Introduction

Many results showed that the use efficiency of fertilizer N is around 20% to 30%. On the other hand fertilizer N losses have made a big problem on environment (Bian Xiuju et al., 1997; Zhu Zhaoliang et al., 1992). So it is very important to solve the two problems. Black soil is one of the most fertile soils in China and the black soil region is the state base of grain production. However the use efficiency of fertilizer N was decreased gradually during the grain production. One of the main reasons for the decrease is the climatic factor and improper employment of fertilizer (Jin Xiang et al., 1999), and the other one is the getting worse physicochemical properties of the soil, which resulted in a low capacity of keeping and supplying N. There are several methods for improving the use efficiency of fertilizer N including the use of technique of coating and the affixation of urease depressor and nitrification inhibitor as well as the improvements of soil management (Wiesler F. 1998). This study was conducted on a ten-year long site-specific experiment in which different soil managements were covered. The change of capacity for keeping and supplying N under different soil managements was evaluated using ^{15}N method in order to find theoretical basis for soil management and new path for improving the use efficiency of N.

Material and methods

Field site description

The field site was located in the Hailun Experimental Station, Chinese Academy of Sciences, the central area of the black soil region in northeast China (47°26′N, 126°38′E). weather conditions are as follows: yearly averaged temperature 1.5℃, accumulated temperature ≥ 10℃2400℃, annually precipitation 550mm, and 120 days without frost. The crops were grown one season per year without irrigation. Test field is flat with following basic fertility: organic C: 26.6g/kg, total N: 2.3 g/kg, total P: 0.7 g/kg, total K: 22.1 g/kg, available nitrogen: 227.0 mg/kg, available phosphorus: 19.5mg/kg, available potassium: 200.1 mg/kg.

Patterns for soil management

Pattern Ⅰ A pattern followed the farmer's custom adopted here as the control of Pattern Ⅱ and Pattern Ⅲ, Crops used in this experiment were wheat (*Triticum aestivum* L.cv.Long 4083), corn (*Zea mays* L. cv. Haiyu 6) and soybean (Glycine max (Merr.) L.cv.Heinong 35) in rotation (see Table 1).

Pattern Ⅱ A soil *management* pattern using chemical fertilizer plus organic amendments, wheat, corn and soybean in rotation.

Pattern Ⅲ A pattern adopting inter-cropping corn and sweet clover, in which the sweet clover were used to feed ox and the cow dung were return to the field. Wheat, corn & sweet clover (2:1) and soybean in rotation.

Table 1 Rate of fertilizer under different soil management

Crops	Pattern Ⅰ		Pattern Ⅱ			Pattern Ⅲ		
	N	P	N	P	Rotted manure	N	P	Rotted manure
	Kg hm^{-2}							
Wheat	48	21.0	69	30.1		48	21.0	
Corn	96	15.1	138	30.1	15000	96	15.1	30000
Soybean	13.5	15.1	20	22.6		13.5	15.1	

Experimental design

On the soil where 12 years long-term experiment has been conducted with the three patterns of soil management listed in 1.2 above, the fates of nitrogen experiment being carried out. The area of micro-plot is $1m^2$, the depth of the soil sample in original state is 1m, the soil sample was wrapped with a water proof fiber cloth, allowing the water moved only in vertical direction, the urea with ^{15}N used in this experiment was produced by Shang Hai design institute of chemical industry with 12% abundance. The experiment was designed in random arrangement with four replicates (Table 2).

