Effects of Chicken Manure Application on Crop Yields and Soil Nutrients Accumulation in Wheat-Corn Rotation System

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***Abstract*: Aimed at resolving the unreasonable disposition and disadvantage to environment of poultry manures, the research on the effect of different chicken manure rates on crop yields and the soil nutrients accumulation were carried out by a field plot experiment. The results showed that aappropriate application rate of chicken manure significantly increased the yield of wheat. No obvious differences of corn yield were observed among the treatments of different chicken manure application rates. The soil organic matter, total nitrogen(N), total phosphorus (P), total Zinc (Zn) and nitrate (NO_3^--N), available P and available Zn contents significantly increased with the increasing rates of the chicken manure respectively. The soil organic matter, N, P and Zn supply could be maintained by the combined application of the low chicken manure rate (15 t/hm^2) and chemical fertilizer in the wheat season. Compared with the check treatment (CK) with no chicken manure, the contents of soil nitrate, available P and available Zn increased when the rate of chicken manure were 90 t/hm^2 and 150 t/hm^2, respectively. After one cycle of wheat-corn rotation, compared with CK, the chicken manures application at a rate of 90 t/hm^2 increased soil NO_3^--N, available P and available Zn content by 68.29%, 91.37% and 77.02%, respectively. For the chicken manures treatment at 150 t/hm^2, soil NO_3^--N, available P and available Zn content were increased by 69.58%, 133.16%and 177.7%, respectively.**

Keywords: Chicken manures; Soil; Wheat; Corn; Zinc

China has become a large livestock and poultry producer in the world. Moreover, its products play an important role in the world. Poultry husbandry with large scale and higher intensification level is the pillar industry in stockbreeding. It is estimated that the amounts of livestock and poultry manure in China were 3.19 billions in 2003, in which of poultry manure was 288 millions tons[1]. Due to the backward technology with proper treatments to harmless substance and recycling utilization of livestock and poultry manure, organic wastes have become the main source of rural non-point pollution. The best way to resolve this problem was to supply to the soil as organic fertilizers through proper treatments and entered nutrient cycling. The organic wastes contain more available nutrients such as N, P and K. However, they also contain harm heavy metals which is harmful for human health due to long term accumulation in the soil and entered human body through the food chain. Some results suggested that organic fertilizers composted from poultry and livestock wastes such as cow manure, chicken manure and pig manure were important sources for soil Zn accumulation[2-3]. Furthermore, organic fertilizer application affected soil Zn bioavailability significantly. Soil available Zn content increased with more organic fertilizers supply[4-7]. This is because that organic fertilizers increase organic matters which can chelate with soil Zn[2]. As a result of the application of feed additives in recent years, livestock and poultry manure from factory farms contained high amounts of heavy metal Zn[8-10]. The objective of this study was to evaluate the effects of chicken manure on crop yields and the soil nutrients accumulation in winter wheat (*Triticum aestivum* L.) and summer corn (*Zea mays* L.) rotation system.

1.1 Materials and Methods

A field experiment was conducted at zhongliu villages of Anxin county in Hebei Province. The site was located in the warm temperate semi-humid continental monsoon climate with four distinct seasons. The mean annual precipitation and air temperature are 529.7 mm and 12.2 ◦C, respectively. The experiment was began in October 2009. Principal chemical properties of chicken manure and soil at experimental site before sowing are shown in Table 1.

Table 1 Principal Chemical Properties of Chicken Manure and Soil at Experimental Site before Sowing

Sample name	Organic matter (g/kg)	Total N (%)	Total P (%)	Total Zn (mg/kg)	Available Zn(mg/kg)
Chicken manure	261.2	1.64	1.13	296.83	
Soil	19.6	0.128	0.151	82.17	1.50

