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Abstract. By analyzing the published literatures of wheat and maize fields in North China, the effects of different farming methods on N_2O emissions and crop yields in grain fields were determined. The results showed that in the North China grain field, the no-tillage technology reduced the N_2O potential in the wheat season, while the N_2O difference in the corn season using no tillage, conventional tillage, deep pine and alfalfa was not significant. Therefore, the implementation of no-till measures in the north wheat grain field in North China can reduce emissions and increase production, while the corn field suggests conventional tillage, deep pine or alfalfa cultivation on the basis of straw returning, which can stabilize production and reduce emissions.

1. Introduction

Greenhouse gas is an important source of climate warming and a range of environmental problems. N_2O is one of the greenhouse gases, and its concentration in the atmosphere is 20% higher than before industrialization and N_2O emissions from agricultural production account for 84% of total N_2O emissions [1-2]. The total grain output of the North China Plain accounts for 1/7 of the country's total grain production area [3]. In order to obtain high yield, farmers put a lot of nitrogen fertilizer into the farmland. However, proper fertilizer application not only is unhelpful for crop growth, but also causes a series of environmental problems such as nitrogen wetting, soil and water eutrophication, and greenhouse effect [4-6]. The research on N_2O emission reduction in farmland in this area mainly focuses on fertilizer dosage and types, farming measures, long-acting fertilizers, and nitrogen control agents. Among them, fertilization and farming measures are important measures to improve wheat yield [7].

Many scholars have pointed out that reducing the nitrogen application rate in wheat/maize rotation in the region to 150-200 kg hm^{-2} can ensure crop yield and reduce environmental pollution [4-6]. With the increase of nitrogen fertilizer application, the N_2O emission of soil increases linearly or curvely, so ensuring the appropriate amount of nitrogen fertilizer will help the region to reduce emissions and increase crop yield [8]. The relevant farming measures have not been conclusive about the reduction of

grain output and production. The traditional ploughing or rotary tillage, which is widely used at present, causes the surface to be exposed, which accelerates the depletion of soil and reduces the quality of cultivated land and the ability of soil to continuously supply fertilizer [7]. Zhang and other studies have shown that Deep pine could promote the growth of maize in the early stage of North China, and no-tillage promotes the growth in the later stage, while Deep pine could promote the increase of wheat yield [9]. Zhang simulated the global warming potential (GWP) of CO_2, CH_4 and N_2O emissions in the winter wheat/summer maize rotation soil in North China. The results showed that the GWP values under different tillage methods were tillage>rotary tillage > No-till [10]. The effects of farming methods on greenhouse gas emissions and winter wheat yield may be a more suitable rotational tillage mode in short-term rotation. The rotary tillage system is not conducive to control greenhouse gas emissions, but it is necessary to strengthen the long-term effects on different rotation methods [11].

Although domestic and foreign scholars have conducted a lot of research on N_2O emissions from farmland in North China, most of them are single test resulting in specific regions and lack systematic. Therefore, this paper comprehensively analyzed the effects of different tillage methods on soil N_2O and crop yields in wheat and corn fields in North China by consulting a large number of published literatures, trying to clarify the rational N_2O emission reduction and crop yield increase mode of the grain field system. Provide scientific basis for agricultural safety production in North China.

2. Materials and Methods

In this paper, winter wheat and summer maize were used as research objects to study the effects of different tillage methods on their N_2O emissions and yields. The recent and published domestic and international journals and doctoral dissertations were reviewed and comprehensively analyzed. The same indicators in different literatures were converted into uniform units, and the calculation of N_2O emission reduction and crop yield increase were based on no-till treatment. The calculation formula for each indicator is:

N_2O emission increase rate (%) = (nitrogen treatment N_2O emissions - no nitrogen treatment N_2O emissions) / no nitrogen treatment N_2O emissions × 100

Crop yield increase (%) = (nitrogen treatment crop yield - no nitrogen treatment crop yield) / no nitrogen treatment crop yield × 100

N_2O emissions per unit of nitrogen fertilizer (g kg^{-1}) = N_2O emissions from nitrogen treatment / pure nitrogen application × 1000

