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Full Length Article

Biomass Composting Combined with Dicyandiamide Lowered Greenhouse Gas Emissions and Grain Quality of Winter Wheat

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Abstract

Straw compost replacement with chemical fertilizers along with dicyandiamide (DCD) can reduce greenhouse gas emissions and improved wheat yield and quality. The experiment was conducted to explore the impact on greenhouse gas emissions of biomass compost combined with DCD. In this research, the influence of combination of compost with nitrification inhibitor on dynamic change in the emission fluxes of nitrous oxide (N_2O), carbon dioxide (CO_2), methane (CH_4) and yield & quality of wheat was investigated. Wheat was sown using ten treatments: CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}. Results showed that the total greenhouse gas emissions in T_2D_3 (202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}) and T_1D_3 treatments (180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}) treatments were reduced by 15.7 and 32.2% compared with the traditional application of nitrogen fertilizer. The grain protein content and amylopectin contents were increased in T_1D_3 (180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}) by 8–14% compared with control. Moreover, the yield didn't have significant different compared with traditional fertilization. In conclusion, straw compost replacement with chemical fertilizers along with DCD can reduce greenhouse gas emissions. The use of 15 t ha^{-1} straw compost + 60 kg ha^{-1} DCD reduced chemical fertilizer demand by 20%.

Keywords: Straw compost; Nitrification inhibitor; Winter wheat; Greenhouse gases; Grain yield

Introduction

Anhui is an important food production base in China with average annual planting area of wheat (*Triticum aestivum* L.) of 2.4 million ha (Zhang *et al*. 2018). The amount of chemical fertilizers used in Anhui is 33.86% higher than that regulated by China's ecological township construction (Dong and Liu 2018). However, the excessive use of chemical fertilizers gradually decreases the marginal effect of production, slightly increases the crop yield while increase greenhouse gas emissions and cause environmental pollution. The contribution rate of nitrous oxide (N_2O), carbon dioxide (CO_2) and methane (CH_4) to global warming in the atmosphere reaches 80%, and N_2O emitted by the application of chemical fertilizers accounts for 25–82% of the total N_2O emissions of the soil. The global warming potential of N_2O is 298-fold higher than of CO_2, and that of CH_4 is 25-fold higher than that of CO_2 (Li *et al*. 2018).

Research on reducing the application of chemical fertilizers and greenhouse gas emissions has become a hot topic. Using slow-release fertilizers, adding nitrification inhibitors, incorporating organic fertilizers, returning straw to the fields, and using biochar and precision agriculture are the main research areas (Ali *et al*. 2017; Hussain *et al.* 2017). The high-temperature compost of crop straw is one of the effective methods used to treat the combination of rural breeding industry. It cannot only prevent pests and diseases but also replace fertilizers. Straw returning to the

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soil can replace fertilizer and reduce CH_4 emissions by 23.6%, but it will increase N_2O gas emissions (Li *et al.* 2018). Nitrification inhibitors are used to reduce the emission of N_2O. Dicyandiamide (DCD) is a chemical nitrification inhibitor that can reduce nitrogen oxide emissions by 49.3–79.4%. DCD is widely used in the US, Europe, and other countries, but its application in China is still at the preliminary research stage (Wang *et al.* 2017). No reports have reported on the combination of compost and DCD. The present study combines compost with several chemical fertilizers and DCD to determine the optimal dosage and its effects on greenhouse gas emissions and wheat yield. Thus, the objectives of this study were to clarify the green ecological agriculture model suitable for winter wheat production with environmental-friendliness.

Materials and Methods

Description of experimental site

This study was conducted in the plantation of Anhui Science and Technology University (E117°33′39″, W32°52′49″) from October 2018 to June 2019. The annual average temperature of the plantation was 15°C, the annual average rainfall was 1200 mm and the frost-free period was 230 days. The previous crop sown was peanut (*Arachis hypogaea* L.). The soil was yellow cinnamon soil that contains 20.8 g kg^{-1} organic matter, 110.9 mg kg^{-1} available nitrogen, 25.8 mg kg^{-1} available phosphorus, and 115.2 mg kg^{-1} available potassium in the 0–20 cm surface soil layer. The winter wheat variety tested was Luomai 23. The sampling black box was 50 cm^3 and the 50 cm relay box was used later.

