Agricultural Journal 3 (3): 216-219, 2008
ISSN: 1816-9155

Effect of Long-Term Fertilization on Organic Carbon and Nitrogen Contents in a Black Soil of Northeast China

[1]Yong Jiang, [1,3]Ying Qin, [1,3]Lili Zhang, [1,3]Yaopeng Liu, [2]Ping Zhu and [2]Hongjun Gao
[1]Institute of Applied Ecology, Chinese Academy of Science, Shenyang 110016, China
[2]Agricultural Environment and Resources Research Center,
Academy of Agricultural Sciences of Jilin Province, Gongzhuling 136100, China
[3]Graduate School of the Chinese Academy of Sciences, Beijing 110039, China

Abstract: The effect of fertilization on soil organic carbon and nitrogen was conducted in a long-term experiment, with monoculture of corn (*Zea mays* L.), established in 1980 at Gongzhuling, Jilin province of China. Six treatments, i.e., CK, N, NP, NK, NPK and MNPK, were established with 165 kg N ha^{-1}, 36 kg P ha^{-1} and 68.5 kg K ha^{-1} for chemical N, P and K fertilizer input, respectively, with 60 Mg farmyard manure ha^{-1} containing 150 kg N ha^{-1} for M and no fertilization for CK. The results showed that soil organic C, total N and alkali N were significantly greater in the MNPK treatment than in the other 5 treatments ($p<0.05$). Soil NH_4^+-N was significantly greater in the NPK and NK treatments than in the CK and N treatments ($p<0.05$). Soil NO_3^--N content was about 6 times as much in the MNPK treatment and 3-4 times as much in the chemical fertilizer treatments as in the CK treatment. Chemical N application alone or together with chemical P or K could not significantly improve the soil organic C or total N content, but chemical fertilizer NPK along with farmyard manure could substantially increase soil organic C and N contents in topsoil layer in the study site.

Key words: Soil organic carbon, nitrogen, nitrate nitrogen, long-term fertilization, soil fertility

INTRODUCTION

The degradation of soil quality is closely related to soil physical, chemical and biological fertility, fertilization is regarded as one of the main reasons leading to the degradation of soil quality in farmland ecosystems (Zhang *et al*., 2007; Zhu *et al*., 2007; Gao *et al*., 2004; Liang *et al*., 2003; Liu *et al*., 2005; Zhuang *et al*., 2007; Brady and Weil, 2002). Soil organic matter is an important component of productive soils, which is an essential indicator for soil quality and health because it exerts a profound influence on nearly every facet of the nature of soil (Brady and Weil, 2002; Xing *et al*., 2005). Nitrogen cycling has long been the subject of intense scientific investigation, because understanding the translocation and transformation of this element is the basis of solving many agricultural, environmental and natural resource problems (Brady and Weil, 2002).

Recent concerns about N as a major source of eutrophication in streams and lakes are focused on the earth's N cycling. The oxidation of soil organic matter together with the application of inorganic fertilizer tends to make cultivated lands as the source of N emissions (Cambardella and Elliott, 1994). Fertilization and irrigation practices may lead to a relatively high NO_3^--N accumulation in deep soil layers of cultivated fields and N leaching loss (Riley *et al*., 2001). Many studies have involved in the effects of fertilization on soil C and N dynamics (Zhu *et al*., 2007; Gao *et al*., 2004; Liu *et al*., 2005; Brady and Weil, 2002), but it is still a hot research spot due to the scientific needs in agriculture, environment and ecology.

The black soil region in northeast China has been one of the major grain production areas for corn and soybean in China. The potential fertility of the black soil was high, but degradation of the black soil has become a serious problem due to poor management practices, which has greatly threatened the security of grain production the agricultural sustainability in China (Zhang *et al*., 2007). The objective of this study was to compare the soil organic carbon and nitrogen contents with different fertilizer treatments in a black soil of a long-term experimental station located in northeast China.

MATERIALS AND METHODS

Study site: The study was conducted at a National Long-term Experimental Station for Soil Fertility Monitoring in

Corresponding Author: Dr. Yong Jiang, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016 China

Black Soil, located in the Academy of Agricultural Sciences of Jilin Province, Gongzhuling city (43°30′N, 124°48′E). The station is located in a continental temperate monsoon zone, with a dry-cold winter and a warm-wet summer. The annual temperature ranges 5.0-6.0°C, annual precipitation ranges 500-650 mm and annual non-frost period ranges 120-140 days. The soil is classified as black soil in Chinese Soil Classification or Typic Halpudoll in USDA Soil Taxonomy.

