

## CUMULATIVE EFFECTS OF DIFFERENT CULTIVATING PATTERNS ON PROPERTIES OF ALBIC SOIL IN SANJIANG PLAIN

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**ABSTRACT:** This paper studied the cumulative effects of different cultivating patterns on the properties of albic soils in the Sanjiang Plain using correlation analysis. The results showed that the physical and chemical properties of the albic soil changed greatly when it was cultivated as farmland. As for physical properties of the soil, bulk density and specific gravity increased gradually, the porosity and field capacity decreased gradually year by year, but they increased after being abandoned. As for chemical properties, pH increased, organic matter and other nutrients decreased with increasing of the cultivating years. For the albic soil cultivated with forage, the cumulative effects were apparently strengthened with the increase of cultivating years, especially for the bulk density, total porosity, capillary porosity and capillary moisture capacity. Moreover, fertilization also had great effects on the albic soil. Applying magnetism fertilizer improved the physical properties such as bulk density, soil moisture and porosity, raised the utilization rate of nitrogen and phosphorus fertilizer. Compared with nutrient fertilizer, utilization of the magnetism fertilizer made production increase by 5.9%- 13.9%. At the same time, using organic material and loosening the albic layer could improve not only the physical, chemical and biological properties of the cultivating layer, but also the ill properties of the albic layer, thus making organic carbon and heavy fraction carbon contents increase, and biological activity increase obviously.

**KEY WORDS:** cultivating pattern; albic soil; soil property; Sanjiang Plain

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### 1 INTRODUCTION

Albic soil is one of the main soils with low yield in the Sanjiang Plain, with an area of  $200 \times 10^3$  ha, accounting for 19% of the total area, among which  $88.4 \times 10^3$  ha is farmland, being 25.4% of the total area of farmland in this region. The albic soil occupies 44% of total area of farmland in the state-owned farms of Heilongjiang Province. There are two reasons for the low yield of albic soil. Firstly, the upper layer of the soil is thin, only 10-20cm for low yield field and 20-25cm for middle yield field, thus making soil nutrients and moisture content be low. Secondly, there is an albic layer that is compact and impermeable below surface layer of the soil, which is off-white, close and unstructured. These reasons make the albic soil with low water conservating ability and poor physical and chemical properties, therefore, the

soil can resist neither drought nor waterlogging. And waterlogging occurred more frequently on the soil because of its viscous and heavy texture. Consequently, the study on albic soil has become a hot topic of soil study (DING, 1994; DING et al. 1992; GUAN and WU, 1992; XIA and GAO, 1992; YU et al., 1992; SHI et al., 1994; ZHAO et al., 1994; LIANG, 1997; MAO et al., 1996; WU et al., 1997; WANG et al., 1997; WU and GAO, 2001; TIAN and LI, 2003; HE et al., 2004). However, after cultivation for a long time, the utilization and protection of albic soil was of imbalance. The cumulative effects of various kinds of land-use patterns made the fertility of the soil decrease obviously. Therefore, it is necessary to study the cumulative effects of different land-use patterns on the albic soil, which could provide scientific basis for using albic soil reasonably.

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## 2 STUDY AREA

The study area is located in the Sanjiang Wetland Ecology Experiment Station (133°31' E, 47°35' N), Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, in Tongjiang City of Heilongjiang Province, being the north border of China. It is the only field station for studying wetland ecology and reasonable use of agriculture in China. The study region is the terrestrial monsoon climate, the average annual temperature is 1.9 °C, the average temperature of January is -21 °C, and the average temperature of July is 22 °C. The annual precipitation is about 600mm, which is mainly concentrated in the period of July- September. The main plants include *Carex lasiocarpa*, *Carex pseudocurica*, *Carex meyeriana*, and *Deyeuxia angustifolia*. The soils include gley albic soil and meadow albic soil. Some sampling sites were selected in the No. 850 farm of Heilongjiang Province.

## 3 MATERIAL AND METHODS

In the Sanjiang Wetland Ecology Experiment Station, we selected the farmlands that have been cultivated for 7a, 10a and 15a respectively as sampling sites, at the same time, we selected marsh-meadow and the abandoned farmland as references. Five soil samples were collected in each sampling site, and the sampling depth is 0-20cm. The collected samples were air-dried and sieved in laboratory for measuring.

