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Actual Challenges: Developing Low Cost No-Till Seeding Technologies for Heavy Residues; Small-Scale No-Till Seeders for Two Wheel Tractors

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Small farmers from South Asia and other parts of the world use two wheel tractors as the main means of land preparation and other farm operations due to small farm and field size combined with an affordable price. These units have become very popular, and over 500,000 are manufactured annually worldwide. There are over 350,000 operating in Bangladesh alone. Two low cost and robust no-till seeders to suit two wheel tractors (12HP) have been developed at the Wheat Research Centre (WRC), Dinajpur, Bangladesh (with support from the Australian Centre for International Agricultural Research). This follows initial research and development work assisted by CIMMYT and Bangladesh Agricultural Research Institute from 1995 to 2004.

A. No till seed drill

This drill is structurally improved, lighter and more versatile than the original prototype. A fertiliser attachment has now been fitted, residue clearance is improved, and the seed drill is easily adjustable for tine layout, row spacing, and depth of seeding. Seed and fertiliser rates are easily adjusted and the machine can conveniently meter all seed sizes from maize to mustard. Press wheels have also been fitted. Attachment hitches for both Chinese made, as well as Thai made two wheel tractors are available.

B. Modified rotary tillage seed drill

This standard rotary tillage drill has been modified by the provision of a fertiliser attachment and an improved seed metering system. Seed placement has been enhanced by the incorporation of superior tine openers. Press wheels have also been fitted. It can be used as a 100% tillage implement, or as a strip tillage seed drill.

The no till seed drill has been intensively tested in farmer's fields in NW Bangladesh for wheat, maize, pulses and rice planting through moderate densities of cereal residues without plugging. Two wheel tractors can pull 4 tines in light soils and 3 tines in heavy soils. It has generally performed well. However, it has done a mediocre job in some hard setting clay soils.

The rotary tillage drill in either strip or full tillage mode has proved to be successful under practically all conditions in Bangladesh. This seed drill generally produces a satisfactory environment for crop establishment, with good seed placement and a fine tilth of soil, except under very wet conditions, when slot smearing by the tractor blades still occurs. Both implements are suitable for traditional or conservation farming systems. Seed placement and depth control in both machines is greatly improved, by the provision of superior tines and press wheels. Plant establishment has improved by17-25% compared to zero press wheel treatments. The seeders are simple, light in weight, and could be fabricated by local farm machinery manufacturers. Costs are expected to be < US$500 once production scales up.

Key words: Two wheel tractor, zero tillage, strip tillage, seed drill, rotary seed drill

Small farmers from South Asia, and other parts of the world use the power tiller (two wheel tractor) as the main means of traction for tillage and other farm operations. These units have become very popular, and over 500,000 are manufactured annually worldwide. There are over 350,000 operating in Bangladesh alone (Alam et al.,2007).

Many small farmers in South Asia are aware of the benefits of conservation farming systems including minimum and zero tillage. However they lack the means to put into action these farming systems due to the unavailability of a suitable seed drill.

The benefits of conservation farming systems are well known, and this system of farming has reached an advanced stage in many parts of the world. However the equipment to put this into practice has been principally designed for traditional four wheeled tractors and there are no commercially available conservation farming implements (principally seed drills) for two wheel tractor. Late planting is one of the main constraints to successful crop production in this region. Saunders (1988) reported that a linear decline in yield of 1-1.5% per day was observed when wheat was planted after the end of November irrespective of short or medium duration varieties. In this case increased nitrogen applications can not compensate for the decline in yield from late planting. Zero tillage option increases the water and nutrient use efficiency by allowing timely planting and producing high yields (Hobbs, 2003).

Haque et al (2004) reported on the fabrication and testing of a power tiller operated zero tillage seed drill in Bangladesh. The development and testing of a prototype was conducted between 1999 and 2004. Results indicated a cost saving of 83-89% over the traditional tillage system, and a time saving of 10-15 days, when planting *rabi* crops into *aman* rice residue in October/November. The research was funded by USAID, FAO and carried out by WRC, CIMMYT Bangladesh. However funding ceased in 2004, and no commercially available implement has been produced.