Table 2 Treatments with ^{15}N in field micro plots

Treatment	Wheat		Corn		Sweet clover		Soybean	
	^{15}N	P	^{15}N	P	^{15}N	P	^{15}N	P
	g m^{-2}							
Pattern Ⅰ	6.9	2.0	13.8	3.0	13.8	3.0	2.0	2.3
Pattern Ⅱ	6.9	2.0	13.8	3.0	13.8	3.0	2.0	2.3
Pattern Ⅲ	6.9	2.0	13.8	3.0	13.8	3.0	2.0	2.3

Result and analysis

Impact on the fates of fertilizer Nitrogen of different soil managements on black soil farmland under wheat

In black soil area, wheat is grown in the spring as the spring wheat. It is grown in April when soil temperature rise to 0 -1℃ with about a 5cm soil thawing layer, fertilizer were applied as seed manure, crop were harvest in August. The results were showed in Table 3 and Figure 1

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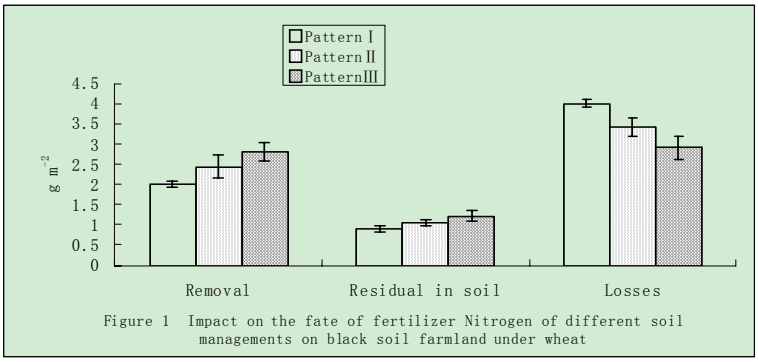

Figure 1 Impact on the fate of fertilizer Nitrogen of different soil managements on black soil farmland under wheat

Table 3 Soil Nitrogen removals of wheat, corn and soybean

	Pattern Ⅰ	Pattern Ⅱ	Pattern Ⅲ
		g m^{-2}	
Wheat removal	6.761	6.969	7.102
Corn removal	9.539	9.985	9.912
Soybean removal	13.453	16.583**	18.146**

From Figure 1, we can see that there were no significant difference between the three management patterns in soil N removal, which means either the farmer's pattern or the improved pattern can not change the wheat removal of soil N. while the removal of chemical fertilizer differed significantly. The use efficiency of fertilizer N in pattern Ⅰ was 29.23%, which was 6 percentage lower than that in pattern Ⅱ, while 11.2 percentage higher in pattern Ⅲ than that in pattern Ⅰ, suggesting that yield increase come from fertilizer N. the residual rate of fertilizer was 12.84% in pattern Ⅰ, while 2.44 and 4.67 percentage higher in pattern Ⅱ and pattern Ⅲ than in pattern Ⅰ respectively. The loss rates of fertilizer in the three patterns were 57.93%, 49.49% and 42.07% respectively. From the analysis of the results above, we can see that farmer's pattern in which chemical fertilizer applied only can not improved the capacity of the soil in keeping and supplying N, while the combination use of chemical and organic fertilizer can improve the basic soil fertility. In addition to the advantage of the combination, intercropping corn and sweet clover can improve the condition for good aeration and illumination and have a harvest of sweet clover to feed cow on the basis of not decreasing the yield of corn. And the cow dung can be return to the field to improve the physicochemical properties and increase the content of the soil organic matter.

Impact on the fates of fertilizer Nitrogen of different soil managements on black soil farmland under corn

In black soil area, the corn is grown in the spring as the spring corn. It is grown in the end of April and harvested in September. One third of fertilizer N were applied as seed manure, two third were applied as dressing at jointing stage. The results of ^{15}N application were showed in Table 3 and Figure 2.