Soil bulk density was measured with cutting ring method; organic matter, with the  $K_2Cr_2O_6$  heating method; total nitrogen, with Semi-micro Kjeldahl method; total phosphorus, with  $H_2SO_4-HClO_4$ -Mo-Sb-Vc-colorimetry; total potassium, with  $HF-HClO_4$ -Flare photometer; available nitrogen, with diffusion and alkaline hydrolysis; available phosphorus, with alkaline hydrolysis  $NaHCO_3$ -extraction-Mo-Sb-Vc-colorimetry; available potassium, with ammonium acetate extracts-Flare photometer; and pH, with potentiometer.

## 4 RESULTS AND ANALYSIS

### 4.1 Cumulative Effect of Reclamation on Albic Soil

#### 4.1.1 Physical property of soil

Great changes of physical properties of albic soil have taken place after wetlands were reclaimed to dry land (Table 1). The bulk density and specific gravity increased with the increase of the cultivating years. The bulk density of the natural meadow albic soil was  $0.70g/cm^3$  before reclamation, it increased to  $1.01g/cm^3$  after being cultivated for 7a,  $1.05g/cm^3$  after 10a,  $1.11g/cm^3$  after 15a, respectively, and the specific gravity was  $1.90g/cm^3$ ,  $2.31g/cm^3$ ,  $2.36g/cm^3$ ,  $2.47g/cm^3$  respectively. But porosity and field moisture capacity decreased gradually.

Table 1 Change in physical property of meadow albic soil (0-20cm) after being cultivated

Time	Bulk density ( $g/cm^3$ )	Specific gravity ( $g/cm^3$ )	Porosity (%)	Field capacity (%)
Before cultivation	0.70	1.90	74.40	64.50
7a after cultivation	1.01*	2.31*	65.10*	42.10*
10a after cultivation	1.05	2.36	62.30	40.50
15a after cultivation	1.11*	2.47*	59.80*	37.00*

\* Data from ZHANG and SONG, 2004

In the Sanjiang Plain, the original texture of wetland soil has changed due to continuous dry farmland cultivation, furthermore, the physical properties of the soil has changed owing to such farming methods as deep ploughing and weeding. Correlation analysis showed that bulk density and specific gravity were positively correlated with cultivating years, but porosity and field moisture capacity were negatively correlated with cultivating years (Table 2).

Table 2 Correlation of cultivating year and physical property of albic soil

	Bulk density	Specific gravity	Porosity	Field moisture capacity
Time	0.896	0.912	-0.943	-0.869

#### 4.1.2 Chemical property of soil

The cultivating mode of dry farmland had significant cumulative effects on chemical properties of soil. Great changes of pH, organic matter, total nutrients and available nutrients had taken place in the study area after cultivation (Table 3).

With the prolonging of cultivating time, pH had increased gradually. The pH of natural meadow albic soil was 5.65, but it became 5.92 after being cultivated for 15a, indicating that the soil tended to be neutral. Cultivation for some years changed the oxidation-deoxidation condition but pH decreased after being abandoned for 7 years. The soil organic matter content had changed greatly as a result of dry farmland cultivation, of which the order was soil being cultivated for 15a < soil being cultivated for 10a < soil being cultivated for 7a < soil being abandoned < natural meadow albic soil. The organic matter of natural meadow albic soil was as high as 139.4g/kg, it decreased 69.51% after being cultivated for 7a, 71.09% after 10a, 72.96% after 15a, however, it in-

Table 3 Change in chemical property of soil in different cultivation times

Time	pH (H <sub>2</sub> O)	OM (g/kg)	TN (g/kg)	TP (g/kg)	TK (g/kg)	AN (mg/kg)	AP (mg/kg)	AK (mg/kg)
Before cultivation	5.65	139.4	8.52	1.32	11.15	811.21	42.44	159.90
7a after cultivation	5.88*	42.5*	3.52*	0.98*	13.36*	358.70*	23.06*	90.86*
10a after cultivation	5.90	40.3	3.40	1.01	12.56	298.90	22.40	91.06
15a after cultivation	5.92*	37.7*	3.12*	1.04*	11.82*	200.28*	21.30*	91.35*
7a after being abandoned	5.91	57.7	3.84	1.10	11.68	479.89	24.43	132.46

\* Data from ZHANG and SONG, 2004

creased 53.13% after being abandoned for 7a compared with that after being cultivated for 15a. The reclamation of albic soil quickened the decomposition rate of organic matter, which made organic matter lose year after year. Abandoned farmland reduced the disturbance to albic soil, and the decomposition rate of organic matter was lowered, which introduced organic matter renewal to some extent.

