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Zero-Till Drill for Wheat Establishment and Comparison of Performance with Power Tiller Operated Seeder (PTOS) and Conventional Method

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Abstract

A power tiller operated Zero-till drill had been developed in Wheat Research Centre (WRC), Dinajpur, Bangladesh with the assistance of CIMMYT. Performance of the Zero-till drill was evaluated at farmers' field in Dinajpur area for the establishment of wheat after rice harvesting. Performance of the Zero-till drill was evaluated on the basis of seed rate, seed spacing, and depth of seeding, effective field capacity, fuel consumption, planting cost, yield, net saving and benefit cost ratio. For justification of suitability of Zero-till drill for the establishment of wheat, performance of the Zero-till drill was also compared with power tiller operated seeder (PTOS) and conventional method (broadcasting). Results showed that effective field capacity and fuel consumption rate of the Zero-till drill was 0.12 ha/hr and 1.5 lit/hr, respectively. During seed sowing 30 kg of seed per hectare was saved with Zero-tillage system. Zero-till drill also maintained uniform depth of seeding with better seed-soil contact. It was also observed that the number of effective tiller and effective spike were more in Zero-tillage system than in conventional method and wheat yield under Zero-tillage and PTOS planting methods were 6.5% and 13% higher than that under conventional method. Furthermore, wheat planted with Zero-till drill was less lodged compared to PTOS and conventional method. From economic view point, Zero-till drill was suitable for wheat establishment because it saved planting cost of Tk. 2585/ha which was 66% less expensive than conventional method and the benefit cost ratio (BCR) of the Zero-till drill was 2.0 indicating that Zero-till drill was profitable than PTOS (BCR = 1.88) and conventional method (BCR = 1.31).

Key words: Zero tillage, Reduced tillage, PTOS, Broadcasting.

1. Introduction

Conventional tillage methods have long resulted in exposed field surface, decrease soil fertility, serious water loss and soil erosion and increasingly worse ecological environment. Moreover, drought has become a critical factor restricting agricultural production in some parts of Bangladesh. In order to achieve sustainable development in agriculture it is now required to promote the systematized protective tillage techniques and implements for preservation of soil moisture suitable to the intensive farming areas. Zero tillage planting is a new system in agriculture. Generalized concept of Zero-tillage is to establish crop without tillage operation. In Zero-tillage system, crop plantation is done in previously unprepared soil by opening a narrow slot or band only of sufficient width and depth to obtain proper seed placing. It results in less soil degradation, enhanced microbial enhanced microbial activities, more efficient use of inputs, and improved soil fertility and sustainable environment. Hatfield and Karlen (1992) reported that the adoption of reduced tillage methods can offer significant environmental benefits while providing energy savings.

Several researchers have reported that Zero-tillage system have distinct economic and environmental benefit over conventional and others tillage systems. Osuji (1986) assessed the effects of four tillage systems namely Zero-tillage, manual cultivation, plough only and conventional tillage (ploughing and harrowing) on soil erosion and nutrient losses. It was reported that nutrient losses in both runoff and eroded sediments were less in Zero-tillage than conventional and other tillage systems. Zhao (1989) studied the relationship between soil physical properties and crop growth to determine the tillage

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requirement of paddy soils in the Taihle lake region (Hubei, China). Results indicated that Zero-tillage was more suitable for paddy soils under rice wheat cropping systems than the traditional tillage systems. However, long-term Zero-tillage would lead to insufficient water supply for crop growth, whereas ploughing would enhance soil puddling which in turn would increase soil water retention. Zhuang *et al.* (1999) reported that the soil organic matter content distribution in soil layers was greater in upper layers under minimum and Zero-tillage. In addition, soil bulk density was greater under minimum and Zero-tillage. Pabin *et al*. (2001) presented the effect of no-tillage on soil water retention. Results showed that soil water retention under no-tillage differed from that under conventional tillage due to increased soil compaction, accumulation of crop residues and straw on the soil surface, and an organic carbon pool in the soil surface layer. Later, Iqbal *et al.* (2002) assessed the status and quantified the impacts of Zero-tillage technology in the rice-wheat zone of Punjab, Pakistan. This study was based on a primary data set collected from 94 farmers. The result suggested that the curve of the production function for Zero-tillage sown wheat would start at a lower intercept. The resulting higher yield was due to the enhanced water and fertilizer use efficiency and the yield losses saved due to improvement in sowing time because of the use of Zero-tillage technology. In addition, costs could be saved due to the minimal tillage requirement of the technology and certain other beneficial externalities associated with its use. Pandey *et al.* (2003) carried out a study among 34 cultivator households during June 2002 to examine the impact of Zero-tillage in terms of changes in the cost structure, returns and resource use efficiency in foothills region of Uttaranchal, India. The parameters such as yield increase, reduction in cost of production and technical and economic efficiency were used to assess the economic benefits. Determination of technical efficiency in terms of the adoption of Zero-tillage technology and producer characteristics were also examined. Impressive cost savings (28%) was observed under Zero-tillage in wheat. The technology had positive and significant impact on environment and sustainability of the system through improved soil quality and reduction in use of inputs like chemical fertilizers, irrigation water, and energy.

