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The adoption of conservation tillage in China

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Conservation tillage (CT) has been recognized as an advanced agricultural technology that may reduce drought and improve the physical condition of soils worldwide. An increase in water infiltration and a reduction in water and wind erosion can be achieved through the use of no-tillage, minimum tillage, and residue cover. In China, CT research started with support from the Ministry of Agriculture (MOA), China and the Australian Centre for International Agricultural Research in 1992. By the end of 1990s, CT research had expanded across China and achieved several important results. In 1999, MOA established the Conservation Tillage Research Centre (CTRC) to lead the national CT research programs in China, and since 2002 some CT demonstration projects have been established in northern China. By the end of 2008, CT has been demonstrated in 226 national and 365 provincial demonstration counties, covering more than 3 Mha. The CTRC of the MOA has established 10 sites within those counties to monitor project results. Some sites have shown consistently that the use of CT resulted in higher yields and net incomes, reduced soil erosion, and improved soil conditions. CT has been widely accepted in China and will be further adopted over wider areas as the development and highbred of indigenous no-tillage seeders.

Keywords: conservation tillage; no-tillage; residue; wind erosion; water erosion; economic benefit; seeder

Introduction

Traditional farming systems in China are characterized by conventional cultivation, mouldboard plows and rotary hoes, and the removal of crop residues from the fields for animal fodder and household fuel (Gao *et al.* 1999). To support the nation's population of 1300 million, which is growing at an estimated annual rate of 4 million, the pressure on farmland to maintain high productivity has been increasing at a phenomenal rate. Conversely, the area of farmland available for production has been decreasing because of the fast growing economy and urbanization (Li and Su 2005). This pressure, coupled with harsh conventional cultivation practices and crop residue removal, has led to soil, water, and nutrient losses, and degraded soils with low organic matter and a fragile physical structure. (Li *et al.* 2007). The drylands became the most affected areas; they constitute 52% of the nation's total land area and are occupied by 43% of the nation's population (Zhai and Deng 2000; Wang *et al.* 2007). These lands are inherently fragile because of their low soil fertility and low annual rainfall that can cause severe drought in most years.

The severe land degradation and serious environmental problems have led the Chinese government to emphasize the need for the implementation of farming practices which contribute to the conservation of soil and water, with tillage as an important component of these practices (Wang 1994). A vital approach is the use of conservation tillage (CT), defined as "All conservation farm practices that leave a minimum of 30% of crop organic residues in the field." The key elements of CT in China are

- Zero or minimum tillage;
- Careful management of residues;
- Use of cover and rotation crops to maintain ground cover, increase organic carbon and soil biodiversity;
- Minimum crop diseases;
- Balanced application of chemical inputs (only as required for improved soil quality and healthy crop and animal production);

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- Precision application of all inputs, including maintaining permanent wheel tracks for all in-field equipment; and
- Precise application of pesticides, fertilizers, and herbicides.

Each of these elements is important. The benefits of CT can only be obtained through integration of these elements.

The Ministry of Agriculture (MOA), China has formulated a plan for promoting a widespread demonstration and extension of CT since 2002. By the end of 2008, 226 national and 365 provincial demonstration counties within 15 provinces (autonomous regions and municipalities) of China, including Beijing, Tianjin, Shanxi, Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shandong, Henan, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang have been set up, respectively, covering more than 3 Mha, and it is expected that CT will be used on 22 Mha of China's farmland, mainly located in the "Three North" one-crop-a-year regions, the "Huang-Huai-Hai" two-crops-a-year regions and the "Yangtze" rice and wheat regions, by the year of 2015 (MOA and NDRC 2009).

This article introduces the typical CT areas and investigates the impacts of CT and the development of no-tillage seeder in China.

Typical conservation tillage areas in China

Figure 1 shows the six main typical areas for CT in China (Li 2004): Northeast ridge tillage areas, Annual double cropping areas, Northwest oasis farming areas, Farming-pastoral areas, Loess Plateau one-crop-a-year region, and South rice cropping areas (Fig. 1).