A long-term fertilization experiment with monoculture corn (*Zea mays* L.) was established in 1980. Six treatments were established as follows: CK, N, NP, NK, NPK and MNPK. In the CK treatment, no fertilizer was applied, while in the other 5 treatments, chemical nitrogen was applied with 165 kg N ha^{-1}, chemical phosphorus 36 kg P ha^{-1} and chemical potassium 68.5 kg K ha^{-1}. In the MNPK treatment, besides the chemical N, P and K fertilizer application, about 60 Mg farmyard manure ha^{-1} containing 150 kg N ha^{-1} was applied. Each plot was about 400 m^2. Before the experiment was established, the soil fertility in 0-20 cm soil layer was as follows, organic matter 23.3g kg^{-1}, total N 1.40 g kg^{-1}, total P 1.39 g kg^{-1}, total K 22.1 g kg^{-1}, alkali N 114 mg kg^{-1}, Olsen P 27.0 mg kg^{-1} and available K 190 mg kg^{-1}.

Sampling and soil analyses: In October 2007, at the end of the harvesting, soil samples were collected from the treatment plots at the depth of 0-20 cm with 3 replications. One part of the fresh samples were prepared for NH_4^+-N and NO_3^--N analyses and the other samples were air-dried and ground to pass a 2 mm sieve for related chemical analysis. Sub-samples from each sample were grounded to power passing through 0.149 mm sieve. Soil organic carbon and total nitrogen contents were determined by the dry combustion method using a Vario ELIII Elemental Analyzer. Alkali nitrogen was determined by 24 h autoclave-Convey micro-diffusion method and NH_4^+-N and NO_3^--N were extracted with 2 M KCl and determined by magnesium oxide-devarda alloy method (Lu, 1999).

Statistical analysis: The obtained data were analyzed with SPSS 11.5, using one-way ANOVA and Duncan's pairwise comparison for means separation. A significance level of $p<0.05$ was chosen for detecting significant differences.

RESULTS

Soil organic C and total N: Table 1 summarized the changes of soil organic C, total N and C/N with different fertilization treatments. Soil organic carbon was significantly greater in MNPK treatment than in the other

Table 1: Changes of soil organic carbon and total nitrogen contents with different fertilization

Treatment	Soil organic C (g kg^{-1})	Total N (g kg^{-1})	C/N
CK	12.51±0.36b	1.22±0.07b	10.31±0.35ab
N	12.27±0.83b	1.20±0.04b	10.18±0.34ab
NP	13.43±0.68b	1.24±0.04b	10.80±0.20a
NK	13.73±0.61b	1.35±0.07b	10.20±0.47ab
NPK	12.56±0.74b	1.29±0.02b	9.72±0.44b
MNPK	18.69±1.11a	1.74±0.19a	10.75±0.53a

Mean values of 3 replicates. In a row, figures followed by different letter (s) are significantly different by Duncan's multiple range test ($p<0.05$)

Table 2: Changes of soil available nitrogen contents with different fertilization

Treatment	Alkali–N (mg kg^{-1})	NH_4^+-N (mg kg^{-1})	NO_3^--N (mg kg^{-1})
CK	56.31±15.44b	20.18±2.06b	4.65±1.36c
N	57.00±1.74b	19.91±1.25b	21.66±6.58b
NP	53.31±0.69b	22.19±0.98ab	20.71±4.50b
NK	65.31±5.89b	23.70±2.15a	18.53±4.31b
NPK	69.41±4.74b	23.59±1.74a	15.31±2.91b
MNPK	87.46±12.88a	22.21±0.33ab	30.69±7.60a

Mean values of 3 replicates. In a row, figures followed by different letter(s) are significantly different by Duncan's multiple range test ($p<0.05$)

5 treatments ($p<0.05$), while in the other five treatments it was not significantly different with Duncan's multiple range test. Soil total nitrogen was also significantly greater in MNPK treatment than in the other 5 treatments ($p<0.05$), while in the other five treatments it was not significantly different. NP and MNPK treatments had higher C/N values than the other 4 treatments, but NPK treatment had the lowest C/N value.

