

Research and Development on Wheat No-Tillage Seeders in Annual Double Cropping System in Central China

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ABSTRACT

There are about 15Mha irrigated croplands in China adopting the wheat-maize (two crops in a year) cropping system. One of these areas is in Central China.

The adoption of conservation tillage (CT) in these areas has significant resource, and environmental and economic benefits. However, no-tillage seeding wheat in maize residue field in Central China was very difficult due to tough maize root and narrow wheat row space. Some foreign wheat no-till seeders have strong anti-blockage ability, but they are heavy (765-1130 kg/m) and expensive. From 1997, research on lighter and cheaper wheat no-till seeders was started.

Through extensive research over the past ten years, three kinds of anti-blockage devices and two kinds of openers have been designed. Furthermore, three kinds of wheat no-till seeders have been developed through the using of these devices. These include: strip rotary hoe minimum-till seeder, strip chop no-till seeder, and oblique driven disc no-till seeder. These three kinds of no-tillage wheat seeder are suitable for Chinese middle sized tractor (500-650 kg/m), while the prices are only 10-15 per cent compared to imported no-tillage wheat seeders. By the end of 2006, the double cropping CT system has been extended to 420,000 hectares, which resulted in 5.5 per cent and 7.2 per cent higher wheat and maize yields, over 20 per cent less operating cost, 20-30 per cent less fuel consumption, and 10-15 per cent less irrigation water.

Key words: Conservation tillage, double cropping, no-till wheat seeder

1. BACKGROUND

The main objective in the design of no-till seeders is to handle crop straw blockage. There are two kinds of methods to handle this: passive and active anti-blockage.

The imported no-till seeders mainly use passive anti-blockage, such as John Deere 750, Great Plain 1500 disk no-till planters of USA, and Morris 7000 narrow point tine no-till seeder of Canada. These seeders are quite heavy weighing from 800-1000kg/m, so the disk can cut through straw and work against blockage through adequate vertical force. The Canada Morris 7000 narrow point tine no-till seeder which weighs 1100kg/m of unit adopts large neighbor-opener distance to let the straws freely pass through and avoid blockage.

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In US and or Canada, the adoption of passive anti-blockage and heavy seeder is suitable because they have large crop field, big tractor and pull type implement. Active anti-blockage means installing power-driven device to avoid blockage by cutting off the straw during in seedling. The no-till seeders with power driven device were less used than passive anti-blockage due to more complex structure and higher power consumption in other countries.

Except for the state farms, most of the crop fields in China are small. As such, the mounted type implements are mainly used in Chinese farming, but tractor lift force is a great limitation for small tractors. For example, the lift forces for middle tractor (50 to 65 hp) and small tractor (less 25 hp) are 500-650kg/m and 300-400kg/m, respectively, so it is impossible to lift the 800-1100kg/m seeders. Machine prices are also a limitation. For example, the Deere 750 wheat no-till seeder costs about US\$30,000 which is very expensive for Chinese farmers.

The team from the China Agricultural University (CAU) started to develop no-till wheat seeder to work on heavy maize residue in 1997. Firstly, passive anti-blockage method was adopted. In row planting and disk type no-till seeders were designed and tested, but were not successful. Thus, the team began to research on active anti-blockage from 2000. Research results showed that active anti-block is an effective way to solve the contradiction of lighter seeder and strong anti-blockage ability, and also made success in no-till seeding wheat in heavy maize stubble field.

2. RESEARCH ON PASSIVE ANTI-BLOCKAGE NO-TILL WHEAT SEEDER

2.1. In-row Planting

The main idea in this design is to seed wheat between two neighboring maize stubbles to avoid the opener encountering maize roots and causing blockage.

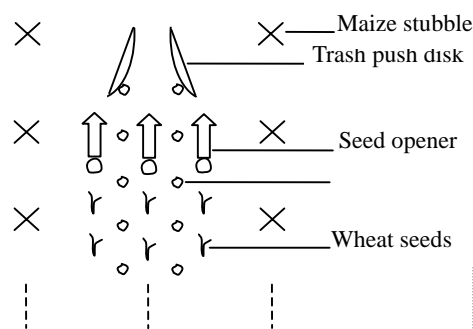


Fig.1 Sketch of wheat rows in maize stubble.

