Development of small/medium size no-till and minimum-till seeders in Asia: A review

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Abstract: The benefits of conservation agriculture (CA) have been widely recognized and CA has been widely adopted in many parts of the world. However, there are some factors that limit the widespread adoption of CA in Asia. The most prominent factor appears to be the lack of suitable CA seeders for small to medium sized land-holding (SLH) farmers. This paper summarizes the small to medium no-till and minimum-till seeders currently available in Asia, and classifies these seeders into four types: manually operated units, animal traction seeders, two-wheel tractor and four-wheel tractor driven seeders. Detailed characteristics have been provided for some typical CA seeders and comparisons were made as to their suitability under particular working conditions. Typically manual and animal traction seeders are confined to small farms and hilly areas, while the larger CA seeders suited to four-wheel tractors are used on larger acreages. To ensure seeding performance on most four-wheel tractor CA seeders, two types of anti-blocking mechanisms (passive and active anti-blocking) have been fitted. Finally, the paper proposes a future direction and development of CA seeders for small/medium size farms in Asia, and also suggests changes in policy support, improvement of anti-blocking mechanisms, suitability for various crops, geographical zones and the contribution of development by public private partnerships to advance the adoption of CA seeders.

Keywords: conservation agriculture (CA), conservation tillage, no-till, minimum-till, seeder, tractor, anti-blockage, Asia

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1 Introduction

Most Asian countries are agrarian with 60%–80% of the population related to farm operations in one way or another[1]. In recent decades, the expansion of croplands, pastures and plantations, accompanied by large increases in energy, water, and fertilizer consumption, along with considerable loss in biodiversity and forest cover, has led to a stressed landscape in most instances. Changes in land use and hydrological flows caused significant loss of structure to the catchments and wetland eco-systems[2]. In South Asia, over 90% of the areas suitable for agriculture have already been cultivated, leaving little provision for agricultural expansion[3]. Rapid population growth in India, Pakistan, Bangladesh, and Nepal, has pled significant and urgent demands on land and water resources[4,5]. In East Asian countries, especially in China, in order to relieve the pressure of food security resulting from rapidly increasing population, agriculture is heavily reliant on intensification and high inputs. Unfortunately, sustainable development of agriculture is facing considerable challenges as the environmental crisis has increased in recent years[6]. For instance, China has been severely affected by desertification. An area of about 280 Mha (30% of the total land area) has been affected, and direct annual economic loss by desertification was as high as 54 billion

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RMB Yuan. In the main cropping regions, particularly in the dryland areas of Northern China, the soil is severely degraded through desertification[7].

In the western and southern coastal areas of Korea, where irrigation is largely dependent on groundwater, sustainable agriculture has been threatened by seawater intrusion due to intensive groundwater pumping, particularly in rice cultivation areas[8]. In the tropical uplands of Southeast Asia, population pressure, climate change, government policy, market demand, etc, have driven rapid changes in land use practices, and the impact of these changes on land degradation and environmental services has affected agricultural productivity[9]. In the Philippines, sloping farmlands suffering from moderate to severe soil erosion have accelerated land degradation, which has caused permanent, irreversible loss of land productivity[10].

Long-term conventional agriculture, which is characterized by using mouldboard plough and rotary hoe, and the removal of crop residues from the fields for use as fodder and household fuel, has resulted in serious land degradation, decline of soil fertility, reduced yield, increased production cost, which severely threats Asian food security[11,12]. In conventional tillage systems, the loss of fertile top soil by erosion has contributed to fertility decline and yield reduction[13,14]. The severe land degradation and serious environmental problems have aroused Asian countries to emphasize the need for the implementation of farming practices which contribute to the conservation of soil and water, with reduced or no-tillage as an important component of these practices. This requires the use of conservation agriculture (CA). CA is described as a biodiversity-friendly agricultural practice which assists farm profitability through reducing inputs such as chemicals, fuel and labor. Several countries in Asia now have significant areas under CA and more countries are investigating and adopting CA. For instance, in China, the CA movement started in the early 1990s and at the end of 2013 had an area of over 6 Mha; In the Indo-Gangetic plains across India, Pakistan, Bangladesh and Nepal, no-till area is about 5 Mha; In Southeast Asia, Maize cultivation under zero tillage with former crop residue management and/or relay association with a legume (beans, forage or shrubby legumes) are the most popular CA systems; In Central Asia, with the active support of development agencies such as FAO, CIMMYT and ICARDA, Kazakhstan and Uzbekistan have successfully adopted CA across large areas of their croplands, with 10.5 Mha under reduced tillage and 1.6 Mha under ideal CA in Kazakhstan[15]. However, CA is a complex, knowledge intensive system which does not lend itself easily to be accepted by farmers, especially in Asia[16]. There are a number of constraints to the adoption of CA. The most prominent constraint is the unavailability of suitable locally made equipment for small-sized land holder farmers. CA seeders, are key to the farming system and are especially significant for the promotion of CA. In Asia, some 52.7% of farms are less than 1.0 ha in area (e.g. smallest farm size in Bangladesh is 0.4 ha and in China it is 0.1 ha)[17,18], therefore medium and small size CA seeders are desperately needed to advance the adoptions of sustainable farming systems such as CA. This paper summarizes currently available small to medium size CA seeders in Asia, and classifies these seeders into four types: CA seeders for manual, animal traction, two-wheel tractor and four-wheel tractor operations.