The total nitrogen of soil decreased rapidly with the increase of cultivation time: it decreased by 58.59% after being cultivated for 7a, 60.09% after 10a, and 63.34% after 15a. The change of total phosphorus resembled with that of total nitrogen, but it changed little. It decreased by 25.50% after being cultivated for 7a, but increased little after 10a, which may be related to the application of chemical fertilizer. In the first several years of cultivation, the total potassium increased little, but decreased after being cultivated for 7a. After being abandoned, the total nitrogen and total phosphorus increased to some extent, but the total potassium tended to decrease.

With the increasing of cultivating years, the available nitrogen, phosphorus and potassium all decreased in the order: natural meadow albic soil > abandoned soil > soil being cultivated for 7a > soil being cultivated for 10a > soil being cultivated for 15a. Compared to natural meadow albic soil, the available nitrogen decreased by 55.78% after 7a, 63.15% after 10a, 75.31% after 15a; the available phosphorus decreased by 45.76%, 47.22%, 49.90% respectively; and the available potassium decreased by 43.71%, 43.05% and 42.87% respectively. The available nitrogen, available phosphorus and available potassium after being abandoned for 7a increased by 139.61%, 14.91% and 9.62% respectively compared to that after being cultivated for 15a.

With the increasing of cultivating years, the cumulative effect rates of dry land cultivation on soil available nutrients fluctuated somewhat. At the early stage of cultivation the nutrients of soil decreased obviously, then lowered gradually, however they were restored to some extent after being abandoned. Above all, the cumulative effects of long-time cultivation exceeded the ability of

regulation of soil, thus making it degenerate.

## 4.2 Cumulative Effect of Planting *Medicago sativa* on Albic Soil

### 4.2.1 Effect of root system on physical properties of albic soil

With the increase of the time of cultivation the weight of *Medicago sativa* root system increased gradually. At the same time, the roots depth increased obviously: *Medicago sativa* root of 1-year-old was 30cm deep, 2-year-old was 60-70cm, 3-year-old was 1m. This character was superior to common plants and crops (NAN et al., 1992).

According to the investigated data, the soil bulk density reduced with the increase of root weight in each unit area, for example, for 1-3-year-old *Medicago sativa* community root system, the correlation coefficient between root weight in each soil volume unit and soil bulk density was  $R = -0.660$ ,  $n = 34$ , but for 1-5-year-old,  $R = -0.668$ ,  $n = 54$ . It was obvious that there was significant correlation between root weight and bulk density.

The data about root system and the physical properties of soil (Fig. 1- Fig. 6) showed that *Medicago sativa* root system had cumulative effects on the physical properties of soil. Firstly, the bulk density was 1.53mg/m<sup>3</sup> for control plot (wheat field), 1.48mg/m<sup>3</sup> for 1-year-old community, 1.43mg/m<sup>3</sup> for 2-year-old community, and 1.43mg/m<sup>3</sup> for 3-year-old community. Secondly, the total porosity was 43.36% for albic soil of control plot, 45.22% for 1-year-old community, 46.10% for 2-year-old community, and 46.60% for 3-year-old community respectively. The capillary porosity of the soil was 40.81% for control plot, 41.81% for 1-year-old community, 42.64% for 2-year-old community, and 29.66% for 3-year-old community respectively.