The openers in the seeder are divided into several groups with each group containing three openers running between two maize rows (Fig 1). Maize row spacing, wheat row spacing and group spacing are 70 cm, 15 cm and 40cm, respectively, so 20cm neighbor openers distance can be achieved in wheat seeding. A 12-row no-till seeder was

manufactured and tested in 1998. The results showed that the seeder could directly plant wheat in the maize stubble, but only when the maize row space was wider than 65-70 cm, the fields had no long stalks or weeds on the ground and the driver concentrated on the operation so blockage could be avoided. Otherwise, stalk or root blockage would occur.

2.2 Disk No-Till Seeder

In order to study the relationship between disk cutting ability and seeder weight, a two-row disk no-till seeder was manufactured and tested in 2000. The maize stubble was 30 cm tall and the other stalks were chopped and spread on the ground. The moisture in maize stalks and roots was 66 per cent and 68 per cent, respectively. The ballast was used to increase disk vertical force and stalk cut off rate and root broken rate were used to express the anti-blockage ability. The measured results are shown by Table 1.

Table 1. Different Results under Various Ballasts for Disk Opener.

	Ballast on each disk (kg)	Stalk cut off rate (%)	Root breakage rate (%)
1	0	0	0
2	100	62	0
3	135	100	82
4	175	100	100

As indicated in Table 1, for the planter to effectively cut off stalk, 135 kg of ballast on each disk was needed. If the planter is targeted to both cut off stalk and roots against blockage, 175kg ballast for each disk is necessary. This result matches many experiments conducted in other countries. However, it was difficult to apply this technique to design Chinese no-till seeders, e.g., six-rows wheat no-till seeder should have more than 1,000kg weight, while Chinese 20 hp tractor with 350-450kg total lift force could not be mounted. In the big farms where large pull-type seeders can be used, the no-till disk seeder may be a good choice.

3. RESEARCH & DEVELOPMENT ON ACTIVE ANTI-BLOCKAGE NO-TILL WHEAT SEEDER

3.1. Strip Rotary Hoe Mini-Till Seeder

The strip rotary hoe mini-till seeder use power driven rotary blades not only to loose seedbed, but also to cut off stalks and break roots, so the openers can pass through easily. A 2BMFS-10 no-till wheat seeder as shown in Figure 2, and the main parameters of the machine are: the rotary tillage width 12cm, no-tillage width 28cm, soil disturbance rate at 30 per cent.

In mini-till seeder, the main functions of the rotary blade are loosening soil, cutting stalks and crushing roots, so the speed of the rotary blade is the main parameter that should be designed. Normally, in order to reduce blade wearing while loosening soil and crushing the



Fig.2 2BMFS-10 No-till wheat seeder.

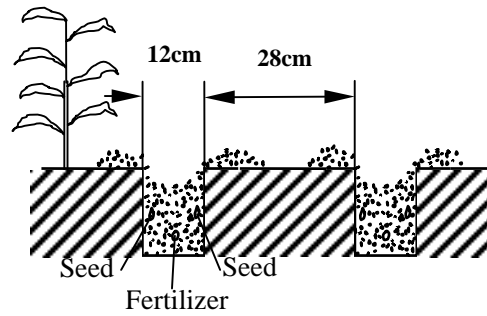


Fig.3 Sketch map of strip rotary hoe mini-seeding

roots, the rotary hoe cultivator usually has low speed (about 200r/min). To ensure the cutting of the stalks, the chopper should have the high speed (over 1500r/min).

According to the experimental results, the speed could be selected at 400r/min to meet the requirements for loosening the soil, breaking the roots, and having minimum stalk-cutting ability. Since the seeder is not purely a chopper, there are no requirements for the chopped stalks, such as length (i.e., 5cm), evenness (for example, 5cm stalks should be more than 90 per cent) or in the chopping operation. Sometimes, stalks could not be cut through and thus, just pushed out of the furrow.