2 Manual and animal-traction seeders

Manual and animal traction seeders are usually small, light-weighted, simple in design and easily manufactured, utilized and maintained. These seeders are invariably used on small farms and hilly areas.

The use of manual equipment is the basic level of mechanization, and improved equipment designs are intended to enhance productivity in respect to energy efficiency and ergonomics. A demand-driven development and an innovation system are necessary for the adoption of improved human and animal dragged equipment[19]. Some typical seeders in Asia are reviewed as follows:

2.1 Manual direct seeder

Li seeder (Figure 1)**:** Li seeder is a typical manual seeder for no-till seeding of maize and soybean. It can be used on small farms under a wide range of conditions, including wet soils. The operating handle contains the seed and a shoulder bag carries the fertilizer. Through a chopping action the seeder can plant one or more seeds simultaneously, while fertilizer can be applied separately and the amount is adjustable. The total weight of Li seeder is 2.2 kg and the working efficiency is 0.2-0.3 ha/day/person.

Jab planter[20] (Figure 2)**:** Jab planter is the most common manual planting tool for row crops in no-till areas. It is a hand-held tool which enables farmers to plant from a standing position. This machine is able to seed into mulch-covered no-tilled soil effectively. There are two containers in which fertilizer and seed are stored, which are mounted on a wooden frame with two planting tips. To allow fertilizer and seed to drop into the planting hole the tips are punched firmly into the soil and opened by a manipulator. Seeding rates can be adjusted accordingly. There is a provision to plant 1, 2 or 3 seeds per hole.


Figure 1 Li Seeder


Figure 2 Jab planter

2.2 Animal traction planters

Animal traction direct planter (Figure 3)**:** The planter is a multicrop planter that generally consists of a coulter to cut plant residue and ripper tine to open a small rip-line. Seed and fertilizer are held in two separate hoppers and delivers into the slot by individual drop tubes. A simple light weight long-beam is couples to draft animals. Mounted behind the tine is a seed and metering device drive wheel which may act as a seed covering device and press wheel. The operator walks behind the seed drill and controls operation through handlebars. The plant population ranges from 36,000 plants/ha to 53,000 plants/ha for maize. It can seed ~2 ha/day.

YT-2B-1 (Figure 4)**:** The YT-2B-1 animal traction, hand controlled planter was specifically designed for planting beans and maize in China. The operator walks behind the seed drill and controls operation through handlebars. It is suitable for seed and fertilizer, with the working width of 600 mm and working depth of 30-50 mm.


Figure 3 Animal traction direct planter

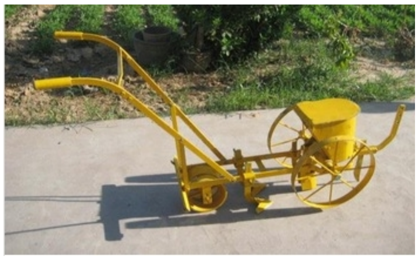
Figure 4 YT-2B-1 animal traction planter

Jambo direct seeder (Figure 5)**:** The Jambo direct seeder can be used for planting maize, soybeans, sunflower and cowpea. It has two containers for seed and fertilizer, a disc to cut residue, a furrow opener to place the fertilizer, a wheel to control the planting depth. The operator walks behind the seed drill and controls operation through handlebars. The total weight of this seeder is 30 kg, and the total working width is 100 mm.