Justice *et al* (2004) also reported on an associated project in Bangladesh where a commercially available Chinese Power Tiller Operated Seeder (PTOS) was modified for strip tillage. This also was used to plant *rabi* crops into *aman* rice residue in October/November. One pass full tillage was compared to strip tillage. In the strip tillage treatment, half of the tiller blades were removed and the seeds placed into the tilled strips. Field capacity of the seed drill was increased by 25%, fuel consumption was reduced by 20% and planting cost reduced by 8% compared to the full tillage treatment. Adoption of the power tiller operated rotary tillage seed drill has been more successful and 400 units were sold in Bangladesh between 2005 and 2007. However ongoing research into this planting system also ceased in 2004.

In 2006 the authors realised that the ongoing research and development of seed drills for two wheel tractor was effectively at a standstill. Also we realised that this technology, although developed for Bangladesh, could also be applied to other South Asian countries where two wheel tractors is the main farm traction unit (East India, Cambodia, Laos PDR, Vietnam, Indonesia, and Mainland China).

Materials and Methods

In mid 2007, application was made to the Australian Centre for International Agricultural Research (ACIAR) who agreed to fund a continuation of this research work. An original Wheat Research Centre (WRC) made zero till (ZT) drill, and a standard rotary drill were modified in Bangladesh in late 2007 at WRC, Dinajpur and field work with these units commenced in November 2007. In addition, A Chinese made (Dong Feng brand, 12Hp) two wheel tractor was imported into Australia in early 2008, along with a rotary drill. This tractor and seed drill was used as the test modules for further prototype seed drill fabrication. Improved examples of the two seed drill types were fabricated at Spring Ridge Engineering using local expertise. This experience has been acquired in the manufacture of larger zero tillage seed drills in Australia. They are as follows:

Tined Type Zero Till Drill. (Tool bar mounted)

This implement is essentially an improved model of the original tined type ZT drill as described by Haque *et al* (2004). A much improved three bar tool bar frame that is 1000mm. wide has been made up from 50mm x 4mm thick square tube. There are two side rails, of 75mm wide x 10mm thick x 825 mm long flat steel. Holes have been drilled in the side rails every 90mm. The tool bars can be fitted at various points to allow adjustable bar spacing. The resultant frame can be set up as a one bar, two bar, or three bar implement at bar spacings of up to 700mm.

Up to four tines can be fitted to the tool bar. The tines are made of 50mm x 12mm high tensile steel. Each tine is 700mm long, and is fitted with a non-detachable point (which is tungsten tipped) and a seed tube. Each tine is in a holding bracket and is clamped to the bar by 50mm square “U” bolts. Tines can be adjusted both vertically and laterally along the bars. Mounted 250mm diameter x 50mm wide press wheels are fitted to a 25mm axle at the rear of the implement. Press wheel spacing is adjustable, and the number of press wheels can be varied to suit the number of tines being used for sowing.

Dual two row bi-compartment boxes are fitted, with the front compartments for seed, and the rears for fertiliser. In order to ensure good seed drop, and allow good clearance for the tines and tool bar, the boxes are mounted either side of the handlebars of the tractor. Box position is adjustable vertically and laterally to allow for suitable fitting to different types of two wheel tractor. Fig.1 shows the two wheel tractor zero till drill.

The front box is fitted with Asian made dual system fluted roller seed meters. These meters can measure out seed of all sizes from maize to mustard at variable rates. A second set of fluted roller meters in the rear box. These meters deliver fertiliser also at variable rate as required. Toolbar frame also facilitated fixing different type of seed metering devices and other implements.

Drive to the seed and fertiliser boxes is by a chain drive, from the main drive wheel of the tractor intermediate shaft above the front bar and hitch. A clutch is fitted to the intermediate shaft. External chains then drive to the metering shafts.

Modification to Rotary Tillage Seed Drill

In the standard commercially available arrangement this Asian made seed drill is set up for one pass seeding with 100% rotary tillage. The seed box is set up above the tillage unit, and the seed delivered by tubes and lightweight soil openers to the soil immediately behind the tilled zone. A steel long roller then lightly firms the soil behind the seed drill. No fertiliser box is available.