1.2 Experimental Design

The wheat and corn varieties used in this study were

978-0-7695-4706-0/12 $26.00 © 2012 IEEE
DOI 10.1109/iCBEB.2012.174

Laoting 639 and Zhengdan 958, respectively. Organic fertilizer used was decaying chicken manure. The experimental design was a randomized complete block. Seven chicken manure（CM）application levels were arranged. The treatments included CK（no chicken manure）, CM1（15 t/hm^2）, CM2（30 t/hm^2）, CM3（45 t/hm^2）, CM 4（60 t/hm^2）, CM5（90 t/hm^2）and CM6（150 t/hm^2）. Each treatment (application rate) was replicated four times in a total of 28 plots. Each plot was 4.0 m wide by 4.0 m long. According to the local chemical fertilizer application rates， the appropriate amounts of fertilizer at rate of 225 kg N /hm^2, 150 kg P_2O_5 /hm^2, and 150 kg K_2O /hm^2 were supplied. On the basis of measured and calculated nitrogen, phosphorus, potassium of organic fertilizer chicken manure, the chemical fertilizer made up no less than amount of the nutrients. Urea, superphosphate and potassium chloride were used. Half of urea was applied before sowing and the rest as top dressing when wheat turned green in spring . Chicken manure, superphosphate, potassium chloride were used as a basal fertilizer applied to the soil before sowing wheat. Corn experiment was conducted after wheat was harvested. The special fertilizers for corn were applied while sowing corn. The nutrition applied was equivalent to the amount of nutrient at 150 kg N /hm^2, 60 kg P_2O_5 /hm^2, 90 kg K_2O /hm^2. During the growth of wheat and corn the conventional management methods were used.

1.3 Sample Collection and Analytical Methods

Soil basic samples were collected before experiment. Composite samples of the 0- to 20-cm soil layer, which was done by mixing equal soil sample amounts from five randomly selected sampling points within each plot, were obtained from every plot after wheat and corn harvested. These samples were air dried and grinded to pass a 2-mm sieve for laboratory analysis. A small part of soil samples was grinded to pass a 0.149 mm sieve for laboratory analysis. The tested indicator included soil organic matter, total N, total P, total Zn, NO_3^--N, available P and available Zn. Wheat and corn were harvested subdistrict alone and weighed to calculate the output.

All the physical and chemical indicators using conventional soil agro-chemistry analysis method[10]. Subsamples of soil samples were digested with a mixture of conc. HCl-HNO_3-HF-$HClO_4$ [11]. The total soil Zn and available Zn contents were determined using atomic emission spectroscopy. All data were analyzed using a SAS statistical package.

2 Result Analysis

2.1 Crop Yield

Table 2. Effect of Chicken Manure Application on Yield of Wheat and Corn

Treatment	Wheat Yield(kg/hm^2)	Corn Yield(kg/hm^2)
CK	4752.4 b*	7853.6 a
CM1	4809.9 ab	7938.9 a
CM2	5082.5 ab	7953.1 a
CM3	5320.2 a	7731.1 a
CM4	5312.7 a	7722.9 a
CM5	5165.1ab	8257.0 a
CM6	5192.6 ab	8175.5 a

*.Means in a column followed by different letters are significantly different at $P \leq 0.05$, the same below.

In the experimental conditions, with the increasing of chicken manure application rates, wheat yield was firstly increased and then decreased (Table 2). Compared with CK (no chicken manure), the yield of wheat increased significantly by 11.95% and 11.79% when the rates of chicken manure were 90 t/hm^2 and 150 t/hm^2. respectively. But there were no significant differences between the treatments of chicken manure of more than 60 t/hm^2 and CK. Thus, the appropriate amount of chicken manure application could increase the yields of wheat, but excessive application of chicken manure had little effect on wheat yield. However, the application of chicken manure had no obvious impact on corn yield(Table 2).

2.2 Soil pH and Nutrients

Table 3. Effect of Chicken Manure Application on Soil pH and Nutrients at Wheat Harvest Period

Treatment	pH	Organic matter (g/kg)	Total N (%)	Total P (%)	NO_3^--N（mg/kg）	Available P (mg/kg)
CK	7.85 a	22.5 de	0.128 b	0.082 b	24.03 bc	37.95 c