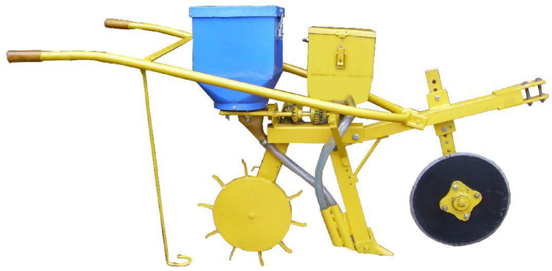
Figure 5 Jambo Direct Seeder

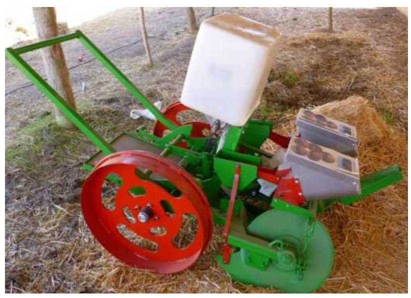
Figure 6 Angled single disc seed drill

Angled single disc seed drill (Figure 6)**:** This seeder is designed for planting maize. It can be pulled by an animal as a two-row seed drill. It has an adjustable depth gauge wheel to control the planting depth from 20 mm and 50 mm, 400 mm angled discs to cut crop residue and two press wheels to firm the seed row. The operator walks behind the seed drill and controls operation through a beam.

The Li seeder and Jab planter are representative manual planting tools for various kinds of grains and other crop seeds (Table 1). Both of them allow the farmer to fertilize and sow the seeds simultaneously. The minimal soil disturbance Jab planter has been used for a long time. However, its performance in muddy or surface crusted soils is poor. The Li seeder is a newer type manual seeder using a chopping action which when compared to Jab planter, increases soil disturbance but performs better in adverse soil conditions, i.e. wet soils.

Table 1 Comparison of manual and animal-driven seeders

Machine name	Utility	Power	Working efficiency	Main structures and Properties	Features
Li seeder	maize; soybean	human labor	0.2-0.3 ha/day	A beak; a seed pipe; a fertilizer bag	Aeparate plant seed and fertilizer; good performance in wet soil
Jab planter	maize	human labor	0.5 ha/day	Two containers; a wooden frame; a handle;	Plant from a standing position; adjustable seeding rates; minimal soil disturbance
YT-2B-1	maize; soybean	animal	1.5 ha/day	Two wheels and tines; a frame; a roller; working depth: 30-50 mm; working width: 600 mm	Light; cheap; less time and energy required
Animal traction direct planter	maize; beans	animal	2 ha/day	A ripper tine; two hoppers; a long-beam; a drive wheel; plant population: 36,000 plants/ha to 53,000 plants/ha for maize	Auitable for drilling seed and fertilizer simultaneously
Jambo direct seeder	maize; soybeans; sunflower	animal	/	Two containers; a disc; a furrow opener; a wheel; working width: 100 mm	Good residue handling capacity
Angled single disc seed drill	maize	animal	/	Two press wheels; single disc; sowing depths: 20 - 50 mm	A two-row seed drill; heavy

Direct seeding implements using animal traction were designed to manage residue whilst seeding and fertilizing in no-tilled soils, so they normally have discs to cut through the surface residue and furrow openers to place the fertilizer and seed. However disc penetration in wet residue and hard soils can be a limitation. These seeders are generally small and light which can also be a disadvantage for seeding depth and control.

3 No/minimum-till seeders powered by two-wheel tractors

Although two wheel tractors (2WT) are popular among small farmers, the development of conservation farming implements suited to two wheel tractors has largely been ignored until recently. Two wheel tractors have been used by small farmers in many parts of the world for over 30 years, and they are essentially the first mechanical progression from animal traction systems[21]. To handle crop residue the design of no/minimum-till seeders can include either passive or active anti-blocking devices. Active anti-blockage devices are power driven cutting or clearing systems of residue near the planting tine. Some typical passive and active anti-blocking no/minimum-till seeders for 2WT are discussed as follows.

3.1 Passive anti-blocking no-till seeders

ACIAR-ROGRO seed drill (now being sold as the ARC Gongli seed drill)[22,23]: This ACIAR-ROGRO seed drill (Figure 7) is a no-till multi-crop planter. The tool bars of this machine can be fitted at various points to the frame to adjust bar spacing, and the main frame can also carry tools. Up to four tines can be fitted to the tool bars which can be adjusted vertically and laterally along the bars. The twin seed and fertilizer boxes are mounted on either side of the handlebars of the power tiller to ensure good clearance for the tines and tool bar. The front box is fitted with Asian made dual system fluted roller seed meter, which can meter seed of all sizes and deliver fertilizer at variable rates as required.