### 4.2.2 Effect of root system on nutrient of albic soil

The root weight of *Medicago sativa* community per unit area was two times that of control plot (wheat field); the total root weight in albic soil was 1740-2100kg/ha. According to the statistic data, the nitrogen content of *Medicago sativa* root system is 3.583%. Therefore, the clover root system per hectare albic soil could provide 62.4-

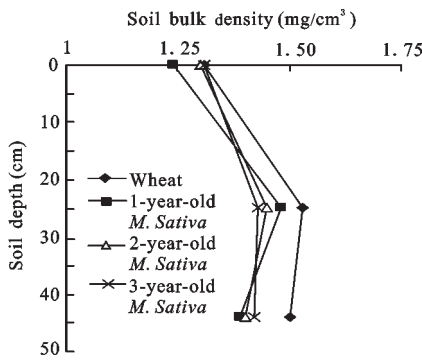


Fig. 1 Effect of *Medicago sativa* root system on bulk density

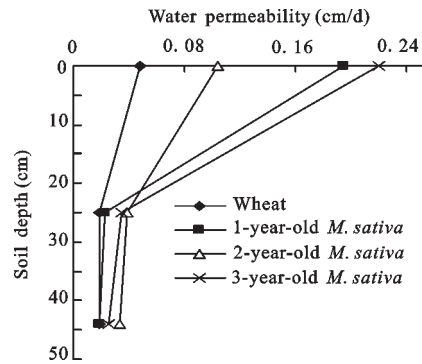


Fig. 2 Effect of *Medicago sativa* root system on water permeability

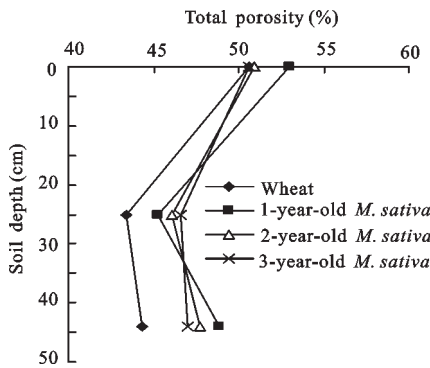


Fig. 3 Effect of *Medicago sativa* community root system on total porosity

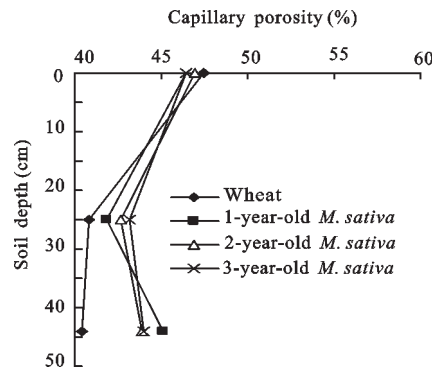


Fig. 4 Effect of *Medicago sativa* community root system on capillary porosity

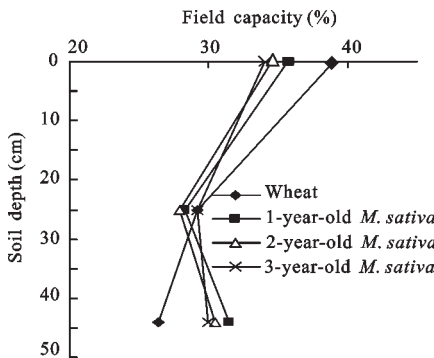


Fig. 5 Effect of *Medicago sativa* community root system on field capacity

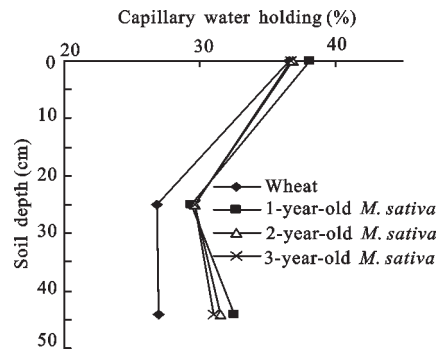


Fig. 6 Effect of *Medicago sativa* community root system on capillary moisture capacity

75.15kg of nitrogen, if we consider the nitrogen fixation of *Medicago sativa* rhizobium, it can provide more nitrogen. In conclusion, because of the cumulation effects of *Medicago sativa* root system the nutrients of albic soil increased prevalently (Fig. 7- Fig. 12). For example, the total nitrogen was 0.052% for control plot, 0.061% for 1-year-old *Medicago sativa* community, 0.064% for 2-year-old community, 0.071% for 3-year-old community respectively.

