Minimum-tillage, mechanized sowing of pulses with two-wheel tractors

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Abstract
Pulse crops in Bangladesh are mainly low-input rainfed crops with broadcast sowing. Since the 1990s, rotary tillage two-wheel tractors (2WT) have largely replaced animal draft for crop establishment. However, rotary tillage causes excessive evaporation from seedbeds in rapidly-drying soils. Therefore 2WT-based minimum tillage (MT) options were explored to optimize seedbed moisture for lentil and chickpea establishment. Two types of 2WT-mounted seeding units were manufactured, a strip tiller retaining rotary blades only in front of the tynes and a tyne seeder in which the rotary tiller shaft is removed. In some soil types, seedling emergence and grain yields of lentil and chickpea with these seeders matched those with broadcasting. In wet soils, the minimal soil disturbance with MT resulted in anaerobic conditions around seedling roots thereby limiting root growth and nodulation. In clay soils with rapid surface drying traction was inadequate for tyne tillage and strip tillage could not adequately penetrate rice paddy hardpans to allow adequate growth of seedling roots. Potential solutions to these limitations are under test so that 2WT-based MT can be adapted for more timely and economic sowing of crops, including pulses, in smallholder plots and to achieve the agronomic benefits of line sowing over broadcast sowing.

Key Words
Bangladesh, chickpea, conservation agriculture, lentil, strip tillage.

Introduction
Pulses remain a dietary staple in Bangladesh despite declines in their local production in recent decades, primarily due to competition with irrigated cereal crops. Traditionally, pulses are broadcast sown and, until recently, reliant on animal-drawn tillage and grown rainfed with few agronomic inputs. Yields of the major pulses grown in Bangladesh – lentil, lathyrus, chickpea, mung bean and black gram – remain low (<1 t/ha). Over the previous 15 years there has been a rapid increase in the use of Chinese-made 2WT which now cover >80% of the tillage operations for most crops. This increases the area of land able to be sown to pulse crops during an already short sowing window due to the soil surface drying rapidly. In soils where the surface dries quickly establishment of crops like chickpea has been impaired due to enhanced surface soil evaporation as a consequence of shallow full rotary tillage. Further, rotary tillage, like other forms of tillage, disrupts macroaggregates and exposes microaggregates (<0.25 mm) and free organic matter to microbial decomposition (Six *et al.* 2000b). Thus there is a loss of carbon and reduced nutrient sequestration in heavily tilled soils (Lupwayi *et al.* 1999; Six *et al.* 2000a). Minimum tillage practices under the concept of conservation agriculture (CA) can reverse such declines in soil quality (e.g. Kushwaha *et al.* 2001).

Following introduction of 2WTs in Bangladesh there has also been recent adoption of Chinese-made single pass power tiller operated seeders (PTOS), which drill seed behind the high speed rotary shaft (Haque *et al.* 2004). Although providing the advantages of line sowing of crops the device retains the disadvantages of full rotary tillage. The device may be modified towards MT in two ways (Hossain *et al.* 2009). Firstly, all except the blades on the rotary shaft immediately ahead of the seed delivering tynes can be removed to produce strip tillage. Secondly, the entire rotary shaft and covering drum may be removed so that the soil is penetrated only by the tynes – known as tyne tillage or zero tillage. Various further modifications have been made to PTOS-based devices to specifically suit them to sowing of rainfed pulses, but also to be able to sow other crops in the cropping cycle. This paper describes the preliminary evaluation of these strip tillage and tyne tillage units for lentil and chickpea grown in different soil types of northern Bangladesh.

Methods

Details of PTOS modification for either strip tillage or zero tillage are described by Hossain *et al.* (2009). Apart from changes to the rotary shaft and drum, other major features included press wheels behind each tyne and a fertilizer box metering and delivering triple superphosphate (TSP) near the seed outlet on each tyne.