China Agricultural University re-designed and modified the ACIAR-ROGRO seed drill for 2WT and is now being sold as the ARC Gongli seed drill. The seeder (Figure 8) is primarily designed for close drill planting of rice and wheat. Variable tine layouts are available to seed in different soil and residue conditions. Integral fertilizer box allows for accurate fertilizer placement in seed rows. Integral press wheels firm the soil to improve soil to seed contact and plant emergence.

Figure 7 ACIAR-ROGRO tined seed drill

Figure 8 ARC GONGLI seed drill

Lao built 2WT seed drill: This 2WT zero tillage seed drill (Figure 9) was developed to directly sow dry season rice. It has a tool bar to mount tines, a single seed box and press wheels to firm the seed row. It has similar design features with that of the ACIAR-Rogro seed drill.

Knapik seed drill: This single row no-till seed drill for 2WT (Figure 10) can be used for maize and soybean. It consists of a cutting coulter, with a following seeding tine, a double disc opener for fertilizer application, and a set of paired press wheels at the rear. A seed metering drive wheel mounted on the side also acts as the depth control mechanism. Various hitches are available for different types of 2WTs.

Figure 9 Lao built 2WT seed drill

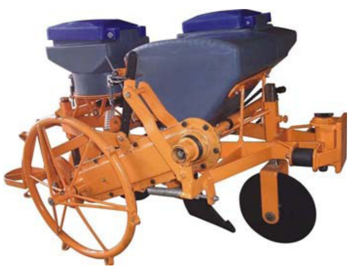

Figure 10 Knapik seed drill

National zero till multi-crop planter: This is a four-row multi-crop planter (Figure 11) which is attached behind a 2WT rotary tiller with the aid of clamps. The existing rotavator (rotary tiller) is retained, and this seed drill is fitted to the rear (not necessarily no till). Four flat inclined plate seed meters are fitted. No press wheels or other seed firming devices are available. Depth control wheels are provided on both sides of the planter.

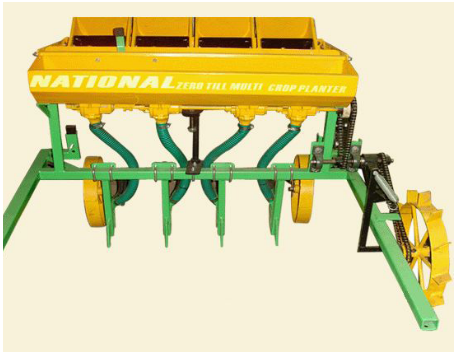

Figure 11 National zero till multi-crop planter

Knapik 2 WT seed drill: This two row Knapik (Brazilian) 2 WT seed drill (Figure 12) can be used to sow maize and beans. A classic seed drill, with disc openers for seed and fertilizer, angled press wheels, and an operator platform. The front discs sow the seed, and another set of discs applies the fertilizer. Seed metering is by a horizontal flat plate system. Two pairs of paired press wheels are at the rear. The large central steel drive/depth wheel is mounted in the center of the seed drill. Large diameter tractor wheels are fitted for increased traction.

Single row Fitarelli CA seed drill[24]: This CA seed drill (Figure 13) consists of a cutting coulter, followed by a tine opener, with a steel drive wheel/press wheel behind. It features a horizontal flat plate metered seed box and a fertilizer box. The rubber tired wheel on the side is for stability and depth control. There are also a small foot pegs for the operator.

Figure 12 Knapik 2 WT seed drill

Figure 13 Single row Fitarelli CA seed drill

3.2 Active anti-blocking no/minimum-till seeders

2BFG-100 model seed and fertilizer machine: This 2BFG-100 model seed and fertilizer machine (Figure 14) is widely used for sowing wheat and rice in 'one pass'. This model is composed of a rotary tiller combined with a seeding and fertilization unit with stand and road wheels. It can be used for either strip and no-till depending on the number of tine fitted and their design. The seed is dropped down along rows and evenly distributed through row units. In a single operation it prepares the soil, controls weed growth, and plants seed as well as applies fertilizer. It is 1160 mm wide allowing it to plant up to six rows of a crop, and covers 0.07-0.21 ha/h.

