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Effect of corn straw manure as dairy manure on productivity and profitability of wheat at Huang-Huai-Hai plain

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Abstract

Aim: The study aimed to assess the effect of corn straw as dairy manure on productivity and profitability of wheat and then set up fertilization scheme of wheat-corn cropping system.

Methodology: Fourteen treatments of N, P₂O₅ and K₂O fertilizer was carried out in the field, where corn was used as silage corn, and dairy manure was returned to customary field. Yield, wheat price, fertilizer cost and incidental expense were investigated. The relationship between the amount of fertilizer and wheat yield was studied. The most economical fertilizer plan was made according to marginal effect.

Results: The result showed that dairy manure with N, P₂O₅ and K₂O influenced the wheat yield components. Significant difference existed among treatments ($P < 0.01$). Application of corn straw manure increased yield to 3108~5747.55 kg hm⁻² which was 163.91~231.78% higher over no fertilizer treatments. The most economical schemes based on dairy manure and straw directly returning to field were studied.

Interpretation: Corn straw as dairy manure can reduce the amount of fertilizer, improve wheat yield and also achieve significant economic benefits.

Key Words : Corn silage, Huang-Huai-Hai plain, Optimized fertilization, Wheat-corn cropping system

Effect of dairy manure on productivity and profitability of wheat

N, P₂O₅ and K₂O fertilizer test on wheat with dairy manure

Assessment yield, wheat price, fertilizer cost and incidental expense

Statistical analysis and marginal effect analysis

The most economical fertilizer plan

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Introduction

Huang-Huai-Hai plain, also known as North China plain is China's largest landscape unit located between 113°E to east coastline, and between 32°00'2" N to 40°30'2" N. It's administrative scope mainly involves 5 provinces (Hebei, Henan, Shandong, Anhui and Jiangsu) and 2 cities (Beijing and Tianjin), and also there are 311 county units (Shuman *et al.*, 2014; Azizan *et al.*, 2017). Huang-Huai-Hai plain is China's major grain producing area. Wheat-corn is the most important cropping system at Huang-Huai-Hai plain. This plain produces about 70% of wheat, and 30% corn in China, which produces 0.8855×10^8 tons wheat straw and 1.1505×10^8 tons corn straw (National Bureau of Statistic of China, 2011; Abd Samad *et al.*, 2017; Ayaz *et al.*, 2018).

Straw is agricultural waste and was used in place firewood in the past. With the emergence of new energy, straw is being piled up and even set on fire leading to serious environmental pollution (Feiyue and Jianfei, 2013; Wei *et al.*, 2011; Hong *et al.*, 2008; Lu *et al.*, 2018). China's Eleventh Five Plan introduced circular agriculture monographic study, and the achievement of the study diversified ways to deal with straw such as directly returning to field, using as edible matrix, silage and pellet fuel, etc. Agricultural industry chain extended with higher output (Kejun *et al.*, 2012; Zhigang *et al.*, 2010; Guoqin, 1997; Qiang *et al.*, 2011). And agricultural environmental pollution improved. Nutrient released and soil microbial biomass was increased as crop straws manure. (Xuecai *et al.*, 2004; Sihai *et al.*, 2011; Ismail and Hanafiah, 2017; Gu and Zhang, 2018).

At the same time, in order to improve resident's quality of life, Premier Wen Jiabao proposed "to carry out milk industry revitalization plan". Corn straw silage effectively alleviated the contradiction between grain and feed (Lizhen *et al.*, 2006; Hassan *et al.*, 2017). Corn straw manure can improve soil structure and nutrient content (Xiaobin *et al.*, 2000; Halim *et al.*, 2017; Kassim, *et al.*, 2018). In dairy farming areas, farmer can gain free manure after selling corn straw as silage. In view of the above, this study aimed to set up fertilization scheme of wheat-corn cropping system, where corn was used as silage corn, and the dairy manure was returned to customary field.