Northeast ridge tillage areas include Heilongjiang, Jilin, Liaoning provinces, and eastern part of Inner Mongolia. In this area ridge tillage is the main farming system, and corn is the main crop. The annual rainfall varies from 400 to 1000 mm, but about four times higher annual cumulative evapotranspiration results in low status of soil moisture in root zone that limits crop production. Furthermore, soil erosion and nutrient loss is a serious environmental issue. As example taken from the black soil region of China, about 4470 km^2 (38%) of black soil land in Northeast China has been subject to moderate-to-severe erosion, which led to 1–5 mm per year loss of dark-colored surface soil, and it is

Figure 1. **The six main demonstration areas for conservation tillage in China.**

estimate that if the erosion can not be controlled, the surface layer would vanish within the next 40–100 years at current rate (Fang *et al.* 2006). So, the objectives for using CT in this area are to slow down the decrease of soil organic matter content, reduce wind erosion, and save water to combat drought.

Annual double cropping areas mainly include Beijing, Tianjin, Hebei, Henan, and Shandong provinces. Double cropping corn and winter wheat is the main cropping system practices in this region. As the main agricultural production base, this region has about 18 Mha of farmland (18.3% of the national total) and represents 20% of total food production in China (Sun *et al.* 2007). In this region, the annual rainfall is 450–800 mm. Annual cumulative evapotranspiration hugely exceeds the annual rainfall. Therefore, shortage of water resource has become a big concern affecting sustainable crop production. With the lack of surface water, groundwater becomes a very significant source of irrigation water in the area. Groundwater levels are persistently declining, and there are a number of regions with large significant zones of groundwater depression. Furthermore, traditional tillage practice uses high application of fertilizer and frequent tillage to maintain crop yields, which results in high production cost and low farmer incomes. So, the objectives for using CT in this area are to increase water-use efficiency, reduce the consumption of groundwater by irrigation, and decrease crop production costs.

Northwest oasis farming areas include Xinjiang and Gansu, and part of Ningxia autonomous region. The annual rainfall in this area is less than 200 mm. Agricultural systems include one-crop a year, two-crops a year, and three-crops in 2 years. Without irrigation, farming in the Gansu Hexi corridor and in most parts of Xinjiang would not be possible, as there are many deserts among which the Gobi is the largest. In the spring season (March to May), strong winds prevail in this region, lifting large quantities of dust particles from the plowed farmlands and deserts into the atmosphere and generating dust storms. So, the objectives for using CT in this area are to reduce the consumption of irrigation water, increase water use efficiency in crop production, and to reduce wind erosion.

The farming-pastoral areas include the main part of Inner Mongolia and parts of Qinghai, Gansu, and Xinjiang provinces. One-crop a year is the main cropping system. In this region, conversion of grassland to crop land, combined with insufficient rainfall and wind erosion, has resulted in serious soil water loss (Jin *et al.* 2008). In the current cropping system, crop residues are removed for fodder after harvest before mouldboard plowing. Using these traditional practices, farmers seek to produce good seedbeds, conserve water, and reduce variability in crop yields. However, in the long term, this traditional tillage has resulted in less water and nutrient unavailability. Consequently, crop yields and farmer incomes become unstable and decline. The extent and impact of soil degradation on crop production in this region also has environmental impacts, for example, dust storms pose a risk to crops. So, the objectives for using CT in this area are to save more water in the soil, combat drought, reduce wind erosion, and decrease crop production costs.

Loess Plateau one-crop-a-year region includes the main parts of Shanxi and Shaanxi provinces, and part of the regions of Ningxia, Qinghai, Gansu, and Henan. In this area annual rainfall ranges from 200 to 600 mm annually, and one-crop a year is the main cropping system. This region has easily eroded soil. Soil erosion and limited crop-available water are the major factors constraining agricultural production, and severe erosion has resulted in degradation of soil physical and chemical properties (Zha and Tang 2003). Traditional farming practices that include intensive plowing and the routine removal of crop residues were identified as the major cause of this degradation. These practices exacerbate soil, water, and nutrient loss, and contribute to land degradation. So, the objectives for using CT are to reduce soil erosion and water loss, combat drought, and increase soil organic matter content.