ACIAR/BARI/CIMMYT modified 2BG-6A rotary tillage seed drill: This Asian made seed drill (Figure 15) is a one pass strip till seeder for wheat and maize. The seed box mounted above the tillage unit delivers seed and fertilizer accurately to narrow profile soil openers immediately behind the strip tilled zone. This differs from the 2BFG-100 as tines are positioned to deliver all the seeds to the bottom of the tilled layer, and into the untilled subsoil if it is required. The steel roller is replaced by a 25 mm axle with press wheels behind seed rows to ensure good seed-soil contact. The row spacing and depth of planting are adjustable to meet different needs. The number of rows that can be planted depends on soil and residue conditions, and the power available from the traction unit.

Figure 14 2BFG-100 seed and fertilizer machine

Figure 15 ACIAR modified 2BG-6A rotary tillage seed drill

2BG-6A: This 2BG-6A planter (Figure 16) is primarily designed for one-pass planting of rain-fed crops following rice harvest either in full till or strip till configurations. This planter is bolted to a Chinese two wheel tractor in place of the standard rotavator with an attached seed box. Metered seed is delivered to wide profile soil openers through seeding tubes, dropping into the soil prepared by the rotary tillage or strip till operation. Soil is lightly firmed by an attached steel roller which also acts as depth control. At 1200 mm wide it can plant up to six rows at 200 mm row spacing. It can provide full rotary tillage or strip tillage and covers 0.14-0.20 ha/h.

VMP[25]: This VMP (Versatile Multi Planter) (Figure 17) has been developed in Bangladesh for strip till sowing of spring crops. It has a square section tiller shaft which is bolted on blade holders. There are four tiller blades at each site mounted in blade holders to match the four row seed and fertilizer boxes, and row spacing and tillage options are infinitely adjustable. In order to ensure deep seed placement an optional set of tine type soil openers can be fixed on a separate tool bar as required in marginal moisture conditions. The net weight of VMP is 152 kg and its overall dimensions are length 990 mm, width 1 220 mm, and height 840 mm.

2BFM (DC) 6: This planter (Figure 18) was developed by a Canadian funded project near Chengdu for strip till operations. It has a three-point hitch for the cultivator that is powered by a 22 hp diesel engine. The planter components are arranged close to center of mass instead of hanging far off the back, which makes it much easier to lift the machine out of the soil while seated via the bushing/hinge on the cultivator itself. Therefore, the operator can quickly turn in the field without dismounting. It can also be driven safely and quickly on the road to next destination. It is 1380 mm wide allowing it to plant up to 6 rows, and covers 0.13-0.26 ha/h.

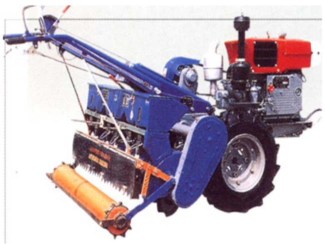

Figure 16 2BG-6A planter

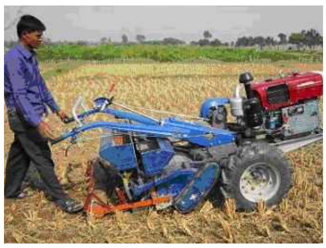

Figure 17 VMP planter

Figure 18 2BFM(DC)6 planter

The Knapik seed drill, Single row Fitarelli CA seed drill and Knapik 2 WT seed drill all have an operator platform for operator to stand on, which saves walking and adds extra weight to the back of the seed drill (Table 2). The ACIAR-ROGRO seed drill has been manufactured to meet the needs of small farmers in South Asia for both no-tillage and traditional tillage systems. The ARC Gongli may have performed better if the maize stalks had been in smaller lengths, or chopped. The National zero till multi-crop planter has no press wheels or other seed firming devices.