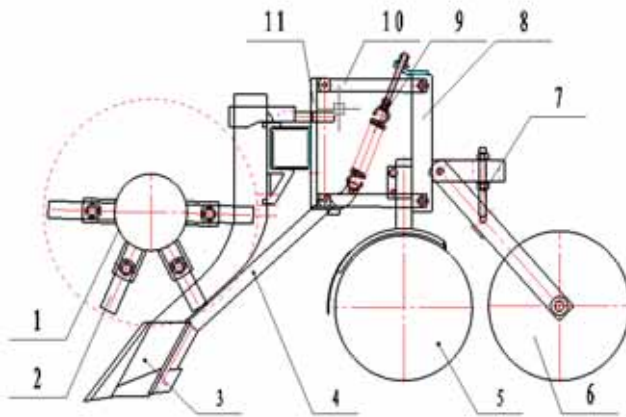
Fertilizer application is the other key issue for the mini-till seeder. In order to avoid seed burning, fertilizer should be immediately placed at the bottom and center of the neighbor furrows after soil loosening by the rotary blade, and then covered by soil (Fig. 3). Fertilizer should be placed between two seed rows and deeper to avoid seed burning.

Based on results of experiments, a 5cm difference between fertilizer and seed rows is helpful for seed root growth.

The seeder can be used on different types or amount of stalk mulch conditions. After planting, the seeds are in furrow, which can be effectively stored during snow and rainfall to resist drought. Since the mini-seeder can chop stalks, break roots, loose soil in furrows, place fertilizers and seeds, cover and press soil in one pass, a 30 per cent reduction in operation costs and 5-10 per cent higher yields can be achieved. The shortcomings of the seeder are large soil disturbance and low productivity.

3.2. Strip Chop No-Till Seeder

To reduce soil disturbance and power consumption, a strip chop no-till seeder called 2BMDF-12 no-till seeder, has been developed. As shown in Figs. 4 and 5, the power driven chop blades (2) beside the opener (3) cut off or push away the stalks hanging on the opener and crush the roots. The seed opener is the disk opener (5), which pushes chopped stalks or grass to the sides, and evenly put seeds in the soil. Then press wheel (6) immediately presses the seeding row. Since the driven blades do not touch the ground, reducing soil disturbance and power consumption and increasing the uniformity of seed depths are achieved.



1 chopping axle 2 blade 3 tine opener 4 fertilizer tube
5 double-disc opener 6.press wheel

Fig .4 Sketch of Strip Chop No-till Wheat Seeder



Fig .5 2BMDF-12 No-Till Wheat Seeder.

The test results of 2BMDF-12 seeder in Zhangziying township of Beijing indicated that the seeder could seed on the standing maize stalk and chopped stalk fields with reduced blockage. Seeding quality is also very good (Tables 2 and 3). The seeder with unit weight of 500kg/m was a little bit complex and has a higher price than the mini-till seeder, making it suitable for city suburb fields where rural economy developed.

Table 2. The Depth of Seed and Fertilizer in Standing Maize Stubble Field.

Item	Average depth (cm)	Eligible rate %	Standard deviation (cm)	Average variance %
Seed depth	4.1	87.6	0.81	19.8
Fertilizer depth	8.5	85.4	1.49	17.5
Distance between seed and fertilizers	4.4	80.5	1.06	24.1

Table 3. The Depth of Seed and Fertilizer in Chopped Maize Stubble Field.

Item	Average depth (cm)	Eligible rate %	Standard deviation (cm)	Average variance %
Seed depth	3.9	84	0.83	21.3
Fertilizer depth	8.2	88.5	1.38	16.8
Distance between seed and fertilizer	4.3	79.4	1.02	23.7