Experimental treatment and methods

Wheat was sown using ten treatments: CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}. Experiment was laid out following randomized complete block design (RCBD) and replicated three times with net plot size of 4 m × 4 m. Sowing was conducted on October 27, 2018 with 15 cm line spacing using seed rate of 300 kg ha^{-1}. Wheat was harvested on June 1, 2019. Compost was the product of the aerobic fermentation of rice (*Oryza sativa* L.) straw and cow dung. The NPK content was 3.25%, the organic matter content was 47.8%, and the pH was 6.67. The experiment was performed in triplicate, and arranged randomly. The farming, sowing, irrigation, pest control and other field operations of each treatment were consistent with the local traditional way.

Determined items and methods

Greenhouse gas collection, measurement, and emission calculations: Gas was collected using static black box sampling method according to seasonal temperature. Gas was collected once a week from November to December, once every 2 weeks from January to March and once a week from April to June. Gas was collected every 10 min during sampling for a total of three times. The gas was recorded while recording the temperature inside the static dark box and surface. After gas samples were collected in each plot, the gas syringe was brought to the laboratory and measured by gas chromatograph Agilen7890A by using Porapak Q packed column at the oven temperature of 70°C with N_2 as carrier gas. The device was equipped with electron capture detector, and the operating temperature was 330°C. The CO_2 and CH_4 were measured by the FID detector at the operating temperature of 250°C. Three of these greenhouse gas emissions were measured. Interpolation was used to calculate the unobserved daily emission flux. The daily measured and calculated values were added to calculate the total emission of CO_2, N_2O and CH_4.

Global warming potential (GWP) of soil-emitted gas

The influence of CO_2, CH_4, and N_2O emitted by wheat field on atmospheric greenhouse effect was quantitatively evaluated by the combined action of three greenhouse gases emitted by soil and was regarded as GWP. In 100-year scale, the global warming effects of 1 kg of CH_4 and 1 kg of N_2O were 25- and 298-folds higher than that of 1 kg of CO_2, respectively (Li *et al.* 2018).

Grain yield and quality

At the maturity stage, a row of wheat was collected from each plot, and the number of productive tillers and the plant height were recorded. The average grain number per spike was calculated by randomly selecting 20 spikes in each plot. The 1000-grain weight and the total grain yield of each plot were calculated by drying and threshing. Grain quality was measured by a NIR grain quality tester (PM-8188).

Data processing and statistical analysis

WPS office 2007 was used to perform data processing and chart drawing. One-way ANONA of SPSS 20.0 was used to check the overall significance of data while least significant test (LSD) was used to compare treatments means at $P < 0.05$. The data in the figure were the average value ± standard error of three repeated measurements.

Results

Emission characteristics of N_2O in soil

Different treatments had significant effect on greenhouse gas emissions (Figs. 1–3). The N_2O emission was significantly higher in plots where alone chemical fertilizers (225 kg N, 75 kg P and 225 kg K ha^{-1}; CKN) were applied compared with all other treatments while the N_2O emission was low where no fertilizers or organic amendments (0 kg N, 0 kg P and 0 kg K ha^{-1}; CK0) were applied. The N_2O emission was decreased by DCD. Such as the N_2O emission of 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1} (T_1D_3) was 65.2 and 35.5% lower than (CKN) and (T_1D_1) within 34 d after sowing, respectively (Fig. 1). The emission flux of N_2O in the soil accounted for a large proportion in the sowing–tillering period. The emission of each treatment reached the peak 30 d after sowing. In late November, wheat entered the overwintering stage, and the emission of each treatment showed a slow change trend. When wheat entered the regreening period on March 26, the emission of each treatment increased significantly. Compared with CKN, which showed the second emission peak 151 d after sowing, the other treatments showed the second emission peak 153 d after sowing. After mid-April, the N_2O emission of different treatments was relatively flat (Fig. 1).