In the South of China, rice cropping areas mainly include most parts of Jiangsu and Anhui, Sichuan, Chongqing, Hubei, Hunan, Jiangxi, etc. The annual rainfall is between 1000 and 1400 mm; Rice-wheat, rice-canola, rice-rice, rice-rice-rice are the main cropping systems. As one of the most important centers of agricultural production in China, crop production in this region depends heavily on water and the application of chemical fertilizers. In many parts of Southern China, excessive use of water because of the high-intensity cropping system has led to serious water shortage. Meanwhile, traditional tillage practices using mouldboard plowing, crop residues removal, and high fertilize input have resulted in serial problems, such as poor soil fertility, decreased crop yields, etc (Bi *et al.* 2009). So, the objectives for using CT in this area are to increase agricultural productivity and improve soil nutrients.

CT evaluation and extension programs

Evaluation and extension

The MOA is responsible for evaluating and assessing of extension activity, providing practical solutions for on-farm problems, strengthening research collaborations, standardizing CT systems, and developing CT program management. Over the past 7 years, MOA has released a set of practical working documents that support the implementation of CT, including

- Key implementation points of CT technology;
- Executing program of CT projects;
- Field monitoring regulation of CT effect in demonstration sites; and
- CT technology training materials.

The following documents have been reviewed and approved:

- CT technology training book;
- Questions and answers of CT knowledge;
- Recommended list of CT machines and implements;

- Videos on CT; and
- Photographic book on CT.

The above mentioned documents provide the basic training materials and courses for farmers. It is believed that these publications play a key role in the successful adoption of CT programs and the strengthening of program management in all regions.

Structure of CT evaluation and extension group

The CT Project Office was established under the Department of Agricultural Mechanization Management, MOA, and includes an Experts Group led by the head of the Conservation Tillage Research Centre (CTRC) of MOA. Other members of the group come from the National Agricultural Mechanization Extension Stations, and the National Test Station of Agricultural Machines. The agronomists come from the China Agricultural University and the China Academy of Agricultural Sciences.

Impacts of CT

The CTRC evaluated the effects of long-term CT (no-tillage, >30% of straw cover) and traditional tillage (TT) (mouldboard plowing, all straw removal) practices on economic benefit and environment in arid areas of China.

Economic impacts

The economic impacts were investigated at the three sites in two-crop-a-year regions and seven sites in one-crop-a-year regions, respectively, selected from the demonstration counties supported by the MOA during the years from 2002 to 2007.

Yield

Measurements conducted by the CTRC suggest that CT is effective in increasing crop yields in arid areas of China. In two-crop-a-year regions, the mean (2002–2007) crop yield under CT was generally greater (0.8–12.9%) than when traditional tillage practices were used, with only the Baodi, Tianjing reporting reduced yields (Table 1). The yield advantage of CT was particularly pronounced in winter wheat production in Changping of Beijing where the yield was 12.9% ($P < 0.05$) higher. A similar result was found in one-crop-a-year regions, where CT increased crop yield 1.4–34% as compared to TT, and statistically ($P < 0.05$) higher yields were observed in Changping of Beijing (bean: 12.9%), Chifeng of Inner Mongolia (millet: 13.0%) and Xifeng of Gansu (winter wheat: 19.2%), respectively. The positive effects on crop yields in CT systems were consistent with the results of Radford *et al.* (1995) and Zhang and Lou (2002) in arid areas. They demonstrated that no-tillage with stubble mulch improved crop yields 10–40% as compared to traditional plowing.

Economic benefit

The results from the 10 demonstration sites, shown in Table 2, suggest that CT provided significant savings in production cost over traditional tillage. In annual double cropping areas of arid northern China, CT reduced the average total input by 106.1 US\$.ha^{-1} for winter wheat and by 102.5 US\$.ha^{-1} for corn as compared to traditional tillage during the experimental years from 2002 to 2007. In areas where a single crop per year is the main farming practice, the average total input of corn under CT was reduced by 69.5 US\$.ha^{-1}, while the cost for wheat production was decreased by 33.6 US\$.ha^{-1}. Production costs for other small coarse cereal crops were reduced by 47.0 US\$.ha^{-1}.