3.3. Oblique Driven Disc No-Till Seeder

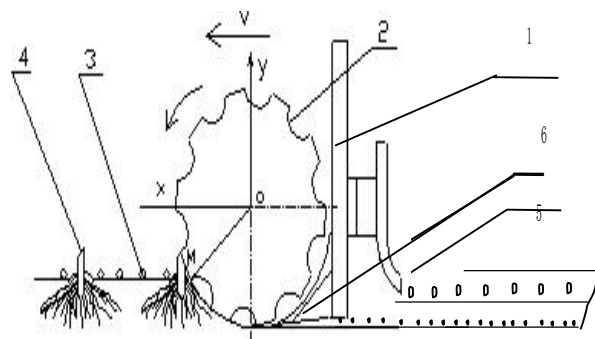
The key part in the oblique driven disc is the fact that the disk does not need to be set to the vertical shift, but instead set in a 5 degree angle with vertical line. The aims of the design are as follows: Firstly, the disk swaying is used to push away 80 per cent of stalks on the seedbed and only cut off 20 per cent of the maize stalks. Secondly, a wider furrow by oblique disk should be opened. Normally, the vertical disk can only open at a 1cm wide furrow, and the following opener must extrude the furrow from 1cm to 4cm to let 4cm diameter of seed tube pass through. The disk with 5 degree angle to vertical line can open 4-6 cm wide furrow for seeding. Another advantage is increasing seedbed temperature by reducing stalk amount on the seedbed, which is suitable to cold areas of northern China.

The problems of the oblique disk are machine vibration, high resistance force, and heavy disk wear. To solve these problems, soil bin experiments and theory calculation were done by CAU. Test results showed that if the disk with 246 cm radius rotates at the speed of 300r/min, the stalk cut off rate can reach 97 per cent and the maize roots can be cut into 1.2-2.5cm small pieces. According to the experiment, 300r/min of disk rotating speed was selected for common use, and 400r/min of disk rotating speed can be used in the field with high yield or heavy straw condition. Soil bin test results also showed that in the typical maize stalk and root condition, the power consumption for vertical disk and oblique disk was 1.52kw per disk and 1.71kw per disk, respectively, and the difference is not significant.

Figs. 6 and 7 show an oblique driven disc wheat seeder-2BMPD-12 no-till seeder and the mechanism of anti-blocking, respectively. The field tests showed that with 300r/min of disk turn speed, roots cut off rate was 98 per cent, indicating that the blockage could be solved by this design. In the experiments, the stalks on the seedbed were 3.06 kg/m² and 0.58 kg/m² before and after planting, indicating the oblique driven disc had strong ability to push the stalks away from the seedbed. The disk is made of 65Mn steel and the least seeding areas are higher than 40 hectares, which means the seeder can seed one season without replacing the disk.



Fig6. 2BMPD-12 No-till seeder



1. Fertilizer tub 2. Gap disk 3. Maize stalk
4. Maize stubble 5. Seed tub 6. Opener

Fig. 7 Diagram of mechanism for cutting corn stalk and roots

Since the oblique disk can cut stalks and roots, and open furrows, the seeder is simple, light (312kg/m) and cheap, and can be extended in large areas. However, the disk will have partial wear after being used for a period of time, and should use the other face for seeding.

When a large amount of fertilizer, especially urea, is applied, seed burning may occur sometimes.

4. CONCLUSION AND DISCUSSION

Three no-till and minimum-till wheat seeders have been largely used in central China, which solved the bottleneck of no-till seeding wheat in heavy maize stubble (15-20t/hm²) field. Compared with imported no-till wheat seeders, the developed seeders were lighter in weight by over 50 per cent and price reduced by over 80 per cent.

Further, these seeders also suit Chinese farmers' small piece of land, use of small tractors, and the poor rural economy. Thus, the equipment strongly supports the realization of all year conservation tillage in annual double cropping areas. As a result, all year CT technology has been extended to 420,000ha in annual double cropping region by the end of 2006 and the accumulative areas reached 1.14Mha, which increased wheat yield by 5.5 per cent, maize yield by 7.2 per cent, and farmers' income by 20 per cent (1500yuan/ha), reduced fuel consumption by 20-30 per cent, and reduction in irrigation water by 10-15 per cent.

However, in order to largely apply all year conservation tillage on 15M hm² of double cropping areas in central China, there is still a need to improve these seeders and develop new ones in the future.

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