#### 4.3 Cumulative Effect of Fertilizer on Albic Soil

##### 4.3.1 Cumulative effect of magnetic fertilizer on albic soil

Based on the field experimental results, some physical properties such as bulk density, water content and porosity were ameliorated in the albic soil to which magnetic fertilizer was applied compared to the albic soil to which chemical fertilizer was applied. In the soil of 0- 20cm under the treatment applying magnetic fertilizer, bulk den-

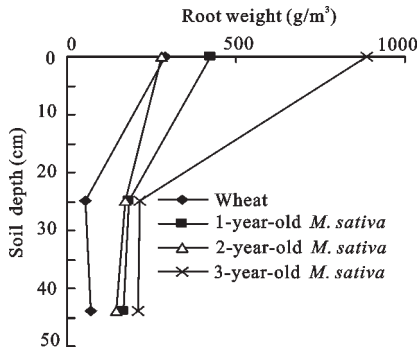


Fig. 7 Root weight of *Medicago sativa* community in different depths of soil

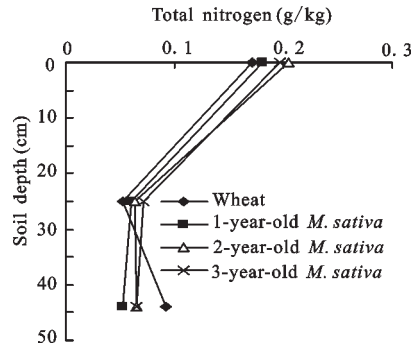


Fig. 8 Effect of *Medicago sativa* community root system on total nitrogen

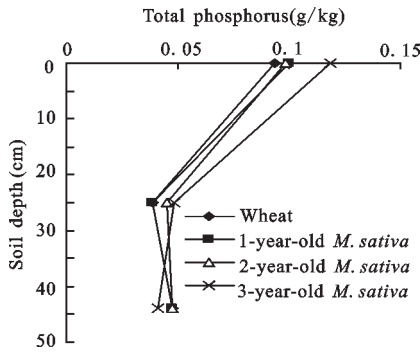


Fig. 9 Effect of *Medicago sativa* community root system on total phosphorus

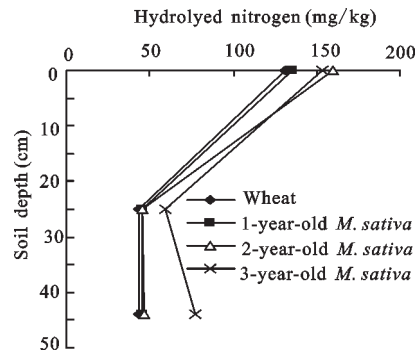


Fig. 10 Effect of *Medicago sativa* community root system on hydrolyzed nitrogen

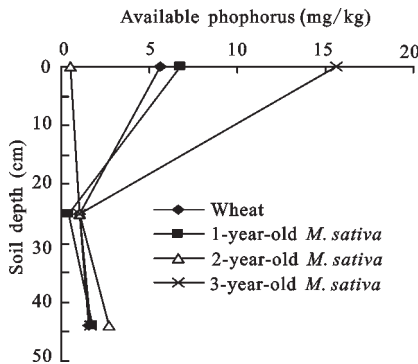


Fig. 11 Effect of *Medicago sativa* community root system on available phosphorus

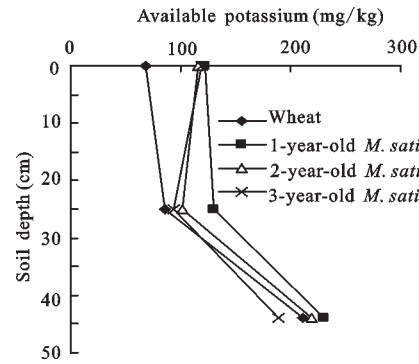


Fig. 12 Effect of *Medicago sativa* community root system on available potassium

sity decreased 0.04- 0.13g/cm<sup>3</sup>, field water content increased 0.2%- 6.8%, total porosity increased 1.98%- 3.84%, aeration porosity increased 0.17%- 4.18%, water-stable aggregates increased 3.57%- 5.25% (Table 4).

