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CHANGES IN SOIL AGGREGATE STABILITY INDUCED BY MINERAL NITROGEN FERTILIZER APPLICATION

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Abstract

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The stability of soil aggregates is one of the most important characteristics of the soil affecting the overall soil quality and its health. In locality Březová nad Svitavou, experiment to reveal the effect of nitrogen dose on the stability of soil aggregates of Rendzina soil was carried out. The aim was to detect changes in soil aggregate stability after 4 and 5 years from the beginning of the experiment. There were tested 7 variants, prepared in triplicate. The results revealed that the stability of soil aggregates decreases with increasing amounts of applied N. Effect of N application was not statistically significant in the fourth but in the fifth year of the experiment. The results also revealed a significant deterioration in the stability of soil aggregates in the fifth year compared to the fourth year of the experiment.

Keywords: nitrogen, soil aggregate stability, quality and health of soil, Rendzina, soil

INTRODUCTION

The stability of soil aggregates is one of the key characteristics of the soil in relation to soil fertility and its overall quality. According to Hillel (1980), we consider the stability of soil aggregates to be the ability of resistance against disintegration force acting on the aggregates. Disintegration caused by water is the most commonly mentioned in respect of the stability of soil aggregates (Hammad *et al.*, 2006, Regelink *et al.*, 2015). The stability of soil aggregates is influenced by the overall condition of the soil, management, and by the natural conditions (Amézketa, 1999; Munkholm *et al.*, 2016). On the other hand, the structure of soil and the aggregate stability influences various soil properties, such as particularly infiltration and water flow in soil (Liebig *et al.*, 2004), the air flow (Du Preez *et al.*, 2011). The stability of soil aggregates is significantly influenced particularly by quality and content of humus, and by biological activity. Increased stability of soil aggregates was detected in soil samples with a high content of organic substances (Epperlein, 2003). Adding organic matter into soil increases the bonding force between aggregates (Huisz *et al.* 2009). These bonds are not permanent and may lead to their re-rupture. Such destructive force is caused i.e. by disruption of optimal physical condition of the soil, such as compaction, use of fertilizers and decline in organic matter content.

The stability of soil aggregates is directly related to the biological activity of the soil. Generally, the more soil is biologically active, the higher is stability of soil aggregates (Bartlová and Badalíková, 2010; Oades, 1995). In this respect, it is needed to recall that the biological activity of soil and stability of the aggregates vary considerably during the season (Lehrsch and Jolley, 1991).

Fonte *et al.* (2009) pointed out that nitrogen has significantly destructive effect on the stability of soil aggregates and on the overall structure of the soil.

Prolonged exposure to high doses of nitrogen leads to reduction in the activity of soil organisms and to the collapse of the structure.

The aim of this study was to evaluate the influence of nitrogen fertilization on the stability of soil aggregates.

MATERIALS AND METHODS

Influence of fertilization method on water stability of soil aggregates was tested by field experiment which was conducted in the protection zone of underground drinking water Březová nad Svitavou in 2012. The protection zone is responsible for protection of underground source of drinking water against contamination by pollutants and residues from agriculture (pesticides and fertilizers). The area of our interest is located in the northern part of the Bohemian-Moravian Highlands, 58 km north of city Brno, in eastern part of the Czech Republic, where annual climatic averages (1962–2012) are 588.47 mm of precipitation and 7.9 °C mean of annual air temperature. Detailed information about area of our interest was published by Elbl *et al.* (2013) and Plošek *et al.* (2017). The experiment was conducted at 470 m above sea level in the Rendzina soil. Individual variants of experiment were arrayed in blocked design, each one with four replicates (one replicate = 2×10 m plot).

These variant were prepared:

1. N0 – without fertilization, sole crop winter wheat
2. N25 – 25 % of recommended dose of N for winter wheat (35 kg N/ha)
3. N50 – 50 % of recommended dose of N for winter wheat (69 kg N/ha)
4. N50 + C – 50% of recommended dose of N for winter wheat and recommended dose of lignohumate (69 kg N/ha + 250 l C/ha)
5. N50 + K – 50% of recommended dose of N for winter wheat and recommended dose of compost (69 kg N/ha + 50,000 kg K/ha)
6. N100 – 100% of recommended dose of N for winter wheat
7. N100 + C – 100 % of recommended dose of N for winter wheat recommended dose of lignohumate (138 kg N/ha + 250 l C/ha)

The following fertilizers were used for establishment of experiment: (a) organic waste compost – K; (b) mineral fertilizer DAM 390; (c) organic-mineral fertilizer Lignohumate – C.