CM1	7.97 a	21.3 e	0.127 b	0.083 b	20.43 c	36.25 c
CM2	7.96 a	21.7 e	0.131 b	0.082 b	21.27 c	37.80 c
CM3	7.83 a	24.4 cd	0.133 b	0.082 b	34.37 ab	37.95 c
CM4	7.67 a	26.0 bc	0.140 b	0.098 a	45.20 a	40.08 bc
CM5	7.83 a	27.1 ab	0.145 ab	0.098 a	42.78 a	49.87 b
CM6	7.70 a	28.4 a	0.169 a	0.100 a	45.27 a	84.05 a

Table 4. Effect of Chicken Manure Application on Soil Nutrients at Corn Harvest Period

Treatment	Organic matter (g/kg)	Total N (%)	Total P (%)	NO_3^--N (mg/kg)	Available P (mg/kg)
CK	19.5 c	0.135 c	0.085 b	29.11 c	30.70 c
CM1	20.4 b	0.144 ab	0.089 b	32.12 c	31.55 c
CM2	22.2 ab	0.143 ab	0.090 b	32.17 c	48.70 bc
CM3	22.7 ab	0.147 ab	0.093 b	33.36 c	48.13 bc
CM4	23.4 a	0.139 b	0.088 b	39.73 bc	49.50 bc
CM5	23.1 ab	0.156 a	0.106 a	48.99 ab	58.75 ab
CM6	23.1 ab	0.153 ab	0.109 a	51.46 a	71.58 a

The content of soil organic matter is closely related to soil fertility level. The changes of organic matter content directly reflected the level of the soil fertility [12]. Although soil N included various forms. To some extent, soil total nitrogen represents the soil nitrogen level [13]. Table 3 and Table 4 showed effects of chicken manure application on soil nutrients at wheat and corn harvest periods. With increasing of chicken manure application, soil organic matter, total N, total P content increased. In the wheat harvest period, compared with CK (no chicken manure), soil organic matter content of CM4, CM5 and CM6 treatment increased by 15.62% and 20.47%, 26.24%, respectively. Total N and total P content in the soil in the CM6 treatment were significantly increased by 32.07% and 21.11%, respectively. In the corn harvest, compared to CK, soil organic matter and total N content of all chick manure treatments were significantly increased. The soil organic matter was increased between 4.62-20.0%. Soil total N content was increased between 2.96-15.6%. Soil total P content of CM5 and CM6 treatments was increased significantly by 24.71% and 28.23%, respectively. Application of organic fertilizer chicken manure could improve soil fertility obviously.

Soil NO_3^--N was directly absorbed by the plants and available for the plants. In wheat harvest period, soil NO_3^--N content of CM4, CM5 and CM6 treatment were significantly increased by 88.10%, 78.02% and 88.40% compared with CK. Soil NO_3^--N content in surface soil of CM1, CM2 treatment were similar to the control level. Compared with CK, soil NO_3^--N content of CM5 and CM6 treatment in corn harvest were increased significantly by 68.29% and 69.58%. Soil NO_3^--N content in surface soil of CM1, CM2, CM3 were similar to CK. Application rate of chicken manure of 15-45 t/hm^2 could basically keep soil NO_3^--N content equivalent with the chemical fertilizer treatment during the whole wheat and corn growth period.

Soil available P is available as the direct source for plant. Soil available P is an important indicator of soil phosphorus supply level. It has been recently reported that long-term application of phosphorus fertilizer and organic fertilizer could significantly enlarge the soil available phosphorus pool [14]. In wheat harvest period, CM5 and CM6 compared with CK were significantly increased by 28.91% and 111.8%. but CM1, CM2, CM3, CM4 and CK were the same level. In corn harvest period, CM5 and CM6 compared with CK were significantly increased by 91.37% and 133.16%. Soil available P content of CM1, CM2, CM3, CM4 treatments were similar to CK. Application rate of chicken manure at 15-60 t/hm^2 could basically keep soil available P content equivalent with the chemical fertilizer treatment in the whole wheat and corn growth period.