Table 2 Comparison of no/minimum-till seeders powered by two-wheel tractors

Machine name	Utility	Type of anti-blocking	Seeding rows	Main structures and Properties	Features
ACIAR-ROGRO seed drill/ ARC Gongli seed drill	various crops	passive anti-blocking	three rows	A tool bar; some tines; three seed metering devices; 0.2 ha/h	The number and spacing of press wheel is adjustable
Lao built 2WT seed drill	dry season rice	passive anti-blocking	three rows	A tool bar; some tines; a huge box ; some press wheels; three seed metering devices	Direct seeding of rice conducted in sandy soil paddy fields
Knapik seed drill	maize; soybean	passive anti-blocking	single row	A seeding tine; some press wheels; a seed metering device	An operator platform for standing and adding weight
National zero till multi crop planter	various crops	passive anti-blocking	four rows	Some depth control wheels; four seed metering devices	No press wheels
Knapik 2 WT seed drill	maize; beans	passive anti-blocking	two rows	Some disc openers; some angled press wheels; two seed metering devices	A classic seed drill; drive/depth wheel in the center
Single row Fitarelli CA seed drill	maize	passive anti-blocking	single row	A cutting coulter; a tine opener; two boxes; a seed metering device	A small operator platform for standing
2BFG-100	wheat; rice	active anti-blocking	six rows	A rotary tiller; some stand and road wheels; six seed metering devices; 0.07-0.21 ha/h	A rear double disc and seat
ACIAR modified 2BG-6A rotary tillage seed drill	wheat; maize	active anti-blocking	four rows	Two boxes; some tines; some press wheels; four seed metering devices	Row spacing and depth of planting are adjustable; no fertilizer box
2BG-6A	rain-fed crops	active anti-blocking	six rows	A steel roller; six seed metering devices; 200 mm row spacing; 0.14–0.20 ha/h	Half of the blades left twist, half right twist；no rear wheel
Versatile Multi Planter	spring crops	active anti-blocking	four rows	A square section tiller shaft; four seed metering devices; 0.07 ha/h	Infinitely adjustable row spacing
2BFM(DC)6	wheat	active anti-blocking	six rows	A rear wheel; two boxes; six seed metering devices; 0.13–0.26 ha/h	All the parts close to center of mass

Both 2BFG-100 and 2BFM(DC) 6 planters have a rear road wheel and seat that enable the operator to be protected and quickly get to the next task. The ACIAR modified 2BG-6A rotary tillage seed drill can be used in both traditional tillage systems as well as conservation farming (no and minimum tillage) systems. The 2BG-6A is better suited to irrigated than rainfed situations, where optimum surface soil moisture can be assured. The Versatile Multi-Planter (VMP) differs from all other rotary seed drills as it has a square section tiller shaft with bolt-on blade holders, which improves flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis.

All the above two wheel tractor seeders that are full rotary tillage or strip tillage devices depending on rotary blade number and design cause significant soil disturbance. However, there are two 2WT seeders that use flail rotors to clear the tine path without engaging the soil. Based on the happy seeder designs of Dr John Blackwell in Australia, the Indian and Chinese versions are currently under testing and further development (pictures not available). The Chinese version is multi-crop seeder powered by a 20 HP engine with narrow profile inverted T tines with individual press wheels.

4 No/minimum-till seeders powered by four-wheel tractors

Larger linkage CA seeders for four-wheel tractors suitable for large acreages, and high horsepower tractors incorporate passive anti-blockage systems, such as the John Deere 750 and Great Plain 1 500 disc type no-till planters. These disc-type seeders are heavy at 800-1 000 kg/m can incorporate row clearance devices and cutting discs to avoid blockages. Most of these are too large and highly unsuitable for Asian farms. In order to suit the smallholder farming system in Asia, smaller passive anti-blocking no-till seeders were developed to handle low residue cover conditions (wheat or rice residues) and some active anti-blocking methods were used for heavy residue cover fields. However, uptake of active anti-blockage CA seeders was less than passive anti-blockage types due to their more complex structure and higher power consumption[26-28]. Some typical passive and active anti-blocking no/minimum-till seeders are shown as follows.

4.1 Passive anti-blocking no-till seeders

4.1.1 No-till wheat seeders

2BMF-7 no-till wheat seeder: The 2BMF-7 (Figure 19) uses the multi-beam structure to achieve anti-blocking. In this design, residue clearance is maximized by mounting three openers on the front, two on the middle and two on the rear bar of the machine. During seeding, the machine used narrow-point openers and press wheels to place and firm seed and fertilizer at depths of 50 mm and 100 mm, respectively. The machine is set to 160 mm row spacing, commonly used by local farmers, giving an operating width of 1.12 m.

2BMF-11 no-till wheat seeder: The 2BMF-11 (Figure 20) was developed by China Agricultural University for a 40 kW tractor. Residue clearance was maximized by mounting five openers on the front and six on the rear bar of the machine. This machine used narrow point openers and press wheels to place and firm seed and fertilizer at depths of 50 mm and 100 mm, respectively.