The authors noted that seed positioning into the tilled soil behind the unit was poor. Some seeds were on the soil surface, some at intermediate positions in the tilled zone, and some were at the bottom of the tilled layer. Seed pressing was also poor. This setup may be satisfactory in optimum moist soils, or where the new crop is to be 'watered up' by irrigation, or where follow up rain to germinate the seeds is assured. However in dry soils, or *rabi* crop planting with no follow-up rain, seed placement is unsatisfactory.

Fertiliser application is by a separate operation, and fertiliser cannot be positioned in the seed row with the seed. The seed box was removed and an add-on tool bar, the width of the tiller (1200 mm.) was made up. This tool bar is also of 50mm x 50mm x 4mm square bar, with similar tines to the tined unit described earlier. The bar is positioned immediately above and behind the tiller. It is attached to the main frame of the tiller. Tine type openers are positioned so that all the seeds can be delivered to the bottom of the tilled layer, and into the untilled subsoil if required. Fig. 2 shows the rotary till drill. The steel roller was removed, and replaced by a 25mm axle with press wheels similar to the tined unit.

Figure 1. Two wheel tractor zero till drill

Figure 2. Two wheel tractor driven strip till drill

Seed and fertiliser boxes similar to the boxes used on the no till drill are fitted. Drive from the two wheel tractor axle, through an intermediate shaft is similar to the no till drill.

General Field Performance

A prototype of each of the Australian made ZT drill and the rotary drill modification were sent to Bangladesh in mid 2008. They are currently undergoing exhaustive evaluation behind a Chinese made (Dong Feng) two wheel tractor.

The ZT drill generally has excellent penetration when used for *rabi* planting in Bangladesh. The 12HP two wheel tractors will pull three tines in the sandy loam soils of NW Bangladesh under most conditions. It will also operate three tines in the clay soils of the Barind High Tract under ideal conditions. However in clay soils when the topsoil is dry and the moist soil layer is at 8-10cm. a 12HP tractor could not operate three tines, and there was excessive wheel slip and vibration.

Many of the clay soils of the Barind High Tract are poorly structured, and when the tined seed drill is operated, the topsoil breaks into large dry clods. Seed cover and pressing under these conditions is poor. There has also been some slot smearing in clay soils under wetter than ideal conditions.

The modified rotary drill has proved to be successful under practically all conditions in Bangladesh. This seed drill generally produces a satisfactory environment for crop establishment, with good seed placement at the bottom of the slots and a fine tilth of soil over the seeds, except under very wet conditions, when slot smearing by the tractor blades still occurs. It has been evaluated as a 100% tillage unit, or as a strip tillage machine. In strip tillage mode, strip widths from 20-50mm. have been tried, with the narrow strip system disturbing less soil. However depending on tractor blade shape and slot width, some disturbed soil from the strips is thrown into the inter-row spaces, and this sometimes results in insufficient cover for the sown seeds in the seed rows.

With both drills the addition of press wheels has been very positive. Loose disturbed soil is considerably compacted over the seeds in the planted rows. Increases in crop establishment rates have been observed. The two wheel tractor driven zero till drill has been evaluated by stress analysis and computer simulation and found to be structurally adequate for the tasks for which it was designed (Fraser, 2008).

Results and Discussion

Data from the last three years using the old version zero till drill, and earlier versions of the modified rotary tillage drill as well as the latest models have been summarised and are presented below. Field performance of the ZT drill for wheat, maize, mungbean establishment and comparisons with the standard tillage system in several farmers fields indicate that wheat can be established immediately after rice using the ZT planter. Data is shown in Table 1. Soil moisture content is the key factor for utilization of ZT machine. It is very difficult to operate drill over soil moisture 35% due to excessive tiller wheel slippage. Effective field capacity of the drill for wheat, maize and mungbean planting is shown. The effective field capacity for maize planting was higher than wheat planting due to wider sowing width in maize planting of 1.30 m (2 lines spacing 65 cm) but in wheat seeding it was 80cm. Fuel consumption figures are also shown. Field efficiency during maize planting 75% which was comparatively lower than wheat and mungbean planting due to more time loss with adjustments.