2.3 Soil Total Zn

Table 5. Effect of Chicken Manure Application on Soil Total Zn Content

Treatment	Soil total Zn(mg/kg)	
	Wheat	*Corn*
CK	81.67 d	84.25 c
CM1	80.13 d	84.46 c
CM2	80.83 d	87.78 abc
CM3	84.08 cd	88.39 abc
CM4	87.65 bc	86.31 bc
CM5	91.11 ab	92.71 ab
CM6	95.06 a	94.77 a

Table 5 showed effect of chicken manure application on soil total Zn content. The soil total Zn content increased with increasing chicken manure application. The soil Zn content could be maintained by the combined application of chicken manure at low rate (15 t/hm^2) and chemical fertilizer in the wheat season. Compared with CK, for the CM4, CM5 and CM6 treatments, soil total Zn content significantly increased at wheat harvest period. The soil total Zn contents were increased 11.99%, 12.46% and 19.10%, respectively. For CM5 and CM6 treatment, soil total Zn content significantly increased at corn harvest period. The soil total Zn contents were increased 10.04% and 12.49%, respectively. According to the 400 mg/kg of Zn maximum limit standard of mature compost in German[15], the total Zn content in chicken manure used in experiment was less than the required standards. In this cropping system of wheat and corn, organic fertilizer applied only once and at high rate before sowing wheat, soil Zn content could reach a maximum of 95.06 mg/kg. The survey showed that Zn content in farm manure of Baoding suburb in Hebei province was 577.82 mg/kg [9]. A large amount of this organic fertilizer application for a long time would lead to the soil Zn accumulation.

2.4 Soil Available Zn

Table 6. Effect of Chicken Manure Application on Soil Available Zn Content

Treatment	Soil available Zn(mg/kg)	
	Wheat	*Corn*
CK	1.58 c	1.48 c
CM1	1.48 c	1.55 c
CM2	1.67 c	1.99 bc
CM3	1.99 bc	1.89 bc
CM4	2.16 bc	2.05 bc
CM5	2.71 b	2.62 b
CM6	4.13 a	4.11 a

DTPA-extractable Zn is closely related to Zn uptake by plants from the soil. DTPA-extractable Zn is one of the important indices showing plant available Zn in the soil. In the experiment application of organic fertilizer had a significant effect on soil available Zn content(Table 6). Soil available Zn content increased remarkably with increasing of chicken manure application. Combined application of a low volume of chicken manure (15 t/hm^2) and a certain amount of chemical fertilizer could basically keep the surface soil available Zn content equivalent with separately application of chemical fertilizer. In the wheat harvest period, compared with CK(no chicken manure), soil available Zn content of CM5 and CM6 increased significantly by 71.4% and 161.3%, respectively. In the corn harvest period, soil available Zn content significantly increased with increasing application rate of chicken manure. Compared with CK，soil available Zn content of CM5 and CM6 increased by 77.02% and 177.7%, respectively. This showed that the manure of livestock and poultry had become important sources of Zn in soil. With reference to the soil available Zn evaluation index of Hebei province [16], when organic fertilizer application amount were 60 t/hm^2, 90 t/hm^2 and 150 t/hm^2, soil available Zn content were higher than 2 mg/kg. The soil available Zn content was very high level. Chicken manure application in large quantities played the very vital role on increasing soil Zn supply capacity.

3 Conclusion

The soil organic matter, total N, total P, total Zn and NO3$^-$-N, available P and available Zn contents significantly increased with the increasing rates of the chicken manure. The soil N, P and Zn supply could be maintained by the combined application of the low chicken manure rate (15 t/hm^2) and chemical fertilizer in the wheat season. Compared with CK of no chicken manure, the contents of soil NO_3^--N, available P and available Zn were increased when the rate of chicken manure were 90 t/hm^2 and 150 t/hm^2, respectively. After one cycle of wheat-corn rotation, compared with CK, when the chicken manures application at a rate of 90 t/hm^2, soil NO_3^--N, available P and available Zn content

were increased by 68.29%, 91.37% and 77.02%, respectively. when the chicken manures application rate of 150 t/hm^2, soil NO_3^--N, available P and available Zn content were increased by 69.58%, 133.16% and 177.7%, respectively. Appropriate application rate of chicken manure increased significantly the yield of wheat. But the yield of corn was not obvious different.

ACKNOWLEDGMENT

A funding program supported by National Key Technology R&D Program during the 12th Five-Year Plan Period(2012BAD15B02), and Agro-scientific Research Special Fund of Ministry of Agriculture (200903015).

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