The lower input for crop production in the CT system was primarily due to reduced operational costs, that is, less labour inputs and lower machinery operating costs. The use of CT also decreased irrigation inputs in those areas containing irrigated farmland, and the increased farming precision achieved when using no-tillage seeders decreased the seed quantity. CT has also been shown to increase fertilizer use efficiency, therefore decreasing fertilizer input. Furthermore, the mean (2002–2007) crop yields of CT system was higher than traditional tillage, which improved the output. Consequently, considerable economic benefit was obtained by CT relative to traditional tillage. In double cropping regions, CT produced higher farmer incomes, ranging from 94.9 to 211.4 US\$.ha^{-1}, with an average of 142.1 US\$.ha^{-1}. In the single cropping regions, from the usage of CT, farmer incomes ranges between 49 and 731.1 US\$.ha^{-1}, with an average of 157.9 US\$.ha^{-1} (Table 2).

Environmental protection

Wind erosion

Wind erosion was monitored in the spring of 2002 to 2005 using the Big Spring Number Eight (BSNE)

Table 1. Average crop yields ($t.ha^{-1}$) for traditional tillage (TT) and conservation tillage (CT) in 10 monitoring sites

Site	Crop	Treatment TT	Treatment CT	Difference (CT − TT)	Increase (%)
Two-crop-a-year regions					
Changping, Beijing	Corn	7.03a	7.21a	0.18	2.6
	Winter wheat	4.65a	5.25b	0.60	12.9
Baodi, Tianjing	Corn	7.33a	7.29a	−0.04	−0.6
	Winter wheat	6.11a	6.16a	0.05	0.8
Gaocheng, Hebei	Corn	7.13a	7.23a	0.10	1.4
	Winter wheat	5.73a	6.00a	0.27	4.7
One-crop-a-year regions					
Fengning, Hebei	Corn	5.88a	6.27a	0.39	6.6
	Spring wheat	2.67a	2.90a	0.23	8.6
	Naked oats	2.07a	2.22a	0.15	7.3
Lingyuan, Liaoning	Corn	4.39a	4.45a	0.06	1.4
Yanggao, Shanxi	Broomcorn millet	2.35a	2.50a	0.15	6.4
	Bean	5.30a	7.10b	1.8	34.0
	Millet	2.27a	2.34a	0.07	3.1
Chifeng, Inner Mongolia	Corn-irrigated	8.70a	9.27a	0.57	6.6
	Corn in upland	2.60a	2.77a	0.17	6.5
	Millet	2.70a	3.05b	0.35	13.0
	Mung bean	8.41a	8.91a	0.50	6.0
Wuchuan, Inner Mongolia	Naked oats	1.45a	1.53a	0.08	5.5
	Broomcorn millet	1.51a	1.60a	0.09	6.0
Pucheng, Shaanxi	Winter wheat	1.48a	1.63a	0.15	10.1
Xifeng, Gansu	Winter wheat	5.27a	6.28b	1.01	19.2
	Corn	6.90a	7.33a	0.43	6.2

Note: The data are the average values of yields from 2002 to 2007. Means within a row for the same crop followed by the same letters are not significantly different ($P > 0.05$).

samplers and wind tunnel (Fig. 2) at the five MOA demonstration sites located in the three main routes traveled by the dust storm in northern China (Li *et al.* 2005).

CT reduced the transport of wind-blown sediment (Table 3). At the Fengning site of Hebei province, the traditionally tilled land produced 42.46 g of wind-blown sediment transport per sample, whereas the CT land produced the value of 12.72 g per sample, a 70% reduction ($P < 0.05$ level) when compared to the traditionally tilled land. Similarly, at Wuchuan, Chifeng, Lingyuan, and Changping, the CT land produced 61.6%, 34.2%, 37.3%, and 12.1% less dust, respectively. Our results indicate that the CT system effectively protected the soil surface and reduced wind erosion by decreasing the exposure of the soil to wind and slowing the wind owing to the increased roughness of the surface, which is similar to the findings of Wang *et al.* (2006).