Table 1. Field performance of power tiller operated ZT planter

Sl No.	Parameters	Wheat	Maize	Mungbean
1	Fuel consumption, lit./hr	1.20	1.2	1.2
2	Speed of operation, km/hr	2.50	2.5	2.5
3	Soil moisture content, %	24	27	25
4	Effective field capacity, ha/hr	0.15	0. 20	0.20
5	Field efficiency, %	75	75	75

Crop performance of the ZT planter is shown in Table 2. Originally the persian wheel type seed metering device was used, but this has now been replaced with the dual system fluted roller meters of Chinese origin. The average widths of opening slots are shown. It was found that slower speed is comparatively better for seed placement into the slots. The adjustment of row spacing between two successive passes depends on operator skill and experiences. The width of slot during maize sowing was bigger due to the slightly deeper position of the opener. No till seed drill minimized turn around time 10-12 days between the two crops. Farmer can establish crops utilizing the residual soil moisture without extra land preparation. As no need pre irrigation, that means water, electricity, diesel fuel and valuable time to be saved.

Table 2. Crop performance on zero tillage

Sl No	Parameter	Wheat	Maize	Mungbean
1	Variety	Prodip	NK 40	BARI Mug-6
2	Seed rate, kg/ha	120	20	20
3	Row to row spacing, cm	20	65	30
4	Depth of planting, cm	3-4	4-5	3-4
5	Width of opening slots, cm	2-3	2.5-3.5	2-3

Table 3 shows the variations of seeding depth and plant population with and without press wheels. Press wheels cover the seeding line which ensures superior seed/soil contact. In the zero press wheel seeded plot direct sunlight and bird damage also contributed to lower establishment. Similarly, in maize and mungbean plots, plant populations in press wheel plot were higher than without press wheel plots.

Table 3. Effect of press wheels on plant stand

Sl No.	Name of crop	Seed germination, %	Seeding depth, mm		Plant population/m^2 (CV %)		
			(+) Press wheel	(-) Press wheel	(+) Press wheel	(-) Press wheel	% Increase
1	Wheat	95	30	20-25	265 (8)	206 (10)	22
2	Maize	90	40	25-40	12(7)	10 (11)	17
3	Mungbean	93	30	30	32(12)	24 (12)	25

The yield of wheat, mungbean and rice in ZT system and conventional method is presented in Table 4. The yield of wheat in zero till method varies from place to place due to land type, soil moisture and weed management. The average wheat yield was found 3.8 t/ha which was 21% higher than conventional method. Mungbean and maize yield were 0.9 t/ha and 8.4t/ha respectively. Maize yield was statistically similar with conventional method. Immediate after T. aman harvest, there was less weed burden and the land was suitable for zero till wheat cultivation. Mungbean was planted immediate after wheat harvest (April 1st week). Planting date should be within March for better crop yield and management. Generally farmers in this area do not grow mungbean conventionally, but plenty of wheat land remains fallow up to T. aman planting June –July and a mungbean cop can conveniently be planted by ZT methods. It was found that BARI mung-6 performed well within this fallow period. It can be harvested within 60-63 days. Last three years demonstration, farmers reported that yield of Aman rice increased average 10-15% over non mungbean planted field. There was a great potential to fit mungeban in rice-wheat cropping system reducing the turn around time. It was also critically observed that zero till wheat was less lodge compare to conventional planted wheat. It was due to not much loose soil as conventional till soil. Three crops can be fitted within a year utilizing the efficient performance of the drill.

Table 4. Comparison of yield between zero tillage and conventional method

Sl No.	Planting system	Yield (t/ha) (CV%)		
		Wheat	Mungbean	Maize
1	Zero tillage system	3.8 (12)	0.90 (13)	8.4(10)
2	Conventional method	3.0 (14)	0.55 (11)	7.6 (14)

Planting cost of wheat, mungbean and maize in zero till with conventional method were presented in Table 5. Planting cost of wheat, mungbean and maize in zero till system were Tk. 1951.27, Tk.1576 and Tk.1576.0/ha**,** respectively. Similarly wheat and maize planting costs were Tk.3740.0 and Tk.7250.0/ha respectively. The planting cost of wheat and maize in zero tillage planters were 48% and 78% less than that of conventional planting method. The cause of variation of planting cost in different crops was different effective field capacity during operation.