Wheat is the major cropping system in northern part of Bangladesh. Generally wheat is planted after T. Aman harvesting followed by 3-4 passes of ploughing operations and traditional seed broadcasting which is time consuming and costly operation. If rice harvesting is delayed, wheat planting is also delayed. In this situation, farmers always suffer from achieving their potential yield. Research finding showed that optimum wheat planting period is November 15 to November 30. Wheat planting after this period causes yield decrease at the rate of 45 kg/ha/day (Saunders, 1988). Timely planting and timely harvesting are the key operations for increase in cropping intensity and achieving the desired yield. Use of reduced tillage machinery such as power tiller operated seeder (PTOS) is an alternate way to ensure timely planting, meet up labour shortage, keep crop production at economic level and enhance cropping intensity. However, PTOS system required at least one pass of tillage for the seeding operation. On the other hand, Zero-till drill does not require any tillage operations for the plantation of crop. Therefore, it reduces planting time and saves fuel and labour costs in both timely planting and late planting situations. It is reported that yield of grains due to Zero-till planting were more in areas where late planting was a common feature as compared to timely sown areas (Gupta *et al.*, 2003). Long turn-around time can be caused by excessive tillage, soil moisture problems, lack of bullock or mechanical power for ploughing and other farm jobs like threshing and managing rice crop before preparing land for wheat (Hobbs and Mehla, 2003). Bangladesh Agricultural Research Institute (BARI) with the financial assistance of CIMMYT took a programme to develop a power tiller operated Zero-till drill with the objective of saving cost, minimizing delay in planting, and improving moisture conservation as compared to conventional or existing tillage techniques through machinery application. Considering the farmers demand and cost involvement in land preparation, an attempt had been undertaken to evaluate the performance of a Zero-till drill with the following objectives:

i) to evaluate the performance of power tiller operated zero till drill for wheat cultivation; and

ii) to compare the field and economic performance of Zero-till dill with those of common power tiller operated seeder and conventional method of sowing.

2. Materials and Methods

Field tests were conducted to evaluate the performance of the Zero-till drill and power tiller operated seeder (PTOS). Performance test of the Zero-till drill was done by attaching it to a 12 HP Dongfeng power tiller which is very common in Bangladesh. The seed variety of wheat was *Sufi*. Planting depth and seed covering mechanism were adjusted during the field operation. Before planting operation round-up herbicide was applied to kill the existing weed at the rate of 100 ml in 10 liter water for 5 decimal lands.

2.1 Zero-till drill machine

The power tiller operated Zero-till drill was been developed in Wheat Research Center, Dinajpur, Bangladesh with the assistance of International Maize and Wheat Improvement Center (CIMMYT). Isometric views of the Zero-till drill is shown in Fig. 1. Field trials were carried out at farmers' field in the Dinajpur district of Bangladesh. Technical detail of Zero-till drill is given in Table 1. The overall performance of the Zero-till drill was also compared with power tiller operated seeder (PTOS) and conventional method of seeding (broadcasting).