Water erosion

Water erosion was studied in Shouyang of Shanxi province from 2003 to 2007 using the data of runoff, which is a significant indicator to evaluate conservation tillage's effects on water erosion (Wang *et al.* 2005). Annual runoff in heavy storm years (2004 and 2006), for the CT system (19 mm in 2004, 58 mm in 2006) was less ($P < 0.05$) than that for TT system (40 mm in 2004, 96 mm in 2006), and in normal years (without heavy storm), the annual runoff were slightly different between CT and TT (Fig. 3). During the experimental years from 2003 to 2007, the cumulative runoff in CT land was 88 mm, and in traditional tillage land was 153 mm, respectively,

Table 2. Economic benefit (US\$.ha^{-1}) for traditional tillage (TT) and conservation tillage (CT) in 10 monitoring sites

Site	Crop	Input (US\$.ha^{-1})		Output (US\$.ha^{-1})		Farmer income (US\$.ha^{-1})	
		TT	CT	TT	CT	TT	CT
Two-crop-a-year regions							
Changping, Beijing	Corn	338.1	223.1	1384.9	1420.4	1046.8	1197.3
	Winter wheat	507.6	413.2	906.8	1023.8	399.2	610.6
Baodi, Tianjing	Corn	311.3	208.5	1444.0	1436.1	1132.7	1227.6
	Winter wheat	487.4	375.2	1191.5	1201.2	704.1	826.0
Gaocheng, Hebei	Corn	297.9	208.2	1404.6	1424.3	1106.7	1216.1
	Winter wheat	452.2	340.4	1117.4	1170.0	665.2	829.6
One-crop-a-year regions							
Fengning, Hebei	Corn	221.8	194.4	1158.4	1235.2	936.6	1040.8
	Spring wheat	174.7	143.8	520.7	565.5	346.0	421.7
	Naked oats	88.7	70.2	790.7	848.0	702.0	777.8
Lingyuan, Liaoning	Corn	359.6	277.4	864.8	876.7	505.2	599.3
Yanggao, Shanxi	Broomcorn millet	380.1	313.4	634.5	675.0	254.4	361.6
	Bean	384.2	315.5	1950.4	2612.8	1566.2	2297.3
	millet	350.7	302.5	612.9	631.8	262.2	329.3
Chifeng, Inner Mongolia	Corn-irrigated	312.2	240.8	1713.9	1826.2	1401.7	1585.4
	Corn in upland	258.3	188.5	512.2	545.7	253.9	357.2
	Millet	199.3	154.5	729.0	823.5	529.7	669.0
	Mung bean	795.4	709.4	3091.2	3275.2	2295.8	2565.8
Wuchuan, Inner Mongolia	Naked oats	61.6	43.2	553.9	584.5	492.3	541.3
	Broomcorn millet	123.3	98.6	407.7	432.0	284.4	333.4
Pucheng, Shaanxi	Winter wheat	133.6	90.4	288.6	317.9	155.0	227.5
Xifeng, Gansu	Winter wheat	86.3	59.6	1027.7	1224.6	941.4	1165.0
	Corn	129.5	32.9	1359.3	1444.0	1229.8	1411.1

Notes: Input includes the cost of seeds, fertilizers, mechanical operations, water, herbicide, and labor; Output is determined using crop yield × price (the domestic market price in 2007); farmer income = output − input. The data are the average values from 2002 to 2007.