Recommended dose in Czech Republic of K is 5 kg/m^2 (50,000 kg/ha) per 5 years according ČSN EN 46 5735, consequently this dose were used and represents 100% dose of K. The certified compost Black Dragon from aerobic composting plant CKB Brno. And recommended total dose of nitrogen for winter wheat, which is grown in protection zone of drinking water is 170 kg N/ha according Government Regulation no. 262/2012 Coll. The presented experiment was established in protection zone of drinking water, therefore 138 kg N/ha was chosen as 100 % dose of nitrogen per one year. Nitrogen was applied by mineral fertilizer DAM 390 (combination of ammonium, nitrate and amidic form of nitrogen) three times per year. Furthermore one variant were fertilized by special kind of organic-mineral fertilizer Lignohumate, which can be described as product of chemical transformation of lignosulfonate. Lignohumate (C) is solid fertilizer which after dissolution forming a solution of humic salts (humic and fulvic acids in the ratio 1:1) and potassium. The dose of 250 l C/ha was applied once a year. All used fertilized have been registered for using in agriculture according Fertilizers Law.

Samples were taken from the surface layer and transferred immediately to the laboratory and air-dried. After sieving the sample through a set of screens in order to separate the fraction with aggregate size of 1–2 mm, 4 g sample of this fraction was placed in a sieve of washing apparatus and washed in distilled water for 5 minutes. The sample was dried at 105 °C to constant weight, and placed into a solution of sodium pyrophosphate. The sample was re-dried at 105 °C to constant weight and content of stable soil aggregates was calculated in accordance with DIN 19683-16.

I: *Descriptive statistics for 2015.*

	N0	N25	N50	N100	N50+K	N50+C	N100+C
N valid	8	8	8	8	8	8	8
Mean	40.83	41.29	39.57	38.53	40.21	40.64	38.20
Median	42.87	41.84	39.94	38.58	40.54	40.50	37.88
Min	33.67	37.70	37.03	34.21	36.50	39.16	34.63
Max	44.22	43.54	41.46	42.33	41.55	41.60	42.03
Variance	19.83	3.45	1.86	9.03	2.67	0.60	6.37
SD	4.45	1.86	1.37	3.00	1.63	0.77	2.52
RSD	10.91	4.50	3.45	7.80	4.07	1.90	6.60

RESULTS AND DISCUSSION

The subject of our interest was to determine the effect of fertilization on aggregate stability of arable soil in area of our interest which was determined in 2015 and 2016.

2015

Tab. I indicates descriptive statistics with ANOVA for the soil aggregate stability in 2015. The highest average soil aggregate stability in 2015 was found to be 41.29 % in the variant N25. The stability was decreasing as follows: N0 (mean 40.83 %), N50 + C (mean 40.64 %), N50 + K (mean 40.21 %), N50 (mean 39.57 %), N100 (mean 38.53 %) and N100 + C (mean 38.20 %).

Increasing the dose of N had a negative impact on the stability of soil aggregates. To confirm the evidence supporting the allegation, the post-hoc Tukey's HSD test was carried out. The test did not prove statistically significant ($P < 0.05$) effect of the fertilization method on the stability of soil aggregates. Therefore, the effect of fertilization on soil aggregate stability in 2015 cannot be confirmed. On the other hand, the Fig. 1 apparently shows that different methods of fertilization could potentially affect the decline in soil aggregate stability. I.e., adding lignohumate into compost reduced the decrease in the stability of soil aggregates (N50 + K; N50 + C), in comparison with the variants fertilized only with mineral fertilizer. The same phenomenon was observed in the study of Udom (2015). However, variant N100 + C did not reveal improvement of the stability of soil aggregates. An *et al.* (2010) states it is probably due to already considerably high dose of mineral N (Fonte *et al.*, 2009).