Materials and Methods

Study area: This study was carried out at Dezhou City, Shandong Province, Zhanghua Town. The soil of study area is sandy loam, with organic matter 16.2 g kg^{-1} alkali solution nitrogen 56.6 mg kg^{-1} available phosphorus 29.4 mg kg^{-1} and available potassium 55.3 mg kg^{-1} . Wheat Jimai 22 was used in the test. Urea (46-0-0), superphosphate (0-12-0) and potassium sulphate (0-0-51) were used as N, P_2O_5 , and K_2O supplement.

Experimental set up: The study used "3414" field trial design,

which involved N, P_2O_5 , K_2O 3 factors, each factor concerned 4 levels, and there were altogether 14 treatments. As shown in Table 1, the 4 levels contented 0 level, 1 level, 2 level and 3 level. 0 level represented not using fertilizer. 2 level represented the optimum fertilizer. 1 level represented half of the optimum fertilizer. 3 level represented 1.5 times as the optimum fertilizer. The 14 treatments were $\text{N}_0\text{P}_0\text{K}_0$, $\text{N}_0\text{P}_2\text{K}_2$, $\text{N}_1\text{P}_2\text{K}_2$, $\text{N}_2\text{P}_0\text{K}_2$, $\text{N}_2\text{P}_1\text{K}_2$, $\text{N}_2\text{P}_2\text{K}_2$, $\text{N}_2\text{P}_3\text{K}_2$, $\text{N}_2\text{P}_2\text{K}_0$, $\text{N}_2\text{P}_2\text{K}_1$, $\text{N}_2\text{P}_2\text{K}_3$, $\text{N}_3\text{P}_2\text{K}_2$, $\text{N}_1\text{P}_1\text{K}_2$, $\text{N}_1\text{P}_2\text{K}_1$, $\text{N}_2\text{P}_1\text{K}_1$, which were shown in Table 2. The study had three repeats and random permutation. Wheat was sown by combined seeder. The seeder was set to seeding rate of $25 \text{ kg } 667\text{m}^2$, row spacing 22-25 cm, and sowing depth 3-5 cm. Fertilizers were mixed and loaded on the seeder. Fertilizers were buried underneath wheat seeds. Urea was applied in half amount while seeding and the rest when dressing. The whole calcium superphosphate and potassium sulfate was all used when seeding. The seeder had compacting device. There were 4 irrigations: after seeding, before over winter, jointing, and flowering with amount of irrigation water were $600 \text{ m}^3 \text{ hm}^{-2}$, $600 \text{ m}^3 \text{ hm}^{-2}$, $900 \text{ m}^3 \text{ hm}^{-2}$, $900 \text{ m}^3 \text{ hm}^{-2}$. Except for fertilizer application, standard agronomic practices were followed for all other field activities.

Dairy manure was provided by Wang Xiang Dairy Farming Cooperative. There will be 45m^3 dairy manure when one-hectare corn straw being used as silage. The study took all 45 m^3 dairy manure as base fertilizer and researched on the best manure amount, rate of N, P_2O_5 and K_2O . Chemical analysis was carried out, N, P_2O_5 and K_2O weigh 48 kg, 37.5 kg and 24 kg for 45m^3 separately (Shidan, B., *et al.*, 2000; Rehman *et al.*, 2017). Based on the level of "the fertilizer effect test of returning straw back to field directly" (Xiaodong, *et al.*, 2016; Chuanlei *et al.*, 2018), this test set 3 nutrient elements' levels as deducting the amount of dairy manure providing for the field. At corn harvest, yield monitor was taken by 5-point sampling method with each point 1 m^2 . The main indexes included ear number per unit, grain number per ear, and then calculated yield with those indexes (Weixing *et al.*, 2011; Fahim and Sathi, 2018).