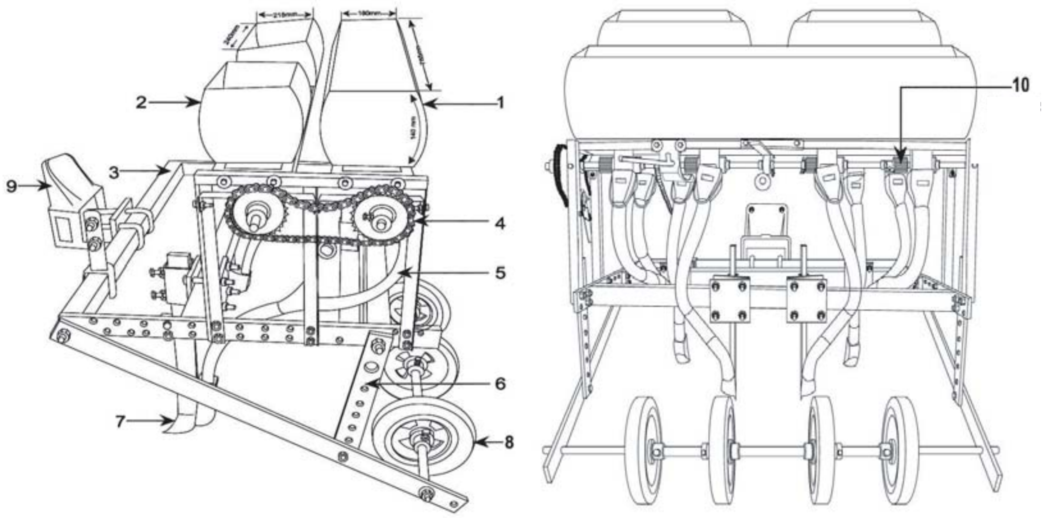

Fig. 1: Isometric views of Zero-till drill machine
1. Seed box, 2. Fertilizer box, 3. Toolbar frame, 4. Chain and sprocket, 5. Seed tube, 6. Depth control device, 7. Furrow opener, 8. Press wheel, 9. Hitch plate,10. Seed metering device

Table 1: Technical specification of Zero-till drill used for wheat establishment

Particulars	Number	Dimension (mm)	Material
Hitch plate	1	255 × 230 & 130 × 135	MS steel
Toolbar frame	1	980 × 660	MS bar
Seed box	1	810 × 210 × 180	Plain sheet
Fertilizer box	2	850 × 240 × 160	Plain sheet
Seed tube	4	100 ×170 × 90	Plastic
Furrow opener	4	233 × 125	Heavy flat bar
Press wheel	4	280 × 50	Rubber
Depth control devices	2	270 × 360	MS bar
Seed metering device	4	Flute type	Molded plastic
Power transmission system	1	Roller-420	Roller chain
Chain-sprocket	2	22 and 19 teeth	Steel
Clutch	1	dog clutch	MS iron

2.2 Calibration of seed rate and fertilizer rate for Zero-till drill and PTOS

Before actual planting operation, both Zero-till drill and PTOS were calibrated for correct seed rate. During calibration for seed rate, two third of the seed box was filled with seed and transparent polythene bags were tagged with each of the seed delivery tubes. After that, Zero-till drill and PTOS were operated on a pre-measured 20 m travel distance with a sowing width of 80 cm. Seed collected in polythene bags through tubes were weighed and seed rate was determined according to the equation (1) as described by Michael and Ojha (1978). This procedure was repeated by adjusting seed metering device until the desired seed rate obtained. The seed rate was kept at 120 kg/ha for both machines.

$$S_d = \frac{W_s}{A_m} \qquad (1)$$

Where,

S_d = Seed rate (kg/ha)
W_s = Total weight of seed (g)
A_m = Measured experimental area, m^2

Along with the seed rate calibration, Zero-till drill was also calibrated for correct fertilizer rate. For fertilizer calibration, similar procedure was followed as described in case of seed rate calibration. The fertilizer rate was determined according to the equation (2) as described by Michael and Ojha (1978). In PTOS system fertilizer is usually applied using broadcasting method. Therefore, it was not necessary to calibrate PTOS for fertilizer rate.

$$S_f = \frac{W_f}{A_m} \qquad (2)$$

Where,

S_f = Fertilizer rate (kg/ha)
W_f = Total weight of fertilizer (g)
A_m = Measured experimental area, m^2

2.3 Land preparation

Land preparation was not required for Zero-till drill and power tiller operated seeder (PTOS). In conventional system, land preparation is a precondition for cultivation of wheat. Land was ploughed by 3 passes of power tiller followed by 2 laddering with straight alternation pattern. A land size of 11.20 decimals with 3 replication plots for each cultivation method was prepared.

2.4 Experimental procedure

During wheat planting time, average moisture content of the soil for the top 50 mm was 22.5% (dry basis). In case of Zero-till drill system, seed and fertilizer was applied at a time in an untilled pre-harvested rice field. Straight alternation pattern was used for sowing. In PTOS system, tilling and sowing were done simultaneously. Before seeding with PTOS, fertilizer was broadcast. For proper seed placement, the speed of operation for both methods was maintained at 2.5 km/hr. In conventional system, both seed and fertilizer was sown by manual broadcasting after second pass of plowing followed by laddering. After sowing/planting operation, all the cultural practices with respect to fertilizer application, irrigation and plant protection were done in all the plots as per the agronomical requirement. Fig. 2 shows photographic views of wheat establishment systems.

(a) Conventional method (b) PTOS system (c) Zero- tillage system

Fig. 2: Photographic views of wheat establishment systems

2.5 Performance evaluation parameters

The performance of Zero-till drill, PTOS and conventional method for wheat establishment was evaluated on the basis of field performance, crop performance and economic of performance.

