An Innovative Versatile Multi-crop Planter for Crop Establishment Using Two-wheel Tractors

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Abstract

A Versatile Multi-crop Planter (VMP) was designed and built for seed and fertilizer application in lines when driven by 2-wheel tractors (2WT) for: single-pass shallow-tillage; strip tillage (ST); zero tillage; bed planting, and conventional tillage (CT). Field performance and operational costs were recorded and analysed in Bangladesh. Field capacity of VMP was 0.07 ha/h for ST which was 34% lower than for CT. Land preparation cost by VMP was decreased by up to 75% for single pass compared to CT. VMP was capable of sowing many crops from small jute seed (2 g/1000 seeds) up to maize (160 g/1000 seeds). The VMP weighs 152 kg and ex-factory price is US$1,000. Acceptance of this multipurpose planter by smallholder farmers who prefer two wheel tractors is expected to be high.

Introduction

Small farm sizes restrict the purchase and utility of 4-wheel tractors in many parts of Asia and Africa. The wide range of options for 4-wheel tractor in mechanised planting is not available for 2WT that are a major form of mechanised tillage in S. Asia (Baker *et al.*, 2007). In Bangladesh, the 2WT accounted for tillage on 75% of fields in 2001 (Meisner 2001). Mostly these have been used in fully rotary tillage mode to prepare land or puddle wet soils for transplanted rice (*Oryza sativa* L.). The large numbers of 2WT operating in South Asia are evidence of considerable interest amongst small farmers in mechanised tillage. However, repeated full rotary tillage of soil, often practiced more than six times per year, is not favourable to maintenance of soil organic matter (SOM) and soil structure. The rapid developments in minimum tillage planting for CA using 4-wheel tractors have largely by-passed the 2WT (Baker *et al.*, 2007). In principle, the same components, tool bars, furrow openers, seed meters, seed box, fertiliser box, etc. can be used on planters for 2WT as for 4-wheel tractors but on a smaller scale with fewer and smaller tool bars, fewer tines and attention to light weight construction. However, the challenge remains to

design such planters and demonstrate their effectiveness, reliability, and durability at a price that allows ready adoption in the target market.

The developments in 2WT-operated minimum tillage planters are reported in Haque *et al*. (2013). Despite these promising developments, none of the present planters for 2WT are capable of planting in all modes of tillage. In diverse, intensive cropping systems such as in the Eastern Gangetic Plain, two or more planters are presently needed to carry out the range of minimum tillage and conventional tillage operations. Hence service providers are reluctant to purchase a planter that can only be used for a narrow selection of crops at a particular time of the year. The challenge is to design a multi-function planter capable of handling many crops and planting methods etc. In the present paper we describe the design, construction and operation of such a planter, called the VMP. The VMP meets the above criteria and has successfully established a diverse range of crops in Bangladesh (Haque *et al*., 2010).

Materials and Methods

The VMP was powered by a Dongfeng or Saifeng 12 - 16 horsepower 2WT but could be used with any 2WT with similar power rating. The Dongfeng or Saifeng 2WT have different but suitable hitching points to attach with the VMP. The appropriate planter hitching needs to be used with the particular type of 2WT. The VMP was designed with capability for seeding and fertilizing with fluted roller or vertical plate meters in lines for: 1) Single-pass shallow-tillage (SPST); 2) strip tillage (ST); 3) zero tillage (ZT); 4) bed planting (BP) (for single-pass new bed-making or re-shaping of permanent beds and simultaneous planting and fertilizer application); and 5) conventional tillage (CT) using full rotary tillage following broadcast seeding and fertiliser spreading.

The rotary shaft is operated by the 2WT at 250 or 375 rpm through a chain and gear mechanism. The power transmission chain box is located on the right side of the planter with 14 teeth on the upper sprocket attached to the drive shaft and 13 teeth on the lower sprocket attached to the rotary shaft. Rotary shaft and blades are covered by a metal sheet fitted with a clearance of 240 mm from the shaft. The net weight of VMP is 152 kg and its overall dimensions are length 990 mm, width 1220 mm, and height 840 mm (**Fig. 1**). The VMP is mounted on a 700 mm toolbar attached through side arms and connecting rods to the main handle of the 2WT. Seed and fertiliser boxes are mounted on the toolbar, as the cover of the rotary shaft. This allows for seeding and fertilizing in four adjustable lines if row spacing is 200 mm, down to a single row in case of maize sown in 600-700 mm rows. The seed box is fitted with four seed meters. Either fluted roller or vertical plate seed meters can be fitted depending on the level of precision in seed placement required. Seed rate can be adjusted by sprocket size in the case of vertical plate meters. Sprocket sizes range from 10-40 teeth giving 5 settings for seed rate and seed size. For the fluted seed meter, seed rate is varied by adjusting the length of the flutes by a handle. By fitting seed meters with 4, 8, or 16 flutes, delivery of different-sized seed can be regulated. The fertiliser box is made from the same iron sheet and has the same external dimensions as the seed box. The fertiliser box is fitted with four fluted meters with eight or four flutes.