Silt loam soils of northern Bangladesh

In the extreme north-west of Bangladesh (districts of Thakurgaon, Dinajpur, Nilphamari and Panchagarh), the soils are mainly non-calcareous brown floodplain soils (Brammer 1996). The soil surface (0-15 cm) is acid (pH 4-6) and mainly silt loam in texture. Comparison of strip tillage with conventional broadcast sowing of lentil (*Lens culinaris* Medikus var. BARI masur 4) and chickpea (*Cicer arietinum* L. var. BARI chola 5) was made by comparing plots sown by broadcasting in a date-of-sowing experiment and by strip tillage in a seed rate experiment. The experiments were adjacent to each other in four dispersed replications around a village and were sown on the same day – 10 Nov 2008 for lentil at Sasla Piala Village, Thaurgaon Sadar and 4 Dec 2008 for chickpea at Bhandardha Village, Baliadangi, Thakurgaon - and the treatments were thus comparable by paired "t" test. Broadcast plot size was 5 x 5 m and plots were cultivated with a rotary power tiller, boric acid and TSP fertilizers and seed were hand broadcast, and the plots then raked to incorporate seed and fertilizer. For strip tillage plots, plot size was 12 rows 40 cm apart and 15 m length. Seed rate in both treatments was 34 kg/ha for lentil and 37.5 kg/ha for chickpea. Seeds were primed overnight prior to sowing with Mo added to the priming water at 1.5 g $Na_2MoO_4.2H_2O$/L and *Rhizobium* inoculum at 40 g/L priming water; there was 1 kg seed/L priming water. TSP rate was 100 kg/ha, which was drilled in the case of strip tillage. Boric acid was hand broadcast at 1 kg B/ha at sowing. Crops were grown rainfed, mainly on residual soil moisture from the preceding rainy season. Three days prior to sowing, plots were sprayed with Roundup® at 1.875 L/ha in 375 L water, with follow-up hand weeding of lentil plots at 15-35 days after sowing (DAS) and of chickpea plots at 45-50 DAS. Stemphilium blight of lentil was managed by spraying Rovral-50® wp @ 0.2% at 45 DAS. Chickpea was protected from Botrytis grey mould (BGM, caused by *Botrytis cinerea*) by spraying Bavistin® at 1 kg/ha at 45-50 DAS and from pod borer (*Helicoverpa armigera*) by spraying Karate® @ 1 L/ha in 500 L water at 65-70 DAS. At harvest, 5 x 1 m^2 quadrates were cut from broadcast plots and 15-20 m row length from strip tillage plots and the grain weight measured after threshing. Chickpea demonstration plots of 1,333 m^2 were sown in farmers' fields in Nov-Dec 2008 following the same agronomy as described above. Nine plots were sown by hand in rows after full tillage and 25 plots sown by strip tillage, without any prior tillage, with 40 cm row spacing in both cases.

Hard setting clay soils of the High Barind Tract

In the High Barind Tract (HBT) grey terrace soils are predominant (Brammer 1996). These soils are acid to neutral (pH 4.0-6.5) with mostly silty clay surface horizons. There is a clay plough pan layer at 10-12 cm, resulting from repeated rainy season rice cultivation and the soil surface rapidly dries and hardens after harvest of rice in Nov-Dec. A chickpea experiment conducted at Choygati Village, Godagari Upazilla, Rajshahi District, where the surface soil was of loamy clay texture and had high water retention capacity, in 2007-08 compared sowing with either PTOS, strip tillage or zero tillage. Four sowing dates (1, 7, 11, 14 Dec 2007) were in main plots and tillage method in sub-plots (9 rows 50 cm apart and 10 m length) in a split plot design with three replicates. In 2008-09 at Choygati, and at Kantopasha Village, Godagari, where the soil was more typical of the HBT with rapid surface drying, four replicate plots of strip tillage were compared with one broadcast sowing plot with full tillage, in 15 x 3 m plots. Plots were sown on 24 Nov 2008 at Choygati and 22 and 28 Nov 2008 at Kantopasha. Also at Kantopasha in 2008-09, a split plot trial compared strip tillage with PTOS sowing of chickpea (main plots), with and without mulching with rice straw prior to sowing (sub-plots). Sub-plot size was 6 rows 40 cm apart and 10 m length and sowing date 28 Nov 2008. All HBT trials used BARI chola 5 sown at 45 kg/ha. The same agronomic practices were followed as described for chickpea in northern Bangladesh, except that Mo and *Rhizobium* was not added to the priming water (surface soil pH>5.5 and native chickpea rhizobia present) and BGM management was unnecessary.

Results and discussion

Silt loam soils of northern Bangladesh

The traction of 12 hp 2WTs, as normally used in this region of light soils, was adequate for four zero-till tynes. Initial unreplicated tests showed that both strip till and zero till options could produce adequate plant stands of lentil and chickpea. In replicated tests, respective values for broadcast and strip tillage sowing for lentil were: plant stand at 30 DAS – 53, 61 plants/m^2; plant height at 47 DAS – 25.0, 27.3 cm; grain yield – 539, 399 kg/ha. Respective values for chickpea were: plant stand at 27 DAS – 41, 47 plants/m^2; plant height at 52 DAS –21.8, 20.0 cm. Differences between broadcast and strip tillage sowing for any parameter were not significant at