Unit production N_2O emissions (mg kg^{-1}) = N_2O emissions / crop yield × 10^6

3. Results and analysis

3.1. Effects of different tillage methods on N_2O emission and yield in wheat fields

The research on the N_2O emission from farmland mainly focused on straw returning and conservation tillage. The author collected different farming methods under the straw returning to the field to avoid no tillage. Compared with no tillage, most other farming practices increased N_2O emissions from wheat fields, ranging from -2.3% to 640%, and wheat yields from -6.6% to 26.7%（Table 1）. Conventional tillage increased soil N_2O emissions by 2.3% to 30.8%, and crops did not achieve significant yield increases when emissions were greatest. Traditional farming not only increases N_2O emissions compared to no-tillage, but also leads to crop yield reduction. Under rotary tillage, N_2O increased by -2.3% to 47.4%, wheat yield increased by -2.5% to 22.9%, crop yield increased by 4.8%, and crop yield decreased by 19.5% to 35.4%, indicating that rotary tillage is not conducive to N_2O emission reduction and crop yield increase in farmland. No-tillage or rotary tillage after deep pine and deep pine increased N_2O emissions, and no-tillage reduced yield by 6.6% after deep pine. The N_2O emission reduction and yield increase by raking were not obvious, straw removal, straw deep application or straw surface increased yield by 6.7%~15.5%, but N_2O emission increased by 640%. Therefore, no-tillage is the current farming measure that both reduces N_2O emission and stabilizes wheat yield.

Table 1. Effects of different tillage methods on soil N_2O emission and yield of wheat

Literature basis	Treatments	Total N_2O emissions /kg hm^{-2}	N_2O increase rate /%	Crop yield /kg hm^{-2}	Rate of wheat growth /%
Zhang [12]	no tillage	0.65	0	7671	0
	conventional tillage	0.85	30.8	7695	0.31
	rotary tillage	0.88	35.4	7481	-2.5
Hojatollah [13]	no tillage	1.33	0	6844	0
	no tillage after deep pine	2.45	84.2	6392	-6.6
	rotary tillage after deep pine	3.06	130.1	7381	7.8
	rotary tillage	1.96	47.4	7172	4.8
Tian [14]	no tillage	1.71	0	3915	0
	conventional tillage	1.75	2.3	4930	25.9
	deep pine	1.77	3.5	4189	7.0
	rake tillage	1.76	2.9	4688	19.7
	rotary tillage	1.67	-2.3	4813	22.9
Wan [15]	no tillage	0.05	0	5543	0
	straw removal	0.32	540	5912	6.7
	straw surface	0.10	100	6212	12.1
	straw deep	0.37	640	6404	15.5
Zhao [16]	no tillage	1.33	0	6096	0
	conventional tillage	1.48	11.3	7088	16.3
	deep pine	1.42	6.8	7726	26.7
	rake tillage	1.64	23.3	7286	19.5
	rotary tillage	1.59	19.5	5945	-2.5

3.2. Effects of tillage methods on soil N_2O emissions and maize yield

Compared with no-tillage, the conventional farming methods of each test reduced N_2O by 5.7% to 17.4%, but increased production by less than 1% (Table 2). Deep pine can reduce N2O by 3.9% to 14.6% and corn yield by 9.7%,raking could reduce N_2O 2.2%～11.9% corn yield 1.5%, it indicated that all three farming methods are conducive to stable yield reduction in corn fields. Under the rotary tillage mode, the N_2O increase rate is -6.9%~5.8%, and the corn yield is reduced by 1.3%, indicated that rotary tillage is not beneficial to corn field yield increase and emission reduction. No tillage after deep pine, the no tillage increased N_2O by 42.6% and the crop yield was reduced by 12.2%; the tillage increased N_2O by 71.1%. Therefore, it is recommended that the corn field use conventional tillage, deep pine or rake tillage.