Related data calculation method: Wheat price was 2.52 RMB kg^{-1} . N price was 3.61 RMB kg^{-1} . P_2O_5 price was 5.25 RMB kg^{-1} . K_2O price was 4.35 RMB kg^{-1} . Incidental expense was 1740 RMB hm^{-2} . The average of three repeats in two years' was calculated as treatment result. Incidental expense included the cost on agricultural machinery, pesticides and irrigation.

$$\text{Wheat output value} = \text{Wheat yield} \times \text{Unit price.}$$

$$\text{Net profit} = \text{Output value} - \text{Fertilizer cost} - \text{Incidental expenses.}$$

Results and Discussion

As shown in Table 3, N, P_2O_5 and K_2O treatment under corn manure affected ear number per hectare and grain number per ear and yield. The different between treatments were

Table 1: Factors and levels of fertilizer test for wheat with dairy manure

Factor	Level	0 (kg hm ⁻²)	1 (kg hm ⁻²)	2 (kg hm ⁻²)	3 (kg hm ⁻²)
N	0		55.5	157.5	261
P ₂ O ₅	0		24	87	148.5
K ₂ O	0		43.5	111	180

Table 2: Fertilizer test's Treatments for Wheat with dairy manure

No.	Treatment	N Level	P ₂ O ₅ Level	K ₂ O Level
T1	N ₀ P ₀ K ₀	0	0	0
T2	N ₀ P ₂ K ₂	0	2	2
T3	N ₁ P ₂ K ₂	1	2	2
T4	N ₂ P ₀ K ₂	2	0	2
T5	N ₂ P ₁ K ₂	2	1	2
T6	N ₂ P ₂ K ₂	2	2	2
T7	N ₂ P ₃ K ₂	2	3	2
T8	N ₂ P ₂ K ₀	2	2	0
T9	N ₂ P ₂ K ₁	2	2	1
T10	N ₂ P ₂ K ₃	2	2	3
T11	N ₃ P ₂ K ₂	3	2	2
T12	N ₁ P ₁ K ₂	1	1	2
T13	N ₁ P ₂ K ₁	1	2	1
T14	N ₂ P ₁ K ₁	2	1	1

Table 3: Effect of treatments on yield attributes, yield and economics of wheat

No.	Treatment	Ear number per unit (10 ⁴ hm ⁻²)	Grain number per ear	Yield (kg hm ⁻²)	Yield grow amount (kg hm ⁻²)	Yield grow rate (%)	Output value (RMB hm ⁻²)	Net income (RMB hm ⁻²)
T1	N ₀ P ₀ K ₀	498.69	J	13.93	G	2480.00	F	-
T2	N ₀ P ₂ K ₂	540.03	I	34.23	CD	6599.83	E	4119.30
T3	N ₁ P ₂ K ₂	558.69	H	38.17	A	7612.49	BC	5131.95
T4	N ₂ P ₀ K ₂	576.70	G	36.55	B	7524.92	C	5044.35
T5	N ₂ P ₁ K ₂	566.70	GH	36.95	AB	7475.36	C	4994.85
T6	N ₂ P ₂ K ₂	649.37	BC	28.97	F	6715.16	DE	4234.65
T7	N ₂ P ₃ K ₂	597.36	F	36.35	B	7751.95	BC	5271.45
T8	N ₂ P ₂ K ₀	554.69	H	35.40	BC	7010.12	D	4529.55
T9	N ₂ P ₂ K ₁	646.03	C	33.60	D	7749.29	BC	5268.75
T10	N ₂ P ₂ K ₃	689.37	A	33.43	D	8228.09	A	5747.55
T11	N ₃ P ₂ K ₂	619.36	DE	31.00	E	6854.50	DE	4374.00
T12	N ₁ P ₁ K ₂	614.03	E	35.77	BC	7840.37	BC	5359.80
T13	N ₁ P ₂ K ₁	661.37	B	33.77	D	7972.57	AB	5491.95
T14	N ₂ P ₁ K ₁	630.00	D	29.10	F	6544.88	E	3108.90

Remark: A, B, C, D, E, F, G, H, I were the results of one-way Anova, which were very significant difference ($P < 0.01$)

significant. The ear number per hectare, grain number per ear and yield was lowest in N₀P₀K₀ treatment. The ear number per hectare and the yield were highest with N₂P₂K₃. The grain number per ear was highest in case of N₁P₂K₂ treatment. Application of corn manure along with additional fertilizer resulted 3108~5747.55 kg hm⁻² wheat yield which was higher than sole corn manure application. Compared with N₀P₀K₀ treatment, yield increasing rate reached within the range of 163.91%~231.78%. All the

treatments input and output were calculated, the net profit for the treatment N₁P₂K₁ was highest.