P<0.05. Lentil yields in this study were low and variable among replications primarily due to seedling disease (caused by *Sclerotium rolfsii*). Yields of chickpea were not recorded due to severe damage to the crop by *S. rolfsii* and limited vegetative growth due to continuing excess soil water. In many locations, when these soils were not tilled the surface remained moist throughout the growing period, exacerbated by low temperatures and foggy conditions in Dec-Jan and high water tables in some locations. Where surface soil moisture remained at or above field capacity it was observed that root growth was minimal and nodulation poor with strip tillage. On the other hand, full tillage to 15 cm, by animal-drawn plough, 2WT, or tractor, allowed drying of the surface soil to the extent that adequate initial root growth and nodulation could occur. This was evidenced in the case of demonstration plots of chickpea sown in farmers' fields. The nine plots hand-sown after full tillage had a mean yield and standard deviation of 900 ± 49 kg/ha. Of the 25 plots sown by strip tillage 20 were abandoned due to poor growth of the crop. The five strip tillage plots harvested averaged 588 ± 167 kg/ha. It is presumed that the continuing high water content of non-tilled soil sown by strip tillage caused anaerobic conditions below the seed, limiting root growth and nodulation. For mechanized sowing under excess moisture conditions, MT does not seem possible unless there is improved aeration of initial roots and crown nodules. A wider and deeper strip, made by leaving more blades on the rotary shaft could facilitate this. Other options are sowing with full tillage (PTOS) or to sow on a permanent bed system (Sayre 2004). These options are under test in the 2009-10 season.

Hard setting clay soils of the High Barind Tract
Preliminary tests indicated that 2WT traction was insufficient for zero tillage in typical HBT soils. Strip tillage provided extra traction through the action of the rotating blades as well as opening a furrow for the following tyne. At both Choygati and Kantopasha in 2008-09, initial plant stand was higher with broadcast sowing but that with strip tillage was satisfactory for chickpea in this environment (Table 1). At Choygati with both broadcast and strip tillage sowing, chickpea grain yield was 1.8 t/ha, more than double normal chickpea yields in the HBT. On the other hand, strip tillage produced only half the yield of broadcast sowing at Kantopasha (Table 1). A comparison of tillage methods at Choygati in 2007-08, indicated less emergence with zero tillage, but there was no significant difference in yield between zero tillage, strip tillage and PTOS sowing (Table 1). At Kantopasha, however, emergence and yield were significantly lower with strip tillage than PTOS (Table 1). Here, seedling growth was less with strip tillage, probably because of impeded root penetration through the undisturbed but rapidly drying plough pan layer below the opened furrow. Modification to produce a deeper and wider furrow, along with deeper placement of seed, would be required for successful use of strip tillage in HBT soils. This modification of strip tillage is currently under test.

Table 1. Effect of sowing method on initial plant stand and grain yield of chickpea in clay-loam (Choygati) and hard-setting clay (Kantopasha) soils in the High Barind Tract of Bangladesh, 2007-08 and 2008-09 seasons.

Sowing method	Choygati		Kantopasha	
	Plant stand (plants/m^2)	Grain yield (kg/ha)	Plant stand (plants/m^2)	Grain yield (kg/ha)
	2008-09		2008-09	
Broadcast	63.8	1,824	48.5	1,082
Strip tillage[1]	40.8 ± 2.8	1,806 ± 330	29.1 ± 5.0	562 ± 129
	2007-08[2]		2008-09[3]	
PTOS	26.7	733	67	571
Strip tillage	20.5	852	40	240
Zero tillage	15.0	862	-	-
Significance	P<0.001	ns[4]	P<0.001	P<0.001

[1] Mean ± standard deviation.
[2] Main effect of tillage treatment.
[3] Values averaged across mulching treatments as no significant effect of mulching.
[4] ns = no significant difference at P = 0.05.

Conclusion
Minimum tillage seeding devices attached to 2WTs have been demonstrated to produce adequate stands of lentil and chickpea, under particular soil conditions in Bangladesh. Strip tillage is preferred as there is insufficient traction with existing 2WTs for operation of zero tillage on heavier, hard setting soils. However, narrow and shallow strip tillage is not effective in soils that remain excessively wet or in quick drying soils with a plough pan layer. Modifications to overcome these problems are feasible, through a deeper and wider strip, deeper seed placement in quick drying soils and shallower placement in wet soils, and more effective covering of the seed after placement. There is a need to classify soil conditions where strip tillage will operate satisfactorily, or where

modification towards full tillage is required. Strip tillage for sowing of pulses provides the advantages of line sowing, which include better weed and disease management and easier harvesting. Other advantages of strip tillage include less labour, fuel cost and time requirement for one-pass sowing, and the possibility of reducing seed and fertilizer rates due to more optimum placement in furrows. These improvements are now within the reach of resource-poor, smallholder farmers already familiar with 2WT.

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