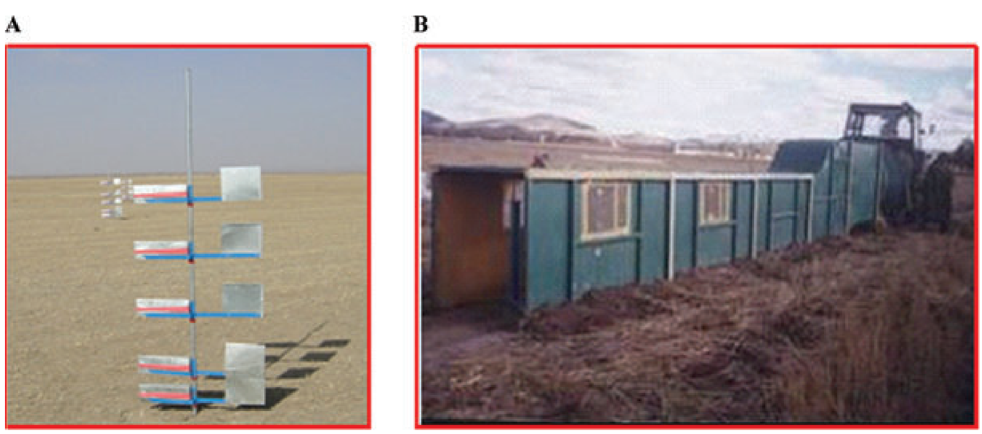

Figure 2. **The big spring number eight dust sampler (collected at 1.5 m height) (A) and portable wind tunnel (B) used in Beijing, Hebei, Inner Mongolia, and Liaoning provinces.**

Table 3. Wind-blown sediment transport (g per sample) collected in traditional tillage (TT) and conservation tillage (CT) plots in five monitoring sites during the springs of 2002–2005

Sites	Collection time	TT	CT
Fengning, Hebei	2002, 3.22–2002, 4.21	42.46*a*	12.72*b*
Wuchuan, Inner Mongolia	2003, 3.26–2003, 4.6	7.43*a*	2.85*b*
Chifeng, Inner Mongolia	2003, 4.22–2003, 5.3	7.08*a*	4.66*b*
Lingyuan, Liaoning	2004, 3.25–2004, 4.3	16.32*a*	10.23*b*
Changping, Beijing	2005, 3.28–2005, 4.17	19.00*a*	16.70*a*

Note: Means within a row followed by the same letters are not significantly different ($P > 0.05$).

representing a decrease of 40.9% in the no-tillage with straw cover (>30%) system. These results indicate that conservation tillage, particularly in heavy storm years, could effectively reduce runoff and control water erosion in agricultural production in the arid areas, which concurs with previous results for the arid Chinese Loess Plateau (Wang *et al.* 2004).

Soil property

The long-term (1992–2007) impacts of CT and traditional tillage on soil physical and chemical properties were investigated in the village of Chenghuang near the city of Linfen (38°6 N, 113°E, 456 m a.s.l.) in the Shanxi province (Table 4). In 2007, after 16 years different tillage management, bulk density was less in CT (1.33 g.cm^{-3}) than that in TT (1.35 g.cm^{-3}). Furthermore, significant ($P < 0.05$) differences were found in the size distribution of water-stable soil aggregates between CT and TT. In long-term no-tillage with straw cover (>30%) soils, the percentage of water-stable aggregates of the largest size class (>2 mm) was approximately twice that in plowing with all straw removal soils (160 compared with 80 g.kg^{-1}), while the percentage of water-stable aggregates of the smallest size class (<0.25 mm), was 32.6% higher in plowing with all straw removal soil. Similar results were found in soil chemical properties in Linfen experimental site in 2007. Soil organic matter, total N and P for CT system (18.2 g.kg^{-1}, 0.668 g.kg^{-1}, 0.738 g.kg^{-1}) were significantly ($P < 0.05$) different from for TT system (13.6 g.kg^{-1}, 0.553 g.kg^{-1}, 0.645 g.kg^{-1}). The improvement of soil physical and chemical property under CT treatment can mainly be explained by increased biotic activity and enhanced soil organic carbon pool in no-tillage soils (Karlen *et al.* 1994), and the significantly better soil structure will facilitate CT farming to mitigate soil degradation and improve soil conditions (Fig. 4).