The relationship between wheat yield and the amount of nitrogen, phosphorus and potassium was significant. Linear model, exponential model and one-place quadratic model were set up between applied nutrients (N, P₂O₅ and K₂O) and yield obtained. Among the three kinds of models, one-place quadratic

Fig. 1 : Yield quadratic regression model with (A) N; (B) P₂O₅ and (C) K₂O.

model is the best one. The best models are shown in Table 4. As shown in Fig.1 to Fig.3, wheat yield grows at first and then gets down with the increasing amount of nutrients which fits the law of diminishing returns.

and K₂O, the ternary quadratic regression models of wheat yield and three kinds of fertilizer were also set up. Which was used SPSS (Statistic Package for Social Science) regression analysis function.

In order to consider interactive effects among N, P₂O₅,

$$Y = 2507.79 - 69.99N - 15.26N^2 + 1034.95 (P_2O_5) + 4.69$$

Table 4: Wheat yield regression models with N, P₂O₅ and K₂O

Independent variable	Model type	Models	Goodness of Fit R ²
N	linear model	$y = 141.68x + 5788.6$	0.1875
	exponential model	$y = 5147.6e^{0.0325x}$	0.2277
	one-place quadratic model	$y = -32.48x^2 + 591.24x + 4893.4$	0.4233 ^{***}
P ₂ O ₅	linear model	$y = 313.82x + 5527.4$	0.2807 [*]
	exponential model	$y = 4950.7e^{0.0674x}$	0.2988 [*]
	one-place quadratic model	$y = -45.193x^2 + 659.34x + 5147.3$	0.3232 [*]
K ₂ O	linear model	$y = 277.49x + 5344.1$	0.3573 [*]
	exponential model	$y = 4829.6e^{0.0571x}$	0.3490 [*]
	one-place quadratic model	$y = -24.884x^2 + 520.22x + 5003.4$	0.3914 ^{***}

Remark: ^{*} showed the difference was significant ($p < 0.05$), and ^{***} showed the difference was extremely significant ($p < 0.01$)

Table 5: A comparison between the highest wheat yield fertilizer program and the most economical fertilizer program

Fertilizer program	N (kg hm ⁻²)	P ₂ O ₅ (kg hm ⁻²)	K ₂ O (kg hm ⁻²)	Yield (kg hm ⁻²)	Output value (RMB hm ⁻²)	Net profit (RMB hm ⁻²)
The highest yield fertilizer program	121.24	88.92	110.38	7659.28	19301.39	9902.11
The most economical fertilizer program	102.59	82.77	105.43	7635.24	19240.80	9865.56
The difference value	-18.65	-6.15	-4.95	-24.04	-60.58	490.92

Remark: The difference value = The most economical fertilizer program - The highest yield fertilizer program

Table 6: A comparison of the most economical fertilizer on wheat between corn straw directly to field and straw dairy manure

Pattern	The most economical fertilizer program		
	N (kg hm ⁻²)	P ₂ O ₅ (kg hm ⁻²)	K ₂ O (kg hm ⁻²)
Corn straw being directly returned to field (Xiaodong, et al., 2016)	210.00	120.00	135.00
Corn straw dairy manure	102.59	82.77	105.43
The difference value of the two patterns	-107.41	-37.23	-29.57
The proportion of the difference value to the pattern corn straw being directly returned to field	-51.15	-31.03	-21.90
The providing fertilizer amount of corn straw dairy manure	48	37.5	24