Emission characteristics of CO_2 in soil

As shown in Fig. 2, the CO_2 emission of CKN treatment was the highest in each stage while the application of DCD by biomass composting reduced the emission of CO_2 to the atmosphere, but the overall trend was relatively consistent. The CO_2 emission of T_1D_3 was 16.9 and 7.8% lower than the N_2O emission in CKN and T_1D_1 treatments on March 27, respectively (Fig. 2); however, the CO_2 emission of CK0 was still lowest. At 34 d after wheat sowing, CO_2 emission showed the peak value. After the peak, wheat entered the wintering period, and the emission flux of CO_2 was low. In March, wheat entered the regreening period. As the temperature increased, the growth rate of wheat and the CO_2 emission flux increased. The CO_2 emission gradually decreased after April. The CO_2 emissions of each treatment were always higher than that of CK0, thereby indicating that the use of fertilizer increased the emission of CO_2 (Fig. 2).

Emission characteristics of CH_4 in soil

The CH_4 emissions didn't have significant different in biomass compost and DCD treatments as shown in Fig. 3. The CH_4 emissions in the wheat growth stage were mostly negative, and the absorption and emission of CH_4 in each treatment were low at the end of February of the next year. From the beginning of March, the first peak of the absorption of CH_4 appeared in each treatment. After the end of the regreening period at mid-April, the absorption rate of CH_4 tended to be stable. The emission law of CH_4 was not evident, indicating that the effect of alternative use of compost on CH_4 emissions was not significant (Fig. 3).

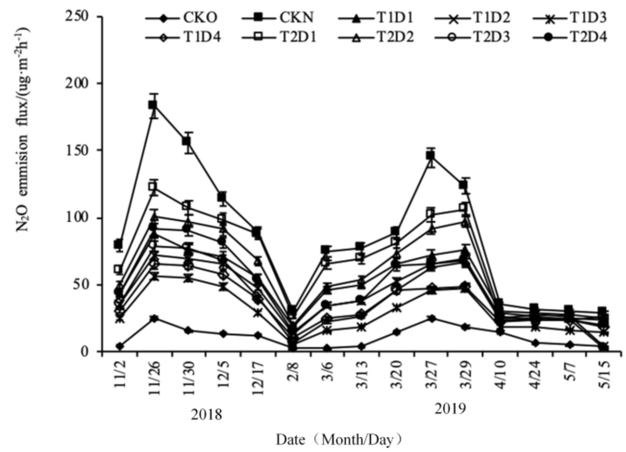

Fig. 1: N_2O Emission flux in wheat soil under crop residue compost added nitrification inhibitor

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide

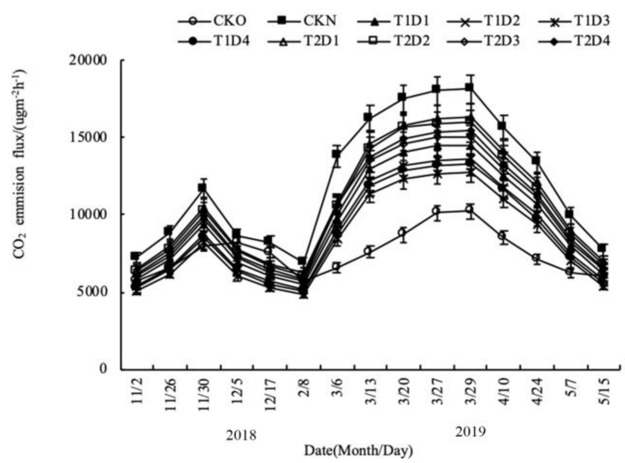

Fig. 2: CO_2 Emission flux in wheat soil under crop residue compost added nitrification

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide

Table 1: Total emission of greenhouse gas in wheat field with compost return added nitrification inhibitor replaces part of chemical fertilizer