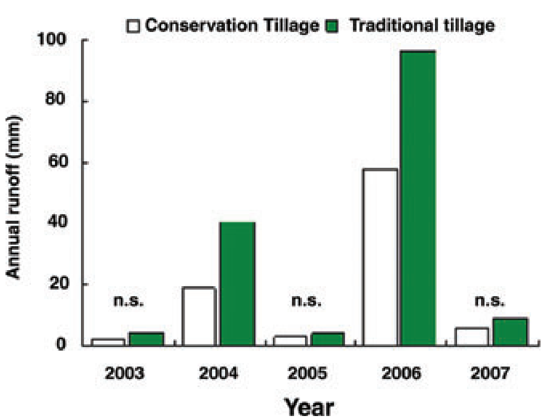

Figure 3. The mean annual runoff in traditional tillage and conservation tillage (which has been adopted since 1992) land in Shouyang of Shanxi province from 2003 to 2007. Annual rainfall was 359, 421, 328, 443, and 417 mm for 2003, 2004, 2005, 2006, and 2007. The storm events happened on August 17 and 18 in 1994, and July 24, 27, August 6–10 in 2006. n.s. = not significantly different ($P < 0.05$).

No-tillage seeder machinery development

At present, there are about 50 enterprises manufacturing CT machinery and testing equipment at various sites throughout China. The most important CT machine is the no-tillage seeder, which plays an important role in the application and extension of conservation tillage. In 1992, led by CTRC, Chinese scientists started to develop a no-tillage seeder for no-till and crop residues cover conditions using the passive antiblocking method for wheat and rice residues. For corn residues, the active antiblocking method was adopted because of its strong ability

Table 4. Bulk density (g.cm^{-3}), total porosity (cm^3.100 cm^{-3}), water stable aggregates (g.kg^{-1}), soil organic matter (g.kg^{-1}), total N (g.kg^{-1}) and P (g.kg^{-1}) for traditional tillage (TT) and conservation tillage (CT) in Linfen of Shanxi province in 2007

			Water stable aggregates*						
Tillage	BD*	TP**	>2 mm	2–1 mm	1–0.25 mm	<0.25 mm	SOM*	TN*	TP*
TT	1.35a	44.89a	80b	210a	161a	549b	13.6b	0.553b	0.645b
CT	1.33a	43.02a	160a	250a	176a	414a	18.2a	0.668a	0.738a

Note: The experiment was conducted from 1992 to 2007. Values within a column followed by the same letters are not significantly different ($P > 0.05$).
BD, bulk density; TP, total porosity; SOM, soil organic matter; TN, total *N*; TP, total P; *, to 10 cm depth; **, to 20 cm depth.

Figure 4. The change of soil surface conditions under traditional tillage (TT) and conservation tillage (CT). (A) Field under TT management; (B) 5 years corn field under CT management; (C) 16 years winter wheat field under CT management.

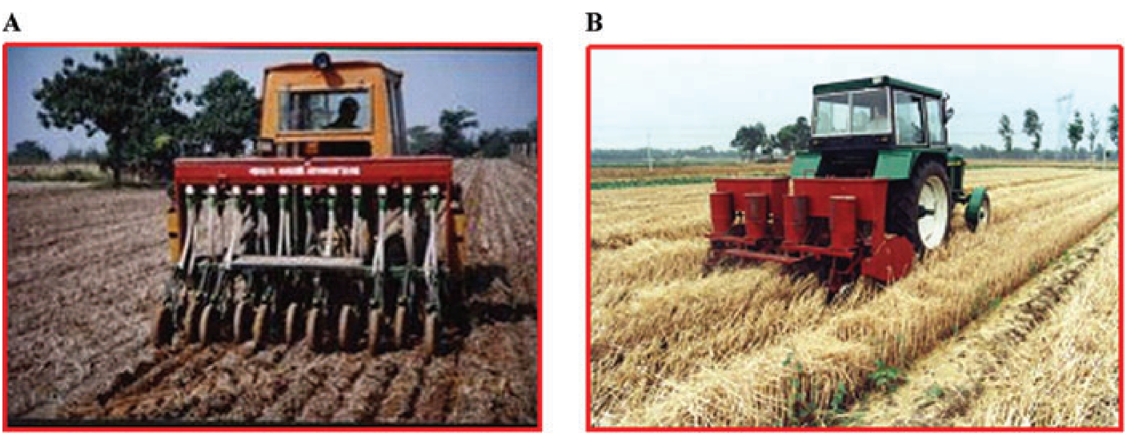

Figure 5. Two typical passive antiblocking no-tillage seeders. (A) 2BMF-11 no-tillage wheat seeder; (B) 2BMQF-4 no-tillage corn seeder.

to handle corn stubble. After 17 years of research, China has made great achievements in the development of wheat and corn no-tillage seeder in CT fields.