2016

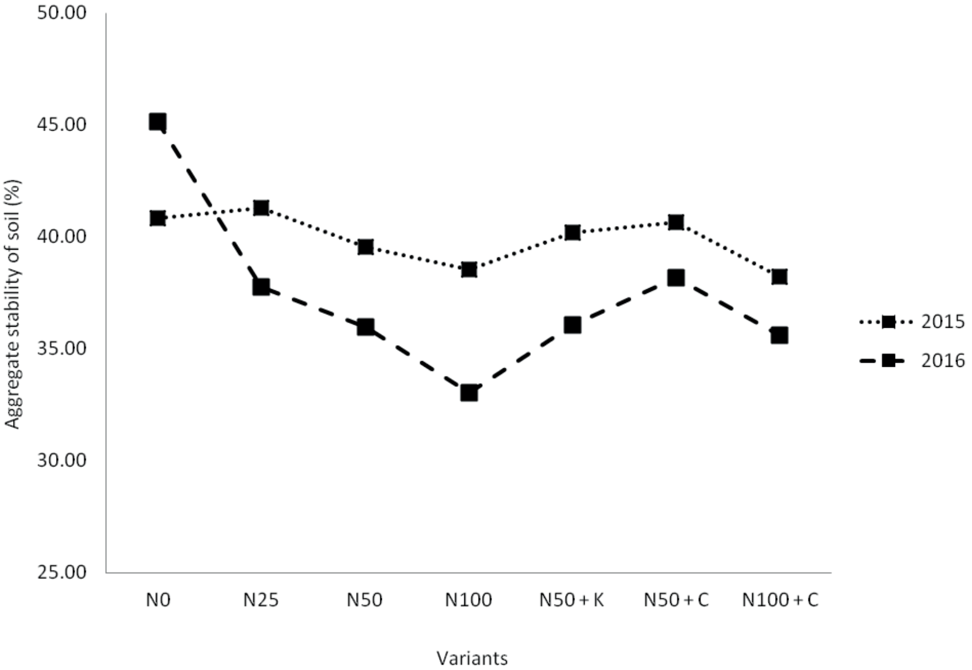
In 2016, samples were taken to determine the effect of the fertilization method on soil aggregates stability. The descriptive statistics of sampling in 2016 supplemented with an analysis of variance (ANOVA) is given in Tab. II. As it can be seen from Tab. II, the highest aggregate stability of the soil was measured in variants N0 (mean 45.15 %), and stability of soil aggregates was decreasing in the following order: N50 + C (mean 38.16 %), N25 (mean 37.76 %), N50 + K (mean 36.06 %), N50 (mean 35.96 %) N100 + C (mean 35.60 %) and N100 (mean 33.02 %). Similarly as in 2015, 2016 detected a higher dose of N has a negative effect on the stability of soil aggregates. Adding lignohumate and compost had a positive effect even in 2016. The statistics (post-hoc Tukey's HSD test) showed that the method of fertilization had statistically significant effect ($P < 0.05$) on the stability of soil aggregates in 2016. Statistically significant differences are shown in Tab. III. Negative impact of the addition of mineral N on soil aggregate stability can be illustrated by the results of the variants N0, N50 and N100. There were found significant differences among these variants in 2016. Increasing dose of N significantly decreased the stability of soil aggregates in the following order N0 > N50 > N100. Conversely, the addition of C and K had a demonstrable impact on reducing the negative impact of the application of mineral N on the stability of soil aggregates.

As seen in the Fig. 1 and Tab. III, it is evident the soil aggregate stability was deteriorated in 2016, with one exception of the variant N0 where step improvement was detected. Moreover, the statistically significant difference ($P < 0.05$) was found between particular years of the experiment. It can be assumed longer monitoring would have confirmed conclusions of other studies (Zhang *et al.*, 2016a; Zhang *et al.* 2016b) dealing with negative effect of long-term fertilization using mineral N on the stability of soil aggregates. The measured values were subsequently subjected to further statistical research. Potential differences between the variants were analyzed using post-hoc Tukey's test and differences within individual variants in 2015 and 2016 using t-test. Found differences among the variants and years are shown in Tab. III. The following Tab. IV shows accurate comparison results of 2015 and 2016. Based on these values, it can be stated that the stability of soil aggregates demonstrably decreased in all fertilized variants in 2015 and 2016, while the stability of soil aggregates was increased in the variant without added fertilizer (N0). These results indicate a negative effect of mineral N application on the stability of soil aggregates and the possibility of elimination of this negative effect using the application of compost or organic-mineral substances. The results are consistent with the work of Wang *et al.* (2013); Zhang *et al.* (2016b); Bronick and Lal (2005).

Soinne *et al.* (2016) warn that the destruction of soil structure exhibiting a reduced stability of aggregates leads to a significant reduction of soil functions, such as changing soil moisture conditions and deterioration of soil infiltration capacity. Due to the collapse of soil structure, soil pores are destroyed. This prevents from the infiltration of surface water that flows into watercourse then. This entails the risk of runoff of fertilizer and other substances applied into the soil. The substances cannot be retained in the soil. In practise, it leads to unnecessary overuse of fertilizers and chemicals.