Treatments	Total CO_2 emission (kg ha^{-1})	Total CH_4 emission (kg ha^{-1})	Total N_2O emission (kg ha^{-1})	Total GWP (kg ha^{-1})
CKN	363.3 ± 1.8i	7.4 ± 0.0a	0.5 ± 0.0i	697.3d
CK0	521.7 ± 3.8a	-17.4 ± 0.1f	3.7 ± 0.0a	1189.3a
T_1D_1	408.3 ± 2.8f	-21.6 ± 0.1g	2.3 ± 0.0c	553.7e
T_1D_2	382.7 ± 4.9g	-32.1 ± 0.4j	1.9 ± 0.0e	146.4g
T_1D_3	357.2 ± 5.8j	-14.0 ± 0.2d	1.3 ± 0.0h	394.6f
T_1D_4	373.3 ± 3.5h	-31.6 ± 0.3i	1.6 ± 0.0g	60.1h
T_2D_1	459.4 ± 0.9b	-21.2 ± 0.0b	3.2 ± 0.0a	883.0c
T_2D_2	449.5 ± 1.8c	-23.9 ± 0.1h	2.7 ± 0.0b	656.6d
T_2D_3	423.7 ± 5.0e	-14.4 ± 0.2e	1.8 ± 0.0f	600.1e
T_2D_4	434.4 ± 3.5d	-5.7 ± 0.1c	2.1 ± 0.0d	917.7b

Means (± standard deviation) sharing same letters differ non-significantly at $P \leq 0.05$

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide; GWP: Global warming potential

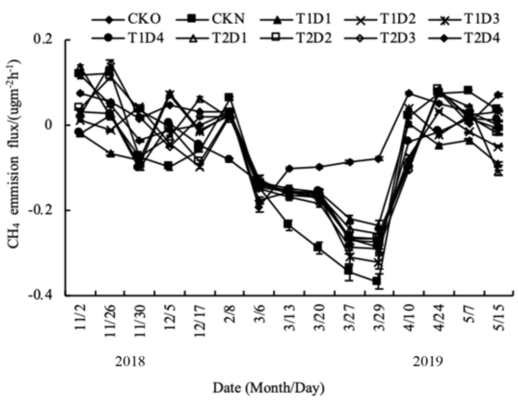

Fig. 3: CH_4 Emission flux in wheat soil under crop residue compost added nitrification

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide

Total emission of greenhouse gas

Applied treatments had significant effect on total emissions of CH_4, CO_2 and N_2O as well as global warming potential (GWP) (Table 1). Total emissions of CH_4, CO_2 and N_2O as well as GWP were higher in CKN compared with all treatments and lower in CK0 (Table 1). The application of DCD by biomass composting reduced the emission of CO_2, N_2O. The CO_2 and N_2O emissions in T_1D_3 were 31.5 and 64.7 lower than CKN and T_1D_1, respectively. The total GWP of T_1D_3 was the highest and DCD treatment significantly decreased GWP (Table 1).

Analysis of wheat yield and yield composition

According to the actual weighing and measurement of wheat after harvest, the interaction between nitrogen-reducing compost replacement and DCD was significant, with the highest T_2D_3 of 5998 kg ha^{-1}. In the two nitrogen reduction treatments, the yield increased with increasing nitrification inhibitors. The highest yield exceeded the fertilization mode, but D_4 did not exceed the yield D_3. Hence, DCD of >60 kg ha^{-1} cannot play a good role. In terms of yield composition, organic fertilizer replacement increased the grain number per spike, 1000-grain weight, and plant height. However, the grain number per spike did not increase due to the replacement of organic fertilizers (Table 2).

Wheat quality analysis

The use of organic fertilizers along with DCD, instead of chemical fertilizers, significantly improved the quality of wheat (Table 3). The increase was significant compared with the situation without fertilizer application and chemical fertilizer application, especially T_1D_3, which led to the highest protein and amylopectin contents. The protein content and amylopectin contents of T_1D_3 wheat were increased by 7.9–13.9% and 7.9–14.0% than CH0, respectively (Table 3).

Discussion

The addition of nitrification inhibitor DCD significantly reduced the emission peak and total discharge of N_2O and CO_2 by 11.9–31.5% compared with traditional fertilizer control treatment, consistent with previously reported findings (Xu *et al.* 2016). Nitrogen in urea exists in the form of ammonium N, and the absorption of wheat is mainly nitrate N. Therefore, the ammonium nitrogen of urea must undergo nitrification in the soil, and N_2O is one of the important intermediate products of nitrification.