Soil available N: Soil alkali nitrogen content was significantly greater in MNPK treatment than in the other five treatments. Although, there had no significant difference for alkali N content in the other five treatments, the NPK and NK treatments tended to had much more alkali N than the CK, N and NP treatments. Soil NH_4^+-N content was significantly greater in NPK and NK treatments than in CK and N treatments. MNPK and NP treatments had the middle ammonia nitrogen content in the 6 treatments. Among the 6 treatments, NO_3^--N content in the MNPK treatment was the highest and it was significantly greater than in the other 5 treatments. It had the lowest content in the CK treatment and was significantly lower than in the other 5 treatments (Table 2).

Correlations of soil organic C and N: Soil organic C was significantly correlated with total N and alkali N ($p<0.01$) and NO_3^--N ($p<0.05$). Total N was significantly correlated with alkali N ($p<0.01$) and NO_3^--N ($p<0.05$). Soil C/N had no significant relationship with organic C or total N, while ammonia N had no significant relationship with the other 5 variables (Table 3).

Table 3: Pearson correlations of soil organic carbon and nitrogen (n = 18)

	Soil organic C	Total N	C/N	Alkali–N	NH_4^+-N	NO_3^--N
Soil organic C	1					
Total N	0.957**	1				
C/N	0.448	0.173	1			
Alkali–N	0.721**	0.764**	0.039	1		
NH_4^+-N	0.195	0.247	-0.093	0.351	1	
NO_3^--N	0.588*	0.521*	0.347	0.443	0.091	1

*, ** Correlation is significant at the 0.05 and 0.01 levels, respectively

DISCUSSION

Soil organic C content can increase by managing land use practices in which the rates of organic C input exceed those of organic C mineralization (Brady and Weil, 2002). Yang *et al*. (2003) had used RothC model to simulate the effects of fertilization on soil organic C changes in continuous corn of northeast China and found that the treatment without fertilizer/farmyard manure addition led to a continuous decline in soil organic C during the study period and N and NPK fertilization were inadequate to maintain the soil organic C levels at the depth of 0-20 cm soil layer, unless farmyard manure was added under the conventional management associated with no above-ground crop residues returning into the soil. Soil organic C could follow the same path of decline if the same management practices are maintained. Liu *et al.* (2005) had studied the changes of soil organic C under long-term fertilization in a black soil of northeast China (47°26′N, 126°38′E), the result showed that using of chemical fertilizer NPK along with return of crop residues could substantially increase soil organic C in topsoil layers. Because of greater addition of organic matter in the manure and in the residues from the high-yield crop, the MNPK treatment maintained much higher organic C level in this study. Although the CK treatment had no fertilizer addition, the soil organic C content was not significantly different from the treatments with chemical fertilizer application, indicating that the organic C content had reached a balance in CK treatment.

The change of soil total N was similar to that of soil organic C in this study. Table 2 showed that soil total N was not significantly different between CK treatment and the chemical fertilizer N addition treatments, indicating that application of chemical fertilizer N only could not increase total N content in the study region. However, chemical fertilizer along with farmyard manure addition could significantly increase total N level. After 27 years of experiment, the total N content was about 1.43 times as much in the MNPK treatment as in the CK treatment. The result is in accordance with Peng *et al*. (2004). The C/N in NPK treatment was lower than the other five treatments, indicating that comparing to N, the combination addition of chemical N, P and K may accelerate organic carbon mineralization.

Soil alkali N content was significantly greater in MNPK treatment than in the other 5 treatments, which showed a similar trend to that of organic C and total N in this study. In most case, soil alkali N is closely correlated with organic C and total N in farmland ecosystems (Zhuang *et al*., 2007; Peng *et al*., 2005; Jiang *et al*., 2006).

Among the test variables, the difference of nitrate N contents was a striking feature. Nitrate N content was about 6 times as much in the MNPK treatment and 3-4 times as much in the chemical fertilizer treatments as in the CK treatment. The significant increase of NO_3^--N was due to addition of either chemical fertilizer N or manure N. Zhang *et al*. (2004) had compared the profile distributions of nitrate N in an aquic brown soil under different land uses and found that the higher content of NO_3^--N in corn and paddy fields was due to N fertilization and anthropogenic disturbance. Several other studies have also proven that NO_3^--N leaching in soil profiles was due to N fertilization (Brady and Weil, 2002).

Long tern application of N may be the leading reason for the differences of total, alkali and nitrate N among treatments. In this study, totally 315 kg ha^{-1} N was applied to the MNPK treatment annually, the amount of N, which was more than the crop need, could lead to the accumulation of both total and nitrate N in the surface soil.