#### 4.3.2 Cumulative effect of organic fertilizer on albic soil

(1) Effect of applying organic matter and subsoiling on carbon, nitrogen, phosphorus contents of albic soil. It is shown from Table 5 that in the treatment of using cattle dung, carbon content of subsoiling albic soil increased

by 50% compared with that of un-subsoiling soil; nitrogen content, 277.1%, phosphorus content, 109.7%. And the average carbon content of subsoiling albic soil increased 79.1% compared with un-subsoiling soil; average nitrogen, 132.6%; average phosphorus, 58.5%. However, in the treatment that does not apply organic fertilizer (control) there were almost no differences on carbon, nitrogen, phosphorus contents between subsoiling soil and un-subsoiling soil.

(2) Effect of applying organic matter and subsoiling on



Table 4 Effect of magnetic fertilizer on physical properties of albic soil

Treatment	Bulk density (g/cm <sup>3</sup> )	Water content (%)		Porosity (%)		Aggregate content (%)					
		CC	FC	TP	AP	<0.25mm	0.25- 0.5mm	0.5- 1.0mm	1.0- 2.0mm	2.0- 5.0mm	>5.0mm
1	1.33	37.4	28.9	50.06	11.56	33.72	36.38	5.32	3.86	1.82	1.34
2	1.23	42.4	30.1	53.36	15.04	37.21	24.72	5.50	3.61	2.23	1.14
3	1.22	40.6	33.4	53.20	15.74	37.36	24.37	11.60	2.73	1.12	0.58
4	1.20	40.2	35.7	53.90	15.36	37.95	24.51	5.73	2.92	2.21	1.13
5	1.27	36.2	29.6	52.04	14.44	33.64	20.36	7.32	4.03	2.14	1.12
6	1.27	37.4	28.9	50.06	11.56	32.12	34.48	7.02	3.68	1.80	1.12
7	1.29	30.9	29.1	46.43	11.73	32.70	36.38	5.32	3.86	1.82	1.34

Notes: 1. control; 2. using magnetic fertilizer 150.00kg/ha; 3. using magnetic fertilizer 300.00kg/ha; 4. using magnetic fertilizer 450.00kg/ha; 5. using magnetic fertilizer 150.00kg/ha, carbamide 33.0kg/ha, potassium dichromate 33.0kg/ha and KCl 12.45kg/ha; 6. using magnetic fertilizer 300.00kg/ha, carbamide 66.0kg/ha, potassium dichromate 66.0kg/ha and KCl 25.05kg/ha; 7. using magnetic fertilizer 450.00kg/ha, carbamide 97.8kg/ha, potassium dichromate 97.8kg/ha and KCl 37.50 kg/ha. CC, capillary capacity; FC, field capacity; TP, total porosity; AP, aeration porosity  
Source: NAN et al., 1992

Table 5 Effect of organic matter and subsoiling albic layer on C, N, P contents (g/kg)

Treatment	Subsoiling			Un-subsoiling		
	C	N	P	C	N	P
Cattle dung	14.36	1.32	0.65	5.73	0.35	0.31
Corn straw	5.80	0.54	0.43	5.38	0.43	0.33
Wheat straw	9.07	0.96	0.49	5.21	0.40	0.35
Control	5.53	0.50	0.39	5.21	0.49	0.37

Source: WU et al., 1995

physical properties of albic soil. From Table 6 it is shown that compared with control, the bulk density of the treatment of subsoiling and applying organic matter decreased 0.01- 0.07g/cm<sup>3</sup>; but saturated capillary capacity, total porosity and aeration porosity increased 0.9% - 2.5%, 0.33%- 2.31% and 1.53%- 6.11% respectively. In all treatments using cattle dung had the best effect.