Seed meters are attached to a shaft and fertiliser meters to a separate shaft. The power for the fertiliser meters comes from the 2WT differential shaft, through a chain driven by a 19-teeth sprocket and is relayed to the seed meter shaft through a chain and sprocket. The furrow openers are each attached on the toolbar by two U-clamps along with bolts and plate. Seed and fertiliser delivery tubes made of 27 mm diameter clear polypropylene pipe join behind the furrow opener. A pressing roller 670 mm long with 127 mm diameter (**Fig. 1**) is attached behind the furrow openers by a pair of arms 560 mm long. The photographs illustrating the VMP (**Fig. 1**) are for the 4th version. Subsequent versions involved changes

1: Seed box, 2: Fertilizer box, 3: Seed delivery tube, 4: Toolbar frame
5: Fertilizer delivery tube, 6: Depth contoroller, 7: Press roller, 8: Furrow opener

Fig. 1 Versatile Multi-crop Planter attached (marked in dash line) to 2WT in strip tillage mode

to seed metering so externally the later generations have the same appearance as shown. The reasons for changes made to earlier generations are outlined below in results.

Data Collection

Seed calibration

Seed rate was calibrated over a 20 m travel distance with an 800 mm sowing width. This procedure was used to calibrate the VMP for a range of species (**Table 1**) before planting in the fields. Data on labour requirement, operational time, time loss, and field capacity were recorded during the field operation. The time losses due to turning, clogging and operators' personal needs were also recorded. Field capacity was determined using the formulae of Hunt (1973).

Field trials with lentil, chickpea, mung bean, black gram, maize, and direct seeded rice

The field trials with lentil, chickpea, mung bean, and black gram were established at the High Barind Tract, Rajshahi; and the maize and direct-seeded monsoon rice were established at the Bangladesh Sugarcane Research Institute, Gazipur, Bangladesh. The treatments were arranged in a randomized complete block (RCB) design with three replications. Treatments for the trials of lentil, chickpea, mung bean, and black gram were i) CT, ii) SPST, iii) ZT, iv) ST, and v) BP. In the case of maize trial, the treatments were i) VMP with vertical disk seed meter in SPST planting mode, ii) Earthway planter in soils that had been tilled four times, and iii) hand planted in soils that had been tilled four times. Two tillage treatments i) SPST and ii) ZT were used in the case of the direct-seeded rice trial. Data on operational capacity of the seed box and coverage per full seed box of different species; plant population/m^2; fuel consumption, field capacity, labour requirement, cost of land preparation and seeding, etc. were collected from trials of lentil, chickpea, mung bean, and black gram; and spacing between adjacent maize plants and rice hills, etc. was determined. Data were analysed statistically using one-way analysis of variance (ANOVA) with MSTAT-C. Means were compared with least significant difference (LSD) test at $P < 0.05$.

Results

The following results are based on 4th and 6th versions of VMP. After version 4, changes focussed on seed metering improvements. Version 6 replaced fluted rollers with vertical plate seed meters.

Table 1 The operating capacity of the seed box and coverage per full seed box of the VMP when used to sow a range of species with different seed sizes and seed rates

Species	Seed size (g/1000 seed)	Seed rates (kg/ha)	Carrying capacity of full seed box (kg)	Planted area per full seed box (ha)
Maize	160	18	21	1.17
Chickpea	138	34	20	0.67
Wheat	52	120	18	0.15
Mung bean	45	40	20	0.59
Lentil	20	34	22	0.65
Rice	18	30	15	0.67
Mustard[a] (*Brassica spp.*)	3.7	8	17	2.13
Sesame[a] (*Sesamum indicum.*)	2.7	6	14	2.27
Jute[a] (*Corchorus capsularis*)	2	5.5	17	3.05

[a] Rice husk at a 1:1 ratio was added with small seed to increase the volume for sowing using the fluted meter.