CONCLUSION

After 27 years of different fertilization treatment, the amount of soil organic C, total N and alkali N was significantly greater in the chemical N, P, K, together with farmyard manure treatment than in the chemical fertilizer treatments or the no fertilization treatment. Long term application of N may be the leading reason for the differences of total, alkali and nitrate N among treatments. The changes of soil organic C, total N and alkali N were similar among the fertilization treatment. Among the test variables, the difference of nitrate N contents was a striking feature. Soil NO_3^--N content was about 6 times as much in the MNPK treatment and 3-4 times as much in the chemical fertilizer treatments as in the CK treatment.

ACKNOWLEDGEMENT

This research was financially supported by the National Basic Research Program of China (2007CB109307) and the National Natural Science Foundation of China (30670379).

REFERENCES

Brady, A.C. and R.R. Weil, 2002. The Nature and Properties of Soils. 13th Edn. Prentice Hall, New Jersey, USA.

Cambardella, C. and E. Elliott, 1994. Carbon and nitrogen dynamics of soil organic matter fractions from cultivated grassland soils. Soil Sci. Soc. Am. J., 58: 122-130.

Gao, L.P., W.J. Liang, Y. Jiang and D.Z. Wen, 2004. Dynamics of organic C in black soil of northeast China, simulated by CENTURY model I. Accumulation of soil organic carbon under natural conditions. Chin. J. Applied Ecol., 15: 772-776.

Jiang, Y., Q.L. Zhuang and W.J. Liang, 2006. Field-scale variability of soybean yield and its relations with soil fundamental fertility. Agric. J., 1: 136-140.

Liang, W.J., Q. Li, Y. Jiang, W.B. Chen and D.Z. Wen, 2003. The effect of cultivation on the spatial distribution of nematode trophic groups in black soil. Pedosphere, 13: 97-102

Liu, X.B., J.D. Liu, B.S. Xing, S.J. Herbert, K. Meng, X.Z. Han and X.Y. Zhang, 2005. Effects of long-term continuous cropping, tillage and fertilization on soil organic carbon and nitrogen of black soils in China. Comm. Soil. Sci. Plant Anal., 36 (9-10): 1229-1239.

Lu, R.K., 1999. Analytical Methods for Soil and Agro-chemistry. China Agricultural Science and Technology Press, Beijing.

Peng, C., P. Zhu, H.J. Gao and S.H. Liu, 2004. Long term monitoring of fertility in black soil. I: The transformation of OM and N nutrition. J. Jilin Agric. Sci., 29 (5): 29-33.

Riley, W.J., I. Ortiz-Monasterio and P.A. Matson, 2001. Nitrogen leaching and soil nitrate, nitrite and ammonium levels under irrigated wheat in Northern Mexico. Nutri. Cycl. Agroecosyst., 61: 1385-1314.

Xing, B.S., J.D. Liu, X.B. Liu and X.Z. Han, 2005. Extraction and characterization of humic acids and humin fractions from a black soil of China. Pedosphere, 15: 1-8.

Yang, X.M., X.P. Zhang, H.J. Fang, P. Zhu, J. Ren and L.C. Wang, 2003. Long-term effects of fertilization on soil organic carbon changes in continuous corn of northeast China: RothC model simulations. Environ. Manag., 32 (4): 459-465.

Zhang, X.Y., X.Y. Sui, X.D. Zhang, K. Meng and S.J. Herbert, 2007. Spatial variability of nutrient properties in black soil of northeast China. Pedosphere, 17: 19-29.

Zhang, Y.G., Y. Jiang, W.J. Liang, D.Z. Wen and Y.L. Zhang, 2004. Vertical variation and storage of nitrogen in an aquic brown soil under different land uses. J. For. Res., 15: 192-196.

Zhu, P., J. Ren, L.C. Wang, X.P. Zhang, X.M. Yang and D. MacTavish, 2007. Long-term fertilization impacts on corn yields and soil organic matter on a clay-loam soil in Northeast China. J. Plant Nut. Soil. Sci., 170: 219-223.

Zhuang, Q.L., Q. Li, Y. Jiang, W.J. Liang and Y. Steinberger, 2007. Vertical distribution of soil organic carbon in agroecosystems of Songliao Plain along a latitudinal gradient. Am. Eur. J. Agric. Environ. Sci., 2: 127-132.