Figure 19 2BMF-7 no-till wheat seeder

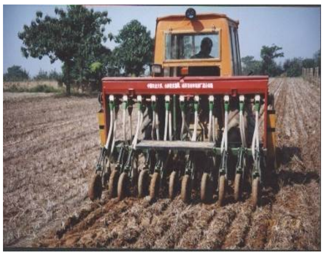

Figure 20 2BMF-11 no-till wheat seeder

4.1.2 No-till corn seeders

2BMQF-4 no-till corn seeder: The 2BMQF-4 (Figure 21) uses the disc coulter combining with dual teeth discs to achieve anti-blocking. The leading disc coulter cuts the residue, and then the following dual teeth discs provide residue clearance from the seeding row; thus the narrow-point opener can easily complete no-till seeding. Furthermore, the wide row spacing (450-650 mm) for maize assists high trash flow.

2BYCF-3 no-till corn seeder: The 2BYCF-3 no-till corn seeder (Figure 22) uses a roller mounted on the tine to shed residue. When the seeder is working the residue in front of the tines is shed to the side by the roller. A seeding tool and precision meter is shielded to prevent the residue from falling back into the seed furrows.

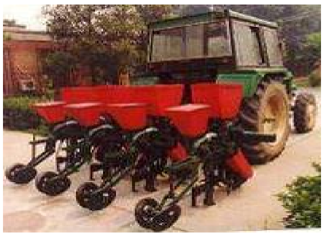

Figure 21 2BMQF-4 no-till corn seeder

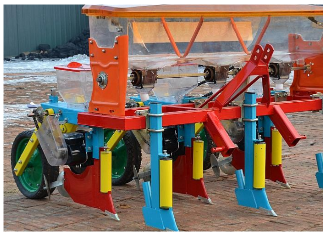

Figure 22 2BYCF-3 no-till corn seeder

The passive anti-blocking no-till seeders powered by four-wheel tractors usually operate on medium size farms for planting more than three rows (Table 3). They normally utilize a multi-beam structure to ensure trash flow and ground clearance and/or utilize anti-blocking components (rollers) to allow residues to flow through the seed drill, when seeding in both heavy and light residue cover fields.

Table 3 Comparison of passive anti-blocking no-till seeders powered by four-wheel tractors

Machine name	Utility	Power	Seeding rows	Anti-blocking method
2BMF-7	wheat	four-wheel tractor	seven rows	multi-beam structure
2BMF-11	wheat	four-wheel tractor	eleven rows	five openers on the front and six on the rear bar
2BMQF-4	corn	four-wheel tractor	four rows	disc coulter combining with dual teeth discs
2BYCF-3	corn	four-wheel tractor	three rows	rotary drum

4.2 Active anti-blocking no/minimum-till seeders

These machines typically use tractor power to drive devices to cut and/or push aside crop residue, to clear the path for the soil openers. The strip rotary hoe mini-till seeders combine powered rotary blades and furrow openers to clear and engage the soil; the powered disc mini-till seeder achieves anti-blocking by embedding the furrow opener in the powered disc; the powered chain no-till seeder uses a powered chain finger and opener in combination; the strip chop no-till seeder utilizes powered chopping blades with a disc opener; the powered coulter mini-till seeder combines a powered disc and powered coulter; the powered straight knife mini-till seeder uses a powered straight knife and opener; the powered residue-throwing finger no-till seeder combines a powered residue-throwing finger and opener. These above mentioned types of seeder are explained as follows.

Strip rotary hoe mini-till seeder: General anti-blocking is achieved by strip rotary tillage (Figure 23) with varying levels of soil disturbance depending on the number of blades and their shape. In the operation, the powered rotary blades loosen most of the seedbed, cut off stalks and break roots, so the broad profile openers can pass through easily. Normally, in order to reduce blade wear the rotary hoe cultivator operates at low speed (about 200 r/min). However to ensure complete effectiveness, the chopper should be operated at higher speed (over 1 500 r/min).

Strip chop no-till seeder: The strip chop no-till seeder's (Figure 24) power driven chopper blades mounted beside the opener cut off or push away the stalks caught on the opener. The following disc opener pushes chopped stalks or residue to the side and opens the soil, for effective seeding.

Figure 23 Strip rotary hoe mini-till seeder

Figure 24 Strip chop no-till seeder

Happy seeder[29,30]: The general ideas for the anti-blocking of earlier designed happy seeder (Figure 25) is that in the operation, the straw management unit cuts, lifts and throws the standing stubble and loose straw caught on the tines, onto the sown area behind the seed drill, which sows into near bare soil.