Table 5. Comparison of cost (1US$=Tk.69.0) of planting by zero tillage and conventional system

Sl No.	Planting system	Cost of planting (Tk./ha)		
		Wheat	Mungbean	Maize
1	Zero tillage system	1951.0	1576.0	1576.0
2	Conventional method	3740.0	3740.0	7250.0

Farmers are getting more interest using no till drill considering less cost involvement and less effort on seed sowing.

Beak-even use of the zero till drill was shown in Fig.3 and it wascalculated on the basis of fixed cost and variable cost of the drill considering purchase price, interest on investment, and machine life according to Hunt (1995). It was observed that cost per hectare decreased with the increasing of land area use annually. Break even use of zero till drill was found 6.5 ha which indicated that it was the point where no loss no profit. An owner must plan for profitable use of the drill over 6.5 ha land annually.

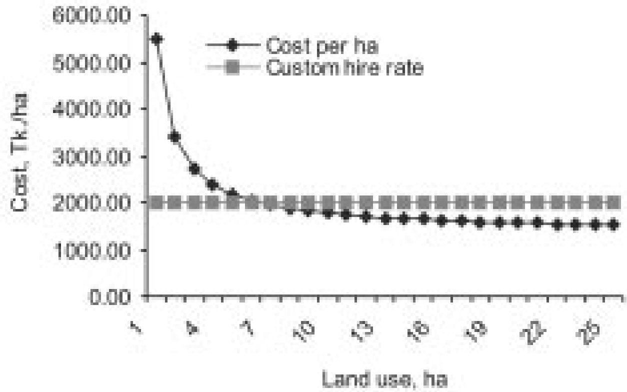

Figure 3. Break even point of zero till drill

Conclusions

The authors consider that these two seed drills have considerable potential to greatly increase productivity in South Asia, and other countries of the world where the two wheel tractor is the main traction unit in farming.

The main task now is to promote this technology and have these drills readily available to farmers at an affordable price. The zero till drill can be readily made from local components in most workshops. Most of the steel for fabrication is simple in design, and tines can be made from old automotive leaf springs. The only specialised items required are the seed meters, which sourced at an inexpensive price from a Chinese manufacturer or local promoter.

The modification to the rotary tillage drill is one which we believe should be seriously considered by the Asian manufacturers of this unit.

Further Work

Zero Till Drill

Although the power tiller ZT seed drill generally operates well, there are avenues for further research that could be contemplated. These include:

- Varying press wheel materials, weight, and profiles to suit different soil types and conditions.
- Different point types on the tines to suit different soil types and cultural operations. (This implement can also be set up as an inter-row cultivator)
- Design and fabrication of a mounted boom spray for power tiller using the seed drill frame.
- The design and fabrication of a small land leveller/road grader for two wheel tractor.

Strip Till Drill

This drill, both in 100% tillage and strip tillage modes is more suited to clay soils which are hard and dry on the surface. The action of the rotary blades pulverises the soil and clods, and there are more small aggregates available in the seed zone for better seed cover and pressing.

- However depending on tractor blade shape and position, some soil is thrown out of the tilled slots and into the inter-row spaces and this can result in insufficient soil being available for adequate seed cover. Further work on the development of shielding to alleviate this problem has commenced.
- Tractor blade shape and seed position can also affect vibration throughout the whole machine as well as the overall quality of the seeding operation. Re-arrangement of blade position and number as described by Lee *et al* (2003) could be a fruitful area of further development of this seed drill.
- In the author's opinion, both seed drills also have potential for direct seeding of rice at the beginning of the monsoon (*kharif*) season. This could be the subject of further work.

- Both seed drills, with little modification, can be used in bed planting systems.
- The disc opener options have not yet been tested in Asia. (However they may be unaffordable to most small farmers).
- One each of the tined drill prototype has also been sent to Cambodia and Lao PDR. These are being evaluated behind a Thai built (Siam Kubota) two wheel tractor. A rotary tillage option is not readily available for Thai built two wheel tractor and thus the strip tillage unit is not being considered in these countries.

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