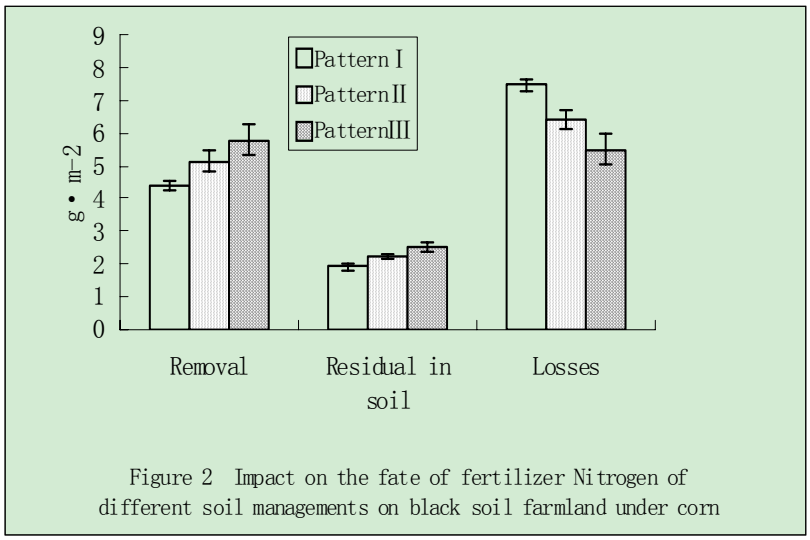

Figure 2 Impact on the fate of fertilizer Nitrogen of different soil managements on black soil farmland under corn

Under the pattern Ⅰ management, soil N removal by corn was less, for the low level of N in the pattern Ⅰ management interfere the growth of plant, resulted in the low absorptivity (Table 3). There were no significant differences on the soil N removal between pattern Ⅱ and pattern Ⅲ, that probably because of the equal effect of high level chemical fertilizer plus organic fertilizer in pattern Ⅱ and low level of chemical fertilizer plus sweet clover in pattern Ⅲ. However there was a significant difference in the removal of chemical fertilizer N among different patterns of managements, the chemical N use ratio was 32.01%, while they were 5.21 and 9.97 percentage higher in pattern Ⅱ and pattern Ⅲ respectively. The loss ratio was 54.19%, 46.61% and 39.94% in pattern Ⅰ, Ⅱ and Ⅲ respectively. The order of the loss ratio of chemical fertilizer N was pattern Ⅰ > pattern Ⅱ > pattern Ⅲ. The residual N in pattern Ⅰ was 13.80% , they were 2.37 and 4.28 percentages higher in pattern Ⅱ and pattern Ⅲ respectively (Figure 2).

Impact on the fates of fertilizer Nitrogen of different soil managements on black soil farmland under soybean

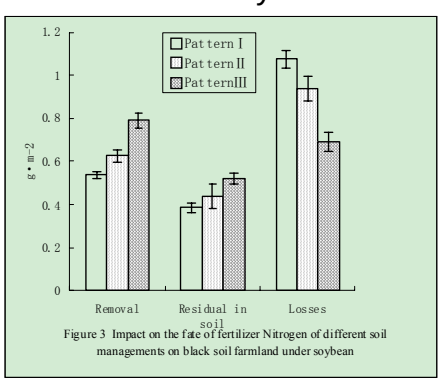

Figure 3 Impact on the fate of fertilizer Nitrogen of different soil managements on black soil farmland under soybean

Soybean as one crop that can fertilizing the soil have the effect of symbiotic fixation, need relatively less chemical fertilizer N. however the use efficiency of chemical N were different

among the different management patterns. The highest is 39.55% in patternⅢ; the lowest is 26.85% in pattern Ⅰ, pattern Ⅱ, 31.25%. The order of N use efficiency of soybean was pattern Ⅲ>pattern Ⅱ>pattern Ⅰ.

Impact on the fates of fertilizer Nitrogen of different crops under the same management patterns

The properties of the soil can influence the adsorption, desorption, fixation and release of chemical fertilizer N. Besides, the soil organic matter and hydrothermal factors affect the nitrification and denitrification come from the activity of microorganism. All the processes jointly controlled the transformation of chemical fertilizer N and its loss ratio, residual ratio and use ratio. In the soil-crop system, biological properties (e.g. symbiotic fixation of soybean) of the crops can also affect the fates of the chemical fertilizer N, such as the time and the strength of peak adsorption by crops, the morphological structure and the development state and so on. Under the farmer's farming, fertilization and rotation conditions (pattern Ⅰ), the use efficiency of chemical fertilizer N of wheat, corn and soybean were 29.93%, 32.01and 26.85% respectively with the order of corn>wheat>soybean (Figure 4).

