2 mg/kg/year (Table 3). Every year (during 2008–2015) the content of K increased by fertilisation in FYM, G+NPK1 and G+NPK3 at an average rate of 4.25, 6.89 and 15.4 mg/kg, respectively, but without any statistical significance.

The results underscore the importance of fertilisation in relation with carbon sequestration and distribution of nutrients in the soil, especially in vineyards and its meaning is emphasised in this study. From the view point of organic carbon and nitrogen, our results confirm that the application of higher doses of nutrients to the soil (3rd intensity of fertilisation for vineyards) resulted in intensive mineralisation of soil organic matter and decreases of carbon sequestration in the soil. On the other hand, lower doses of nutrients to the soil (1st intensity of fertilisation for vineyards) can be responsible for higher carbon sequestration in the soil. The present results indicate that the application of FYM increases contents of C_{ore}, N, P and K. Furthermore, the application of nutrients at higher rates significantly increases their pool in the soil. This information is very important for farmers (winegrowers), because they can optimise soil management practices on this basis, mainly fertilisation in productive vineyards, and avoid environmental degradation due to the application of high doses of fertilisers to the soil. To future, the substantial effects of long-term application of fertilisation should be investigated in the productive vineyards.

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REFERENCES

- ABOU EL-MAGD, M.M. MOHAMMED, A.H. FAWZY, Z.F. 2005. Relationship, growth and yield of broccoli with increasing N, P or K ratio in a mixture of NPK fertilizers. In Annals of Agricultural Science, Moshtohor Journal, vol. 43, pp.791–805.
- AZIZ, T. ULLAH, S. SATTAR, A. NASIM, M. FA-ROOQ, M. – KHAN, M.M. 2010. Nutrient avail-ability and maize (*Zea mays*) growth in soil amended with

organic manures. In International Journal of Agriculture and Biology, vol. 12, pp. 621-624.

- DZIADOWIEC, H. GONET, S.S. 1999. Przewodnik metodyczny do badań materii organicznej gleb [Methodical guide-book for soil organic matter studies]. Prace Komisji Naukowych Polskiego Towarzystwa Gleboznawczego, N. 120, Komisja chemii gleb, Zespół Materii Organicznej Gleb, N II/16, 65 p.
- ERCOLI, L. MARIOTTI, M. MASONI, A. BONARI, E. 1999. Effect of irrigation and nitrogen fertilization on biomass yield and efficiency of energy use in crop production of Miscanthus. In *Field Crops Research*, vol. 63, pp. 3–11. DOI: 10.1016/S0378-4290(99)00022-2.
- FECENKO, J. LOŽEK, O. 2000. Výživa a hnojenie poľných plodín [Nutrition and fertilization of field crops]. Nitra: SPU, pp. 452.
- FIALA, K. KOBZA, J. MATÚŠKOVÁ, Ľ. BREČ-KOVÁ, V. MAKOVNÍKOVÁ, J. BARANČÍ-KOVÁ, G. BÚRIK, V. LITAVEC, T. HOUŠ-KOVÁ, B. CHROMANIČOVÁ, A. VÁRADIOVÁ, D. PECHOVÁ B. 1999. Záväzné metódy rozborov pôd. Čiastkový monitorovací system Pôda [Approved methods of soil analyses. Partial monitoring system Soil]. Bratislava: VÚPOP, 142 p.
- GU, Q.Z. YANG, X.Y. SUN, B.H. MA, L.J. TONG, Y.A. - ZHAO, B.Q. - ZHANG, F.D. 2004. Effects of long-term fertilization on grain yield and quality of wheat. In *Journal of Triticeae Crops*, vol. 24, pp. 76-79.
- HALVORSON, A.D. WIENHOLD, B.J. BLACK, A.L. 2002. Tillage, nitrogen and cropping system effects on soil carbon sequestration. In Soil Science Society of America Journal, vol. 66, pp. 906–912. DOI: 10.2136/sssaj2002.9060.
- IUSS Working Group WRB. 2006. World reference base for soil resources 2006. 2nd edition. World Soil Resources Reports No. 103. Rome: FAO, pp. 145.
- KORSAETH, A. 2012. N, P, and K budgets and changes in selected topsoil nutrients over 10 years in a longterm experiment with conventional and organic crop rotations. In *Applied and Environmental Soil Science Journal*, vol. 25, pp. 1–17.
- KOVÁČIK, P. 2014. Princípy a spôsoby výživy rastlín [Principles and methods of plant nutrition]. Nitra: SPU, pp. 278.
- KUNZOVA, E. HEJCMAN, M. 2009. Yield development of winter wheat over 50 years of FYM, N, P and K fertilizer application on black earth soil in the Czech Republic. In *Field Crops Research*, vol. 111, pp. 226–234. DOI: 10.1016/j.fcr.2008.12.008.
- MARSCHNER, P. 2011. Marschner's mineral nutrition of higher plants. 3rd ed. London: Academic Press, pp. 269.
- MEHLICH, A. 1984. Mehlich No. 3 soil test extractant: A modification of Mehlich No. 2. In *Communication in Soil Science and Plant Analysis*, vol. 15, pp. 1409– 1416. DOI: 10.1080/00103628409367568.
- RAHMATULLAH, G.M.A. SHAIKH, B.Z. SAL-IM, M. 1994. Bioavailability and distribution of P among inorganic fractions in calcareous soils. In