II: *Descriptive statistics for 2016.*

	N0	N25	N50	N100	N50 + K	N50 + C	N100 + C
N valid	8	8	8	8	8	8	8
Mean	45.15	37.76	35.96	33.02	36.06	38.16	35.60
Median	44.75	37.63	35.92	33.18	36.09	38.32	35.70
Min	43.44	36.99	35.32	32.13	35.16	37.37	34.59
Max	48.31	38.69	36.62	33.55	36.86	39.16	36.12
Variance	2.36	0.44	0.33	0.25	0.63	0.44	0.27
SD	1.54	0.66	0.58	0.50	0.79	0.66	0.52
RSD	3.40	1.75	1.60	1.51	2.20	1.73	1.46



1: *Aggregate stability of soil within individual variants in 2015 and 2016.*

III: *Statistical analyses of potential differences in aggregate stability of soil among individual variants.*

Variants	2015	2016	2015 vs. 2016
N0	A	B	*
N25	A	C,F	*
N50	A	D	*
N100	A	E	*
N50 + K	A	A,D	*
N50 + C	A	F	*
N100 + C	A	A,D	*

Different letters indicate significat differences between individual variants in 2015 and 2016 at the level P < 0.05 (ANOVA; post-hoc Tuke's HSD test). Symbol * indicates significant differences in soil aggregate stability within one variants between 2015 and 2016 at the level P < 0.05 (t-test). The results of t-test are listed in Tab. IV.

IV: *Comparison of soil aggregate stability within individual variants in 2015 and 2016 – results of t-test.*

Variants	Year	Mean average	±SD	Mean differences	t	P
N0	2015	40.83	0.12	**–4.33**	–25.66	0.001515
	2016	45.15	0.29			
N25	2015	37.76	0.08	**3.53**	32.50	0.000945
	2016	41.29	0.11			
N50	2015	39.57	0.07	**3.61**	66.35	0.000227
	2016	35.96	0.16			
N100	2015	38.53	0.04	**5.51**	74.42	0.000180
	2016	33.02	0.17			
N50 + K	2015	40.21	0.05	**4.15**	69.07	0.000210
	2016	36.06	0.09			
N50 + C	2015	40.64	0.13	**2.48**	20.77	0.002310
	2016	38.16	0.08			
N100 + C	2015	38.20	0.12	**2.61**	72.86	0.000188
	2016	35.60	0.07			

The means of differences in stability of soil aggregates are signifficant at the level $P < 0.05$ if the value is shown in bold.

CONCLUSION

Based on the obtained results, we can conclude that nitrogen has destructive influence on the stability of soil aggregates. The highest stability of soil aggregates was measured in case of N0 variant. Increasing doses of nitrogen degrade the stability of soil aggregates. This is probably due to the supressing soil biological activity after the addition of nitrogen. The exception is the N50 + C variant where slight increase in soil aggregate stability was observed, probably due to the addition of carbon. The findings of this study are consistent with other studies. Furthermore, it can be assumed the same fertilization would deepen the negative effect described there, thus deteriorate soil aggregate stability.

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REFERENCES

AMÉZKETA, E. 1999. Soil Aggregate Stability: A Review. *Journal of Sustainable Agriculture*, 14(2–3): 83–151.

AN, S., MENTLER A., MAYER, H. and BLUM, W. E. H. 2010. Soil aggregation, aggregate stability, organic carbon and nitrogen in different soil aggregate fractions under forest and shrub vegetation on the Loess Plateau, China. *Catena*, 81(3): 226–233.

BÁRTLOVÁ, J. and BADALÍKOVÁ, B. 2010. Vliv obhospodařování půdy na změny ornice a podorničí. *Úroda*, 58(9): 56–57.

BRONICK, C. J. and LAL, R. 2005. Soil structure and management: a review. *Geoderma*, 124(1–2): 3–22.

ČESKO. 2012. Government Regulation no. 262/2012 – on the identification of vulnerable areas and the action program [in Czech: Nařízení vlády č. 262/2012 Sb., o stanovení zranitelných oblastí a akčním programu]. In: *Sbírka zákonů České republiky*. Částka 89/12.

DIN.2015. *Soil quality – Phasical laboratory tests – part 16: Determination of aggregate stability using the method of wet sieving*. DIN 19683-16. Berlin: Deutsches Institut für Normung.

DU PREEZ, C. C., VAN HUYSSTEEN, C. W. and MNKENI, P. N. S. 2011. Land use and soil organic matter in South Africa 2: A review on the influence of arable crop production. *South African Journal of Science*, 107(5/6).