Blade Arrangement for Different Tillage Operations

By contrast with the standard rotary tiller that has blades bolted at fixed positions; the VMP has flexible blade positioning. This was achieved by replacing the round shaft with a square shaft and then designing brackets that can be flexibly re-positioned across the shaft while holding two or four blades each. The sliding of the bracket sideways without blade removal enables row spacing to be adjusted quickly in the field according the crop requirements. The previous rotary shaft had to be dissembled in a workshop if the row spacing was to be changed. Hence the square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. For SPST planting, 32 blades are attached on eight brackets (**Fig. 1**), evenly spread across the shaft. Blades alternate between left and right twist. For ST, one bracket containing 2-4 blades is retained for each furrow opener. Blade size with either straight or twisted shape provided strip tillage to 140 mm depth and 100 mm width. Settings for bed shaping involve a decrease in the wheel-base from 740 to 600 mm (centre-to-centre) by flipping each wheel around and re-bolting to the axle. The centre line of the wheel is then aligned with both the outer blade and the outer edge of the cones used to shape beds. For newly-formed beds, blades are arranged with longer blades (230 mm) on the outer six brackets (holding 24 blades altogether) and with a twist that throws soil towards the centre of the bed. Shorter blades (155 mm) with alternate left and right twist are fitted to the two central brackets. For re-shaping of old beds, only the two or three outer brackets on

each side of the rotary shaft retain the long blades, while all blades on the three or four inner brackets may be retained. If there is little residue or weeds on the beds, only the longer outer blades need to be fitted to throw soil from the furrow on to the bed to re-shape it. The VMP can be operated in ZT mode with blades retained to clear some residue, but the furrow openers need to be set deep enough to ensure sufficient clearance of the blades above the soil and residue.

Seed Metering

Several types of seed metering device have been tested leading to the vertical plate device in the 6th version VMP. The vertical plate is modelled on the Earthway Garden Planter (from USA). It is made from moulded plastic in 5 different aperture sizes to accommodate seed sizes from 2 to 160 g seeds/1000 (**Table 1**). However, if continuous seed dropping is preferred, the fluted rollers are satisfactory and cheaper. Among tillage treatments, no significant difference was observed in the case of lentil and chickpea emergence after seed metering using the fluted roller; however, significant improvements were observed for emergence of mung bean and black gram compared to CT (**Table 2**).

Field Operation and Costs

Field capacities of CT, SPST, ST, ZT and BP were 0.11, 0.07, 0.07, 0.06 and 0.05 ha/h, respectively (**Table 3**). Field capacity of CT was higher (0.11 ha/h) since broadcast seeding did not require precision seed alignment like row planting. Fuel consumption was higher with CT (33.1 l/ha) and lowest in ST (5.83 l/ha) by VMP (**Table 3**). The SPST, ST, ZT and BP by VMP saved 38, 82, 50 and 13% diesel fuel over CT. The maximum cost (US$ 41.47/ha) of land preparation and seeding was incurred in case of CT system and the lowest (US$ 10.27/ha) for ST systems (**Table 3**). Compared to CT, planting by SPST, ST, ZT, and BP systems lowered costs by 52, 75, 23, and 13%, respectively (**Table 3**).

Table 2 Plant populations (plants/m^2) established using the fluted type seed meter on the VMP for lentil, chickpea, mung bean and black gram sowing in CT, SPST, ZT, ST, and BP at the High Barind Tract, Rajshahi, Bangladesh.

Crop	CT	SPST	ZT	ST	BP	CV, %	Significance
Lentil	25	100	178	171	-	59.9	NS
Chickpea	56	55	47	57	31	24.7	NS
Mung bean	27c	145ab	121b	209a	101b	20.5	**
Black gram	22b	-	99a	93a	52ab	29.6	**

Values in a row, followed by a common letter are not significantly different at P < 0.01 by Duncan's Multiple Range Test.

Table 3 Effect of tillage mode by the Versatile Multi-crop Planter on fuel consumption, field capacity, labour requirement and cost of land preparation and seeding of lentil, chickpea, mung bean and black gram in clay soil at High Barind Tract, Rajshahi, Bangladesh, 2010-11.

Tillage type	Field capacity (ha/h)	Fuel consumption (l/ha)	Labour requirement, (person-h/ha)	Cost of land preparation and seeding[a], (US$/ha)
Conventional tillage	0.11a	33.1a	48.1a	41.5a
Single pass shallow tillage	0.07b	20.6c (38)	15.4c (68)	19.8d (52)
Strip tillage	0.07b	5.83e (82)	15.3c (68)	10.3d (75)
Zero tillage	0.06b	16.6d (50)	17.3c (64)	18.1c (23)
Bed planting	0.05b	28.9b (13)	23.9b (51)	28.8b (13)
CV, %	31.9	30.8	45.4	26
Significance	**	**	**	**