Arid Soil Research and Rehabilitation, vol. 8, pp. 227–234.

ROBERTS, T.L. 2009. The role of fertilizer in growing the world's food. In *Better Crops*, vol. 93, pp. 12–15.

- SEMENOV, V.M. TULINA, A.S. SEMENOVA, N.A. IVANNIKOVA, L.A. 2013. Humification and Nonhumification Pathways of the Organic Matter Stabilization in Soil: A Review. In *Eurasian Soil Science*, vol. 46, pp. 355–368. DOI: 10.1134/S106422931304011X.
- ŠIMANSKÝ, V. BAJČAN, D. DUCSAY, L. 2013. The effect of organic matter on aggregation under different soil management practices in a vineyard in an extremely humid year. In *Catena*, vol. 101, pp. 108–113. DOI: 10.1016/j.catena.2012.10.011.
- ŠIMANSKÝ, V. BOKOR, P. 2012. Reakcia fyzikálnych vlastností pôdy na stupňované dávky živín v produkčnom vinohrade [Response of soil physical properties to increasing doses of nutrients in a productive vineyard]. In Agrochémia, vol. XVI (52), no. 4, p. 8–12.
- ŠIMANSKÝ, V. POLLÁKOVÁ, N. 2012. Využitie progresívnejších parametrov pôdnej organickej hmoty na sledovanie jej zmien v agregátoch vo vinohrade [The use of "more progressive" parameters of soil organic matter aimed to study its changes in aggregates of vineyard soil]. In Acta fytotechnica et zootechnica, vol. 15, no. 4, p. 109–112.
- ŠIMANSKÝ, V. TOBIAŠOVÁ, E. 2012. Organic matter and chemical properties in Haplic Luvisol as affected by tillage and fertilizers intensity. In Acta fytotechnica et zootechnica, vol. 15, pp. 52–56.

- SU, Y.Z. WANG, F. SUO, D.R. ZHANG, Z.H. DU, M.W. 2006. Long term effect of fertilizer and manure application on soil carbon sequestration and soil fertility under the wheat-wheat-maize cropping system in Northwest China. In *Nutrient Cycling in Agroecosystems*, vol. 75, pp. 285–295. DOI: 10.1007/s10705-006-9034-x.
- TISDALE, S.L. NELSON, W.L. BEATON, J.D. HAVLIN, J.L. 1993. Soil Fertility and Fertilizers. New York, NY, United States: MacMillan Publishing Co.
- TRIBERTI, L. NASTRI, A. GIORDANI, G. COMEL-LINI, F. – BALDONI, G. – TODERI, G. 2008. Can mineral and organic fertilization help sequestrate carbon dioxide in cropland? In *European Journal* of Agronomy, vol. 29, pp. 13–20. DOI: 10.1016/j. eja.2008.01.009.
- WHALEN, J.K. CHANG, C. 2002. Macroaggregate characteristics in cultivated soils after 25 annual manure applications. In Soil Science Society of America Journal, vol. 66, pp. 1637–1647. DOI: 10.2136/ sssaj2002.1637.
- YANG, X.M. ZHANG, X.P. FANG, H.J. ZHU, P. – REN, J. – WANG, L.C. 2003. Long term effects of fertilization on soil organic carbon changes in continuous corn of Northeast China: Roth C model simulations. In *Environmental Management*, vol. 32, pp. 459–465.

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