Data of Table 7 showed that, the treatments of subsoiling and using organic matter had influences on aggre-

Table 6 Effect of organic matter on physical properties of albic layer

Treatment	Depth* (cm)	Bulk content (g/cm <sup>3</sup> )	Moisture content (%)		Soil porosity (%)	
			Saturated capi- llary capacity	Field capacity	Total porosity	Aeration porosity
Cattle feces	30- 40	1.52	28.0	21.4	43.80	11.20
Corn straw	30- 40	1.56	26.4	23.1	42.82	6.48
Wheat straw	30- 40	1.58	26.9	22.7	41.82	6.22
Control	30- 40	1.59	22.3	22.3	41.49	5.09

\* albic layer  
Source: WU et al., 1995

Table 7 Effect of organic fertilizer on composition of albic layer aggregate of subsoiling soil (wet sieving)

Treatment	Depth (cm)	Content aggregate (%)					
		< 0.25mm	0.25- 0.5mm	0.5- 1.0mm	1.0- 2.0mm	2.0- 5.0mm	> 5.0mm
Cattle feces	30- 40*	0.65	15.02	6.00	4.02	2.18	72.13
Corn straw	30- 40	0.90	19.10	4.00	2.06	1.32	72.68
Wheat straw	30- 40	0.92	29.54	4.22	2.18	1.30	61.84
Control	30- 40	1.81	13.54	3.64	1.84	1.58	77.59

\* albic layer  
Source: WU et al., 1995

gates of < 2.0mm, but aggregates of >2.0mm.

5 CONCLUSIONS AND DISCUSSION

5.1 Conclusions

The physical and chemical properties of albic soil

changed greatly with the increase of the cultivating years in the Sanjiang Plain. As far as physical properties are concerned, bulk density and specific gravity increased gradually, the porosity and field capacity decreased gradually with the increase of cultivating years, but they increased after being abandoned. As far as chemical prop-

erties are concerned, with the increase of cultivating years, pH increased, and organic matter and other nutrients decreased.

For albic soil cultivated with *Medicago sativa*, the cumulative effects were apparently strengthened with the increase of cultivating years, especially for the bulk density, total porosity, capillary porosity and capillary moisture capacity.

Moreover, fertilization also had great effects on the albic soil. Applying magnetic fertilizer improved the physical properties such as soil bulk density, soil moisture and porosity, increased the utilization rate of nitrogen and phosphorus fertilizer. Compared with nutrient fertilizer, utilization of the magnetic fertilizer made production increase by 5.9%-13.9%. At the same time, utilization of organic matter and subsoiling of albic layer could improve both the physical, chemical and biological properties, and the poor properties of the albic layer. In addition, organic carbon and heavy fraction carbon content and biological activity increased obviously.

## 5.2 Discussion

Environmental cumulative effects had hysteresis and concealment feature. Only when they reached some extent, could they show up, which accorded with the principle of sudden-change theory. Firstly, conversion from wetland to farmland is a sudden-change. Secondly, human effect on some environmental factors is a cumulative course. For example, dry land cultivation affected the physical properties of wetland soil, and wetland soil converted into farmland soil under the cumulative effects for certain time. Finally, if we exerted further cumulative effects on farmland soil, qualitative change may occur for farmland, and furthermore some nutrients of soil may not satisfy the need of crops. This made cost of agriculture higher than output, which means another sudden-change will take place in farmland soil. In the Sanjiang Plain, the first sudden-change has taken place, the second sudden-change has showed up in some regions, for example, the soil of being cultivated for 15 years had almost been mature, changing from wetland soil to farmland soil. Moreover, with the increase of farmland cultivation time, the bulk density and specific gravity increased obviously, but porosity and field capacity decreased gradually. Most nutrients of soil decreased obviously. Soil degeneration is obvious. Therefore, if we do not regulate planting mode and agricultural structure, the third sudden-change may happen, which will affect the sustainable use of soil resources.

Planting *Medicago sativa* increased the weight and volume of the root system of albic soil. They changed the

proportion of organism and physical components of each soil unit. Furthermore, they cumulated to improve all kinds of physical properties of albic soil and created avail condition for crop growth.

Through combining using organic matter on the upper soil and subsoiling, organic carbon and heavy fraction carbon of albic soil increased. But if we only used organic matter without subsoiling albic layer, there were little effects on the physical-chemical properties and biological pollution quantity of albic soil. This suggested that using organic matter must combine with subsoiling to produce cumulative effects. Subsoiling albic layer must combine with the use of organic matter to improve albic soil.

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