Values in the parenthesis indicate the percent saving over CT.
Values in a column, followed by a common letter are not significantly different at P < 0.01 by Duncan's Multiple Range Test.
[a]Considering variable costs for labour (land preparation @Taka 30 and seeding @ Taka 20/ha); diesel fuel (@Taka 45/l). 1 US$ = 68 Taka

Planting Options, Methods, Species, and Seed Rate

Seeding has been tested for the different crops, in order of increasing seed size: jute, sesame, mustard, lentil, mung bean, rice, wheat, black gram, chickpea and maize. The vertical plate seed meter with VMP was evaluated when planting by ZT and SPST systems to sow direct-seeded monsoon rice. In the case of SPST by VMP about 78% of rice plants were spaced between 160 and 250 mm apart (mean 187; SE ± 7.6 mm) in a single-pass operation. The establishment of plants by ZT planting with the VMP achieved 70% at 160-250 mm apart (mean 170; SE ± 8.7 mm). With vertical plate seed meter in VMP, about 96% of maize plants were placed 180 to 260 mm apart (mean 205 mm; SE ± 3.9 mm) with a single-pass operation. The spacing between plants was less even (mean 231 mm; SE ± 6.7 mm) in the case of maize planted by hand in well-prepared land after four tillage operations. However, the maize planted by Earthway planter performed slightly better (mean 215 mm; SE ± 2.3 mm) compared to the vertical plate seed meter of VMP. The vertical plate seed meter has a tendency to drop more seed at <170 mm spacing than the Earthway Planter.

Discussion

The 6th version of VMP ex-factory price is ~US$ 1,000 per unit. Further reductions in cost are possible with increased scale of

production. Moreover, if continuous seeding rather than spaced planting is acceptable, a further reduction in price to US$ 600 could be achieved by fitting only fluted rollers rather than the vertical plate seed meter. The VMP is fully fabricated in Bangladesh. Three manufacturers have begun production, commercialisation and scale-up. To date a total of more than 120 units have been sold including 40 to international buyers in India, Mexico, Uganda, Ethiopia, Tanzania, Zimbabwe and Vietnam. With the VMP, an operator can adjust row spacing using a spanner in the field. In two seasons of planting, contractors have sown 132 ha comprising nine crop species. No serious concerns about planter performance, operation or reliability have been identified. The multi-functional, multi-crop capabilities of VMP allow it to be used all year round in intensive crop rotations. In the dry season, planting of rainfed and irrigated crops has been accomplished on alluvial soil as well as the hard-setting High Barind Tract soil (Haque *et al*., 2010). In the early wet season, mung bean, black gram and direct seeded rice have been planted successfully. The VMP shaped permanent beds and is able to re-shape beds for each crop in a rotation. The flexibility of VMP and adaptability for a range of crops and planting methods means that service providers can feasibly make a year-round business from hiring a VMP for planting farmers' crops. Miah *et al*. (2010) reported that using of the 2WT-mounted Chinese planter in SPST mode was highly profitable as a business for service providers with the capacity of year-round operation. A similar business model should be applicable to the VMP.

Clear gains in fuel efficiency were obtained with the VMP, but essentially all the single-pass modes of planting were fuel-saving compared to CT. The field capacity of 0.07 ha/h for ST was comparable to rates with the SPST planter (Hossain *et al*., 2005). Hence in a single day's operation about 1 ha can be planted by the VMP in ST and SPST modes. Erenstein & Laxmi, (2008) reported the net benefit of ZT over CT averages US$97/ha across the Indo-Gangetic Plains with the contribution from the cost saving effect (53%) being slightly higher than the yield improvement (47%). The present study with 2WT and VMP reported that the ZT cost saving effect averages US$52/ha across the experiments and crops. Brief results in the present paper show similar or greater plant populations of chickpea and mung bean established using VMP in single pass planting (ST, ZT, and BP) using a fluted roller seed metering compared to CT.

China (10 million), Thailand (3 million), Bangladesh (0.45 million) and Sri Lanka (0.12 million) have the highest usage of 2WT (Anonymous, 2011). Parts of Africa have begun importing Chinese tractors and Nigeria may have close to 1,000. Southern Germany, northern and southern Italy, and many countries of central Europe also have significant numbers of 2WT (Anonymous, 2011). Hence the potential for application of minimum tillage planters with these 2WTs is extensive. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Asia and Africa (Johansen *et al*., 2012).

Conclusion

The VMP is a unique multi-functional and multi-crop planter powered by 12-16 hp 2WT with capability for seed and fertilizer application in variable row spacing using SPST, ST, ZT, BP, and CT. The square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. By using the VMP, the establishment costs for various crops in different tillage systems were significantly reduced compared to CT. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Asia, Africa and other regions.

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