Turbo happy seeder[31,32] and Chinese modified turbo seeder: High speed rotating flails are mounted immediately in front of the non-adjustable inverted T narrow profile planting tines to have an effect of residue clearance and anti-blockage on the turbo happy seeder (Figure 26).

Figure 25 Happy seeder

Figure 26 Turbo happy seeder

The Chinese modified turbo seeder (Figure 27) is based on the happy seeder designs of Dr John Blackwell with significant differences of twin forward rotating flail rotors, with the additional rear rotor set further back for inter-row clearing under very heavy residue conditions. Furthermore, the twin forward rotating flail rotors operating at 1 400 r/min at the shaft provides superior anti blocking operations and reduces power requirements as well.

Powered disc mini-till seeder: The general idea for the anti-blocking of powered disc mini-till seeder (Figure 28) is to use a scalloped powered disc, to cut roots and residues. These are followed by shark tooth row clearance devices. The following narrow-point opener opens the slot for the seed and fertilizer.

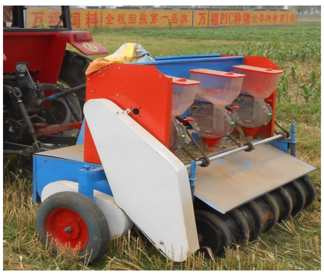

Figure 27 Chinese modified turbo seeder

Figure 28 Powered disc mini-till seeder

Powered coulter mini-till seeder: The anti-blocking of powered coulter mini-till seeder (Figure 29) uses a powered disc and powered coulter, driven by the tractor, cut the corn root and residue. The following narrow-point opener open the furrow further and prepares the seedbed for the seeds without residue blockage.

Powered straight knife mini-till seeder: The powered straight knife mini-till seeder (Figure 30) utilizes a straight knife to cut the corn roots and residue. The following opener can open the furrow further and produces a seedbed for the seeds without the interference of residue.

Figure 29 Powered coulter mini-till seeder

Figure 30 Powered straight knife mini-till seeder

Powered chain no-till seeder: The powered chain no-till seeder (Figure 31) uses tractor power to drive a chain finger. Any residue which is not cut off is thrown to either side of the opener by the action of the chain finger, and a clean seeding strip is formed to avoid blockage.

Powered residue-throwing finger no-till seeder: The powered residue-throwing finger no-till seeder (Figure 32) uses a tractor driven residue-throwing finger, which throws the straw in front of the tine to either side of the opener, clearing the path of residue for the soil opener.

Figure 31 Powered chain no-till seeder

Figure 32 Powered residue-throwing finger no-till seeder

5 Conclusions

Currently there are small to medium size no/minimum-till seeders which can promote the extension of CA in Asia with variable levels of soil disturbance and residue management, particularly for SLH farming areas. However, their development is slow and their uptake limited. In order to develop high-performance no/minimum-till seeders, the following recommendations can be made.

1) Policy support is crucial for the rapid development of the seeders, including providing adequate research projects, funds and establishing proper guiding mechanisms for the implementation of CA. A specific targeted subsidy system that supports the implementation of CA would be an advantage.

2) Although a variety of no-till seeders have been developed and fabricated, some improvements can be made to suit a range of crops and soils in different geographical regions.

In SLH and marginal cropping areas, the limitations in terms of natural resources and farm size, constrain the purchase of large purpose built (imported machinery), therefore, the no-till seeders need to be light-weighted, simple, affordable and suited to low horsepower tractors.

In clay soil areas, no-till seeders should use tines instead of discs, to facilitate planting and simplicity in design and operation.

In no till fields, but especially in mountainous areas, agricultural production is hampered by natural obstacles (rough surfaces), therefore all no-till seeders should have depth-control and contour following capability with individual soil covering devices and pressing wheels.

3) Anti-blocking mechanisms play an important role in the no-till seeder, especially in high residue conditions. Development of no-till seeder anti-blocking technology is necessary to ensure good performance and adoption of the seeders. Efforts could be made to:

① Pay more attention to the property and principal of anti-blocking mechanism, and improve testing methods to

● Reduce the speed of anti-blocking mechanism and improve the ability of directionally scattering straw to save energy;

● Do more research on the motion law and motion locus of the scattered straw via advanced testing facilities;

② Obtain more knowledge of the geometric and mechanical properties of crop residue and select appropriate cutting units and anti-blocking methods according to the geometric and mechanical properties of crops.

4) Universities, scientific research institutions and enterprises should have closer cooperation to design suitable no/minimum-till seeders for different cropping areas.

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