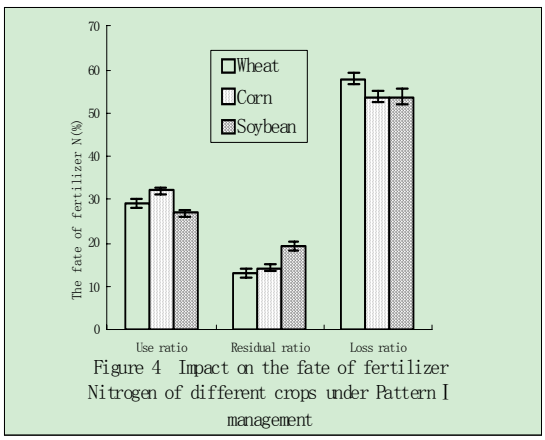

Figure 4 Impact on the fate of fertilizer Nitrogen of different crops under Pattern Ⅰ management

Under the management of chemical fertilizer plus organic manure (Pattern Ⅱ), the use efficiency of chemical fertilizer N of wheat, corn and soybean were 35.23%, 37.22% and 31.25% respectively with the same order as in pattern Ⅰ (Figure 5). Under the management of intercrop of corn and sweet clover in which the sweet clover were returned to the field (Pattern Ⅲ), the use efficiency of chemical fertilizer N of wheat, corn and soybean were 40.42%, 41.98% and 39.55% respectively with no significant difference, indication that a favorable soil management can improve the use efficiency of chemical fertilizer (Figure 6).

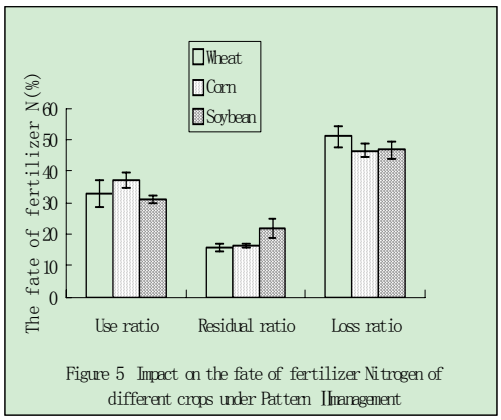

Figure 5 Impact on the fate of fertilizer Nitrogen of different crops under Pattern Ⅱmanagement

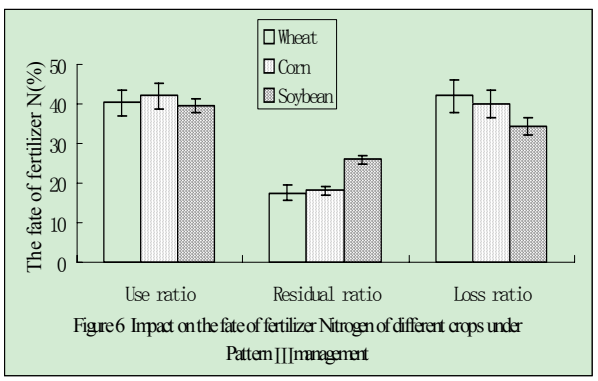

Figure 6 Impact on the fate of fertilizer Nitrogen of different crops under Pattern ⅢⅢmanagement

Conclusion

In the black soil region, the use efficiency was very low under the farmer's management pattern. The use efficiency can be improved through changing the farming method (Pattern Ⅱ) by changing the physicochemical characters of the soil to increase the adsorption quantity of organic acid produced in the transformation process of organic manure. And the advanced management (Pattern ⅢⅢ) can further improve the use efficiency through the ecological effect of intercropping of corn and pasture, which even up the difference in use efficiency (Li Huixin et al., 2002). The experiment testified that improving the soil management pattern to enhance the capacity of keeping and supplying the N is an effective way for improving the use efficacy of Nitrogen.

Acknowledgement

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