Conventional straw returning to the field increased the N content in the soil, thereby promoting nitrification and denitrification and further increasing N_2O emissions. Moreover, the N_2O emission of straw returning to the field

Table 2: Effects of composting return and nitrification inhibitors on wheat grain yield

Treatments	Plant height (cm)	Number of productive tillers (m^{-2})	Number of grains per spike	1000-grain weight (g)	Grain yield (kg ha^{-1})
CKN	72.1 ± 2.3c	528.6 ± 3.5a	34.6 ± 1.2b	42.3 ± 3.5b	5946 ± 25.5a
CK0	65.0 ± 0.5d	461.3 ± 3.6c	29.0 ± 0.8c	39.7 ± 2.3b	5023 ± 32.2c
T_1D_1	73.2 ± 1.5b	525.4 ± 2.3a	34.4 ± 1.1b	42.6 ± 0.6b	5887 ± 23.8b
T_1D_2	73.8 ± 2.1a	522.1 ± 1.2a	34.8 ± 1.5b	42.7 ± 0.6b	5907 ± 18.9a
T_1D_3	74.5 ± 1.2a	514.3 ± 1.3b	35.9 ± 0.6a	43.1 ± 1.4a	5929 ± 62.1a
T_1D_4	73.6 ± 0.4b	514.6 ± 1.3b	35.5 ± 0.6a	42.9 ± 1.3b	5908 ± 8.2a
T_2D_1	72.5 ± 1.0c	521.3 ± 0.9a	35.1 ± 1.4a	42.2 ± 1.7b	5865 ± 92.2b
T_2D_2	72.8 ± 0.6b	514.6 ± 1.1b	35.8 ± 0.1a	42.4 ± 0.4b	5901 ± 12.9a
T_2D_3	73.6 ± 1.1b	518.2 ± 1.3b	35.7 ± 1.1a	42.8 ± 0.6b	5998 ± 32.9a
T_2D_4	73.1 ± 1.1b	525.5 ± 1.2a	34.9 ± 0.6b	42.4 ± 0.9b	5916 ± 54.4a

Means (± standard deviation) sharing same letters differ non-significantly at $P \leq 0.05$

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide

Table 3: Effects of composting return and nitrification inhibitors on quality of wheat

Treatments	Protein (%)	Unit weight (g l^{-1})	Gluten (%)	Sedimentation value (ml)	Amylopectin (%)
CKN	10.7 ± 0.2b	810.5 ± 0.1b	21.0 ± 0.1a	5.45 ± 0.32b	55.8 ± 0.15b
CK0	9.5 ± 0.1c	790.5 ± 0.1c	19.1 ± 0.2b	3.75 ± 0.07c	50.1 ± 0.03c
T_1D_1	11.8 ± 0.1a	899.7 ± 1.4a	23.3 ± 0.1a	6.05 ± 0.03a	61.9 ± 0.01a
T_1D_2	12.0 ± 0.1a	907.8 ± 0.2a	23.6 ± 0.2a	6.10 ± 0.05a	62.5 ± 0.05a
T_1D_3	12.2 ± 0.1a	924.0 ± 1.2a	23.9 ± 0.1a	6.21 ± 0.03a	63.6 ± 0.03a
T_1D_4	12.1 ± 0.1a	915.9 ± 0.1a	23.7 ± 0.0a	6.16 ± 0.02a	63.1 ± 0.01a
T_2D_1	11.5 ± 0.1a	875.3 ± 1.0a	22.7 ± 0.0a	5.89 ± 0.01a	60.3 ± 0.01a
T_2D_2	11.6 ± 0.2a	883.4 ± 2.3a	22.9 ± 0.1a	5.94 ± 0.02a	60.8 ± 0.03a
T_2D_3	11.7 ± 0.2a	891.5 ± 0.1a	23.1 ± 0.0a	5.99 ± 0.03a	61.4 ± 0.02a
T_2D_4	11.7 ± 0.4a	887.5 ± 0.1a	23.1 ± 0.0a	5.97 ± 0.03a	61.1 ± 0.03a

Means (± standard deviation) sharing same letters differ non-significantly at $P \leq 0.05$