ELBL, J., KURT, J. F., PLOŠEK, L., KINTL, A., PŘICHYSTALOVÁ, J., HYNŠT, J., DOSTÁLOVÁ L. and ZÁKOUTSKÁ, K. 2013. Leaching of mineral nitrogen and phosphate from rhizosphere soil stressed by drought and intensive rainfall. *World Academy of Science, Engineering and Technology*, 7: 324–330.

EPPERLEIN, J. 2003. Development of the Biological Activity in Different Tillage Systems. In: GARCIA-TORRES, L., BENITES, J., MARTÍNEZ-VILELA, A., and HOLGADO-CABRERA, A. (Eds.) *Conservation Agriculture*. Dordrecht: Springer Netherlands.

FONTE, S. J., YEBOAH, E., OFORI, P., QUANSAH, Q. W., VANLAUWE, B. and SIX, J. 2009. Fertilizer and Residue Quality Effects on Organic Matter Stabilization in Soil Aggregates. *Soil Science Society of America Journal*, 73(3): 961–966.

HAMMAD, A. H. A, BØRRESEN, T. and HAUGEN, L. E. 2006. Effects of rain characteristics and terracing on runoff and erosion under the Mediterranean. *Soil and Tillage Research*, 87(1): 39–47.

HILLEL, D. 1980. *Fundamentals of soil physics*. New York: Academic Press.

HUISZ, A., TÓTH, T. and NÉMETH, T. 2009. Water-Stable Aggregation in Relation to the Normalized Stability Index. *Communications in Soil Science and Plant Analysis*, 40(1–6): 800–814.

LEHRSCH, G. A., SOJKA, R. E., CARTER, D. L. and JOLLEY, P. M. 1991. Freezing Effects on Aggregate Stability Affected by Texture, Mineralogy, and Organic Matter. *Soil Science Society of America Journal*, 55(5): 1401–1406.

LIEBIG, M. A., TANAKA, D. L. and WIENHOLD, B. J. 2004. Tillage and cropping effects on soil quality indicators in the northern Great Plains. *Soil and Tillage Research*, 78(2): 131–141.

MUNKHOLM, L. J., HECK, R. J., DEEN, B., ZIDAR, T. 2016. Relationship between soil aggregate strength, shape and porosity for soils under different long-term management. *Geoderma*, 268: 52–59.

OADES, J. M. 1995. Krasnozems – organic-matter. *Australian Journal of Soil Research*, 33(1): 43–57.

PLOŠEK, L., ELBL J., LOŠÁK, T., KUŽEL, S., KINTL, A., JUŘIČKA, D. and KYNICKÝ, J. 2017. Leaching of mineral nitrogen in the soil influenced by addition of compost and N-mineral fertilizer. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, In press.

REGELINK, I. C., STOOF, C. R., ROUSSEVA, S., WENG, L., LAIR, G. J., KKRAM, P., NIKOLAIDIS, N. P., KERCHEVA, M., BANWART, S. and COMANS, R. N. J. 2015. Linkages between aggregate formation, porosity and soil chemical properties. *Geoderma*. 247–248: 24–37.

SOINNE, H., HYVÄLUOMA, J., KETOJA, E. and TURTOLA, E., 2016. Relative importance of organic carbon, land use and moisture conditions for the aggregate stability of post-glacial clay soils. *Soil and Tillage Research*, 158: 1–9.

UDOM, B. E. and OGUNWOLE, J. O. 2015. Soil organic carbon, nitrogen, and phosphorus distribution in stable aggregates of an Ultisol under contrasting land use and management history. *Journal of Plant Nutrition and Soil Science*, 178(3): 460–467.

ÚNMZ. 1991. *Průmyslové komposty*. ČSN EN 46 5735. Praha: Vydavatelství norem.

WANG, F., TONG, Y. A., ZHANG, J. S., GAO, P. C. and COFFIE, J. N. 2013. Effects of various organic materials on soil aggregate stability and soil microbiological properties on the Loess Plateau of China. *Plant Soil and Environment*, 59(4): 162–168.

ZHANG, S., WANG, R., YANG, X., SUN, B. and LI, Q. 2016b. Soil aggregation and aggregating agents as affected by long term contrasting management of an Anthrosol. *Scientific Reports*, 6: 39107.

ZHANG, Z., ZHANG, X., MAHAMOOD, M., ZHANG, S., HUANG, S. and LIANG, W. 2016a. Effect of long-term combined application of organic and inorganic fertilizers on soil nematode communities within aggregates. *Scientific Reports*, 6: 31118.

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