Remark: The difference value of the two patterns = the most economical fertilizer program of corn straw being directly returned to field - The highest yield fertilizer program of corn straw dairy manure; The proportion of the difference value to the pattern corn straw being directly returned to field = The difference value of the two patterns / Corn straw being directly returned to field

$$(P_2O_5)^2 + 643.32 (K_2O) + 6.20 (K_2O)^2 + 15.65N (P_2O_5) + 30.42N (K_2O) - 165.40 (P_2O_5) (K_2O) \quad (n=9, R^2=0.96^{**})$$

Based on the model, when marginal revenue and N, P₂O₅ and K₂O were zero, highest yield of wheat was obtained. Highest yield of wheat (7659.28 kg hm⁻²) was obtained when 121.24 kg hm⁻² N, 88.92 kg hm⁻² P₂O₅, and 110.38 kg hm⁻² K₂O was used.

Based on the model, the optimum economic fertilization for wheat was obtained when marginal revenue of fertilization cost equal to the output value. The economic optimal rates of nitrogen, phosphorus and potassium fertilization is 102.59, 82.77 and 105.43 kg hm⁻², respectively, which leads to a significant

increase in grain yield. Compare to the fertilization program of highest yield, the optimum economic fertilization program can save 18.65 kg hm⁻² N, 6.15 kg hm⁻² P₂O₅ and 4.95 kg hm⁻² K, respectively, when wheat grain yield reduced 60.58 kg hm⁻². While the net profit increased 490.92 RMB hm⁻² (table 5).

The most optimum economic nitrogen, phosphorus and potassium fertilization with retention of corn straw was lower than that those values under direct residues retention (table 5). Nitrogen, phosphorus and potassium fertilization decreased by 51.15, 31.03 and 29.57%, respectively. Specifically, the reduction of nitrogen (107.41 kg hm⁻²) is much higher than that value with addition of cow dung (48 kg hm⁻²), followed by potassium, and phosphorus had insignificant change.

Wheat fertilizer can save consumption under the condition of corn straw being returned back to field by dairy manure as organic fertilizer, which experienced composting fermentation, then that under corn straw being returned back to field directly. The saved consumption contains 107.41 kg hm⁻² N, 37.23 kg hm⁻² P₂O₅, 29.57 kg hm⁻² K₂O. Corn straw being returned back to field by dairy manure *in situ* field can provide 48 kg hm⁻² N, 37.5 kg hm⁻² P₂O₅, and 24 kg hm⁻² K₂O. In addition to the amount dairy manure providing fertilizer, corn straw being returned back to field by dairy manure can save 59.41 kg hm⁻² N, 5.57 kg hm⁻² K₂O. The efficiency of dairy manure is much higher than that of chemical fertilizer. Nitrogen is required by both corn straw decomposition and wheat growth. There is a huge competition (Cuiping *et al.*, 2011; Hanafiah *et al.*, 2017). Dairy manure can provide wheat growth with nitrogen directly and promote the transformation of potassium forms in fertilizers and soils. This is consistent with Zhang Ming's research results, that is, dairy manure combined with chemical fertilizer can significantly improve the utilization rate of nitrogen and potassium fertilizer, but the improvement effect of phosphorus fertilizer utilization rate is not significant. (Ming *et al.*, 2014; Elsayed, 2017; Biswas, 2018).

The study recommends the most economical wheat fertilizer; 102.59 kg hm⁻² N, 82.77 kg hm⁻² P₂O₅, and 105.43 kg hm⁻² K₂O in the field when corn straw is returned back by dairy manure *in situ*. Breaking straw costs a lot of fuel power when returned back to field directly. In order to reduce the cost, a large number of agricultural machinery drivers couldn't break straw fully with low fragmentation degree, which influenced wheat sowing and emergence (Shaokun *et al.*, 2006). While the commercial organic fertilizer by dairy manure can improve soil structure and supply wheat with nutrients, with no influence on wheat sowing and emergence.

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