Passive antiblocking no-tillage seeder

2BMF-11 no-tillage wheat seeder

The 2BMF-7 11 no-tillage wheat seeder (Fig. 5A), matched with 40 kW class tractor, was used to seed wheat in wheat residue cover fields in one-crop-a-year region of China. The seeder uses passive antiblocking multibeams structure to provide high trash flow and/or antiblocking components needed to handle wheat or rice residues. Residue clearance was maximized by mounting five openers on the front and six on the rear bar of the machine. During planting, the machine used narrow-point openers and press wheels to place and firm seed and fertilizer at depths of 5 and 10 cm, respectively. The machine was set to the 16-cm row spacing commonly used by local farmers for a total operating width of 1.12 m.

2BMQF-4 no-tillage corn seeder

The 2BMQF-4 no-tillage corn seeder (Fig. 5B) is currently widely used to plant no-till corn into wheat residue in the two-crop-a-year regions in northern China. The main antiblocking device of the seeder is a disk coulter combined with dual dentate disks. The disk coulter first cuts the residue, and then the following dual dentate disks remove the residue from the seeding row, so the narrow-point opener can easily finish the no-tillage seeding. Furthermore, the wide row space (45–65 cm) of corn also helps the machine to maintain high trash flow for corn residue.

Active antiblocking no-tillage seeder

Active antiblocking is the main method for handling of corn residues in annual double cropping (winter wheat-summer corn) areas in the North China Plain. The following machines are three main typical active antiblocking no-tillage seeders in China.

2BMFS-5/10 no-tillage seeder

The 2BMFS-5/10 no-tillage seeder (Fig. 6A) was used for seeding corn and wheat into corn residues. This machine cleans strips by residue chopping and rotary hoeing before knife-type tine openers, so the machine can no-till plant wheat after corn. The

Figure 6. Three typical active antiblocking no-tillage seeders. (A) 2BMFS-5/10 no-tillage seeder; (B) 2BMDF-12 no-tillage wheat seeder; (C) 2BDPM-12 no-tillage wheat seeder.

metal press wheels are used to place and firm the seed and fertilizer at depths of 5 and 10 cm, respectively. The machine can seed 10 rows of wheat or 5 rows of corn. In wheat seeding, the 10 openers are spaced to alternate between 11 and 39 cm to achieve maximum residue clearance. The row spacing used in corn was 50 cm.

2BMDF-12 no-tillage wheat seeder

The 2BMDF-12 no-tillage wheat seeder sets two powered strip-chopping rotary coulters ahead of each opener to keep the above-ground section of the fertilizer tine-type opener free from residue blockage (Fig. 6B). This complete machine is 2.4 m wide with 12 openers at 20 cm spacing. It is equipped with tine openers to provide a groove 3–5 cm wide and 8–12 cm deep for fertilizer placement and a double-disc opener with individual row depth control mechanisms to place seed 4–5 cm above the fertilizer.

2BDPM-12 no-tillage wheat seeder

The key part for 2BDPM-12 no-tillage wheat seeder (Fig. 6C) is the oblique-driven disc set at a 5 degree angle from the vertical line. This design allows the use of disk swaying to push away 80% of stalks on the seedbed and only cut 20% of the corn stalks. Furthermore, a 4–6 cm furrow is opened using an oblique disk, several times wider than the 1 cm-wide furrow normally opened when vertical disks are used. This machine can seed 12 rows wheat at 20 cm spacing, so the operating width is 2.4 m.

Conclusions

After more than 17 years of experiment, implementation, and demonstration, China has found its own way to develop CT systems. Manufacturing systems for no-till equipment are on a smaller scale, which is typical from other countries. The Chinese government recognizes the importance of CT, and more and more farmers are accepting it. An increasing number of machinery companies found that CT will bring them new markets. It is believed that CT will be adopted in broader areas in the near future.

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Conflicts of interest

The authors declare no conflicts of interest.

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