Table 2. Effects of different tillage methods on soil N_2O emission and yield of maize

Literature basis	Treatments	Total N_2O emissions /kg hm^{-2}	N_2O increase rate /%	Crop yield /kg hm^{-2}	Rate of maize growth /%
Hojatollah [13]	no tillage	2.70	0	9683	0
	no tillage after deep pine	3.85	42.6	8499	-12.2
Tian[14]	no tillage	2.29	0	—	—
	conventional tillage	2.16	-5.7	—	—
	deep pine	2.20	-3.9	—	—
	rake tillage	2.24	-2.2	—	—
	rotary tillage	2.32	1.3	—	—
Zhao[16]	no tillage	5.63	0	8581	0

	conventional tillage	4.65	-17.4	8657	0.9
	deep pine	4.81	-14.6	9411	9.7
	rake tillage	4.96	-11.9	8712	1.5
	rotary tillage	5.24	-6.9	8467	-1.3
	no tillage	1.21	0	—	—
Zhang[17]	tillage	2.07	71.1	—	—
	rotary tillage	1.28	5.8	—	—

Notes："-" in the table indicates that the crop yield was not measured and the relevant data could not be calculated.

4. Conclusions and discussion

Straw returning has been applied to North China in large scale, and the research on the impact of farming methods on N_2O emissions from farmland is still controversial. This paper showed that on the basis of straw returning to the field, no potential for no tillage and yield reduction was high, but there was no significant difference between the cornfield farming practices. Zhang reported that N_2O emissions from wheat fields under no-tillage and straw returning were lower than traditional tillage, and conservation tillage reduced soil N_2O emissions [12]. Flechard pointed out that traditional farming had higher N_2O emissions than no till, which was related to soil temperature, soil moisture and soil properties [18]. No tillage increased N_2O emissions from soil with poor ventilation conditions had little effect on well ventilated soil [19]. Related to the application of nitrogen fertilizer, the nitrogen fertilizer input in the maize season was generally higher than that in the wheat season, which results in a larger nitrogen fertilizer input than the tillage method had a greater effect on N_2O emissions [20-21]. Straw mulching can also interact with farming methods [22], but the mechanism of N_2O emission was complex and the results were uncertained.

Therefore, taking both N_2O emission reduction and crop yield in grain fields into account, the recommended management techniques for wheat and maize season are: no till measures could reduced emissions in the wheat season; conventional tillage, deep pine or rake tillage on the basis of straw returning in the maize season, could stabilize production and reduce emissions.

References

[1] IPCC. Climate change (2014) mitigation of climate change. Cambridge University Press.

[2] Wang, M.X., Zhang, Z.X. (2015) Optimal water-saving irrigation mode reducing N_2O emission from rice paddy field in cold region and increasing rice yield. Transactions of the Chinese Society of Agricultural Engineering, 31: 72-79.

[3] Sun, Y.L., Lu, P.L., Li, J., Yu, Q., Sun, S.B., Wang, J.S., Ou, Y.Z. (2008) Characteristics of soil N_2O flux in a winter wheat-summer maize rotation system in North China Plain and analysis of influencing factors. Chinese Journal of Agrometeorology, 29: 15.

[4] Chen, X.P., Cui, Z.L., Vitousek, P.M., Cassman, K. G., Matson, P. A., Bai, J. S., Meng, Q.F., Hou, P., Yue, S.C., Romheld, V., Zhang, F.S. (2011) Integrated soil-crop system management for food security. Proceeding of the National Academy of Sciences, 108:6399-6404.

[5] Cui, Z.L., Chen, X.P., Miao, Y.X., Zhang, F.S., Sun, Q.P., Schroder, J., Zhang, H., Li, J.L., Shi, L.W., Xu, J.F., Ye, Y.L., Liu, C.S., Yang, Z.P., Zhang, Q., Huang, S.M., Bao, D.J. (2008) On-farm evaluation of the improved soil N-based nitrogen management for summer maize in North China Plain. Agronomy Journal, 100:517-525.

[6] Ju, X.T., Xing, G.X., Chen, X.P., Zhang, S.L., Zhang, L.J., Liu, X.J., Cui, Z.L., Yin, B., Christie, P., Zhu, Z.L., Zhang, F.S. (2009) Reducing environment risk by improving N management in intensive Chinese agricultural systems. Proceeding of the National Academy of Sciences, 106: 3041-3046.

[7] Zhang, R.Z., Luo, Z.Z., Cai, L.Q., Huang, G.B., Li, L.L., Xie, J.H. (2011) Effects of long-term conservation tillage on soil physical quality of rainfed areas of the loess plateau. Acta Prataculturae Sinica, 20:1-10.