Here CKN: 225 kg N, 75 kg P and 225 kg K ha^{-1}; CK0: 0 kg N, 0 kg P and 0 kg K ha^{-1}; T_1D_1: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 20 kg DCD ha^{-1}; T_1D_2: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 40 kg DCD ha^{-1}; T_1D_3: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 60 kg DCD ha^{-1}; T_1D_4: 180 kg N, 60 kg P, 180 kg K, 15 t biomass compost and 80 kg DCD ha^{-1}; T_2D_1: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 20 kg DCD ha^{-1}; T_2D_2: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 40 kg DCD ha^{-1}; T_2D_3: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 60 kg DCD ha^{-1}; T_2D_4: 202.5 kg N, 67.5 kg P, 202.5 kg K, 7.5 t biomass compost and 80 kg DCD ha^{-1}; DCD: Dicyandiamide

was ~25% higher than that of not returning (Li *et al.* 2018). In the present study, the addition of DCD to straw compost for replacing chemical fertilizer significantly inhibited the nitrification and denitrification reactions. The N_2O emission after DCD addition was lower than that of conventional fertilizer application, similar to a previous study that reported that the application of organic fertilizer and decomposed manure can also reduce N_2O emissions (Ren *et al.* 2019). Organic fertilizer and decomposed manure undergo full aerobic fermentation of organic matter. Thus, N is relatively stable, and straw directly returning to the field has not become thoroughly decomposed. The process of decomposition mainly includes carbon–nitrogen conversion. When microorganisms decompose cellulose, hemicellulose, lignin, and other organic matter, N undergoes numerous nitrification and denitrification cycles. This process also exacerbates nitrification and denitrification in the soil, thereby promoting N_2O emission. However, decomposed straw compost and manure reduce nitrification and denitrification and decrease the emission of N_2O.

As a nitrification inhibitor, DCD is widely used in Europe and the US. In this study, the effect of 60 kg ha^{-1} DCD was the most remarkable among the treatments. Many researchers locally and internationally have suggested that DCD can reduce the emission of greenhouse gases. Research found that adding 5% nitrification inhibitor DCD and 0.5% urease inhibitor reduced the N_2O emission by 40.6% compared with traditional fertilization, and the yield increased by ~21% (Maike *et al.* 2017). This study did not achieve such a significant effect probably because the application of compost was relatively slow and long-term positioning may obtain improved results. In each treatment, the application of chemical fertilizer treatment of 225 kg N ha^{-1}, 75 kg P ha^{-1}, 225 kg K ha^{-1} increased the wheat yield compared with 0 kg N ha^{-1}, 0 kg P ha^{-1}, 0 kg K ha^{-1}, but the effect was not superior to the treatment of DCD supplemented with straw compost. Compared with that of 225 kg N ha^{-1}, 75 kg P ha^{-1}, 225 kg K ha^{-1}, the yields of the other treatments didn't have significant difference; but the quality increased by 7.9–13.8%. The compost returning to field combined with DCD will inevitably affect microbes, which can explain the mechanism of gas emission in this study. The mechanism of action of microorganisms needs to be further studied.

Green agricultural products are one of the research hotspots in recent years. The reduction of chemical fertilizer and the substitution of organic fertilizer can improve the quality of agricultural products, but also bring about the reduction of yield. While nitrification inhibitor can reduce the gas emission, it can also increase the yield. It has been reported that adding 5% nitrification inhibitor DCD and 0.5% urease inhibitor can reduce the N_2O emission by 40% compared with traditional fertilization 60%, and the yield increased by 21% (Zhu *et al*. 2019). This experiment did not achieve such a significant effect; maybe because the application effect of compost is relatively slow, long-term positioning should get better effect.

Conclusion

Straw compost replacement with chemical fertilizers along with DCD reduced greenhouse gas emissions and improved wheat yield and quality. The use of 15 t ha^{-1} straw compost + 60 kg ha^{-1} DCD reduced chemical fertilizer demand by 20%. Compared with commercial organic fertilizer, the cost of compost can be greatly reduced. Compost can replace chemical fertilizers in the production and reduce the transportation cost of straw and organic fertilizers and, therefore, compost can be widely used in wheat production.

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