[8] Hu, X.K., Huang, B.X., Su, F., Ju, X.T., Jiang, R.F., Zhang, F.S. (2011) Effects of nitrogen management on methane and nitrous oxide emissions from summer maize soil in North China Plain. Scientia Sinica Chimica, 41:117-128.
[9] Zhang, X.C., Li, H.W., He, J., Wang, Q.J., Zheng, Z.Q., Jing, P. (2013) Effects of Different Tillage Managements on Characteristics of Soil and Crop in Annual Double Cropping Areas in Northern China. Transactions of the Chinese Society for Agricultural Machinery, 44(z1).
[10] Zhang, M.Y., Wei, Y.H., Kong, F.L., Chen, F., Zhang, H.L. (2012) Effects of tillage practices on soil carbon storage and greenhouse gas emission of farmland in North China. Transactions of the Chinese Society of Agricultural Engineering, 28: 203-209.
[11] Zhao, L.Y., Dong, W.X., Hu, C.S., Li, J.Z., Chen, T. (2018) Effect of tillage method change on soil greenhouse gas emission and yield during winter-wheat growing season. Chinese Journal of Eco-Agriculture, 26: 17-27.
[12] Zhang H., Guo L.P., Xie L.Y., Lin, M., Ye, D.D., Yan, H.L. (2013) The effect of management practices on the emission of CO_2 and N_2O from the winter wheat field in north China plain. Journal of Soil Science, 2013,44: 654-659.
[13] Hojatollah, L. (2015) Effects of soil tillage on crop yield and greenhouse gas emission of corn-wheat cropping system. Chinese Academy of Agricultural Sciences, Bei jing.
[14] Tian S.Z. (2010) Effects of tillage measures and conversion on the emission of soil CH_4, N_2O and carbon sequestration capability in wheat-maize farmland. Shandong Agricultural University, Tai an.
[15] Wan, Y.F., Li Y.E., Gao Q.Z., Qin, X.B, Lin, E.D. (2009) Field managements affect yield, soil carbon, and greenhouse gases emission of winter wheat in north China plain Journal of Agro-Environment Science, 28: 2459-2500.
[16] Zhao J.B. (2010) Effect of conservation tillage on soil environmental factors and the emission of greenhouse gas in the field. Shandong Agricultural University, Tai an.
[17] Zhang, Y.M. (2011) Greenhouse gases emission from wheat-maize rotation field in the North China Plain and evaluation on its comprehensive effect. University of Chinese Academy of Sciences, Beijing.
[18] Flechard, C.R., Ambus, P., Skiba, U., Rees, R.M., Hensen, A., Van Amstel, A., Van denpol-van Dasselaar, A., Soussana, J.F., Jones, M., Clifton-Brown. J., Raschi, A., Horvath, L., Neftel, A., Jocher, M., Ammann, C., Leifeld, J., Fuhrer, J., Calanca, P., Grosz, B. (2007) Effects of climate and management intensity on nitrous oxide emissions in grassland systems across Europe. Agriculture Ecosystems and Environment, 121:135-152.
[19] Rochette, P. (2008) No-till only increases N_2O emissions in poorly-aerated soils. Soil and Tillage Research, 101: 97-100.
[20] Ahmad, S., Li, C.F., Dai, G.Z., Zhang, M., Wang, J.P., Pan, S.G., Cao, C.G. (2009) Greenhouse gas emission from direct seeding paddy field under different rice tillage systems in central China. Soil and Tillage Research, 106: 54-61.
[21] Jarechi, M. K., Parkin, T.B., Alvarus, S.K.C, Kaspar, T.C., Moorman, T.B., Singer, J.W., Kerr, B.J., Hatfield, J.L., Jones, R. (2009) Cover crop effects on nitrous oxide emission from a manure-treated Mollisol. Agriculture, Ecosystems and Environment, 134: 29-35.
[22] Li, Y.C., Hou, C.C., Li, Y., Guo, Z.J. (2014) Effects of no-till and straw mulch on greenhouse gas emission from farmland: A review. Ecology and Environmental Sciences, 23: 1076-1083.