2.5.1 Field performance

Field capacity, field efficiency and fuel consumption were calculated using the following equations:

$$\text{Theoretical field capacity} = \left(\frac{ha}{hr}\right) = \frac{SW}{10}$$

Where,

S = Rated forward speed for machine, (km/hr)

W = Rated width of the machine, (m)

$$\text{Effective field capacity} = \left(\frac{ha}{hr}\right) = \frac{A}{T}$$

Where,

A = Area coverage, (ha)
T = Total time for the operation, (hr)

$$\text{Field efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100$$

$$\text{Fuel consumption} = \frac{\text{Fuel used during operation (l)}}{\text{Total time needed for operation (hr)}}$$

2.5.2 Crop yield performance

Crop yield performance of Zero-till drill, PTOS and conventional method for wheat establishment was evaluated on the basis of number of plants, number of tillers, number of spikes and grain yield.

2.5.3 Economic performance

Economic performance of Zero-till drill, PTOS and conventional method for wheat establishment was evaluated on the basis of cost of production, total output, net saving and benefit-cost ratio (BCR).The cost of operation of Zero-till drill and PTOS was computed using the following equations involving the fixed and variable cost items.

Total cost per year can be expressed as (Hunt, 1973):

$$AC = \frac{(FC\%)P}{100} + \frac{cA}{Swe}[(R\ \&\ M)P + L + O + F]$$

Where,

AC = annual cost of operating machine, (Tk./yr)
$FC\%$ = annual fixed cost percentage
P = purchase price of machine, (Tk.)
A = annual sowing area, (ha)
S = forward speed, km/hr
w = effective width of action of machine, m
e = field efficiency, decimal
$R\&M$ = repair and maintenance cost (Tk./hr)
L = labour rate, Tk./hr
O = oil cost, Tk./hr.
F = fuel cost, Tk./hr

Fixed cost was determined by using the capital consumption method. Capital Consumption (CC) was expressed by the following equation:

$$CC = (P - S)\ CRF + Si$$

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1}$$

Where,

S = Salvage value (10% of P)
i = Compound interest
L = 10 years

3. Results and Discussion

3.1 Field performance evaluation

The field performance of Zero-till drill, PTOS and conventional method for establishment of wheat was evaluated on the basis of effective field capacity, field efficiency, seed rate and fuel consumption rate. Field performance of different tillage methods for wheat establishment is shown in Table 2. Soil moisture content is the key factor for the planting operation. The average soil moisture of the top 50 cm soil of the land was 25% (db.). Effective filed capacity of Zero-till drill, PTOS and conventional method were 0.12 ha/hr, 0.18 ha/hr and 0.27 ha/hr, respectively. Field efficiency was 55%, 60% and 67% for the Zero-till drill, PTOS and conventional system, respectively. Fuel consumption of Zero-till drill, PTOS and conventional method were 12.5 l/ha, 9 l/ha and 15.56 l/ha, respectively. Applied seed rate was 120 kg/ha in Zero-tillage and PTOS system and 150 kg/ha in conventional system. Therefore, Zero-tillage and PTOS system required 30 kg less seed per hectare compared to conventional system. In addition, the line to line space was 20 cm and average width of opening slits for wheat was 2-3 cm and depth of planting was 3-4 cm in both Zero-till drill and PTOS system. It was also found that slower speed was comparatively better for seed placement into the opening slit. The adjustment of row spacing between two successive pass was maintained by operator skill and experience. In conventional method, seed spacing and depth of seeding was uneven due to broadcasting and laddering.

3.2 Crop yield performance evaluation

A photographic view of the growing stage of wheat in different tillage method is shown in Fig. 3. From the figure it is evident that vegetative growth of wheat was better in Zero-tillage and PTOS system compared to conventional method. Yield contributing characters of wheat cultivation in Zero-tillage, PTOS and conventional method are shown in Table 3.

Table 3 shows that wheat plant population in Zero-tillage, PTOS and conventional methods were 187/m^2, 202/m^2 and 214/m^2, respectively. Plant population was higher at conventional method compared to Zero-tillage and PTOS due to higher seed rate applied by the farmers. Number of effective tiller of wheat for Zero-tillage, PTOS and conventional method were 360/m^2, 335/m^2 and 300/m^2, respectively. Number of effective tiller per square meter was higher at Zero-till drill system and lowest at conventional method. It was due to the better seed-soil contact than in conventional and PTOS planting. Again, the number of effective spike of wheat for Zero-tillage, PTOS and conventional method were 350/m^2, 330/m^2 and 295/m^2, respectively. From the result it was observed that both Zero-till drill and PTOS system showed the similar performance for wheat establishment. A small variation in yield between Zero-till drill and PTOS system may be due to land type, soil moisture, and shortage of fertilizer application and weed management. Wheat yield under Zero-tillage and PTOS planting methods were 6.5% and 13% higher than that under conventional system, respectively. This result is consistent because it matched with the results obtained by Aslam *et al.* (1993).

Table 2: Field performance of different tillage method for wheat establishment

Parameters	Zero-till drill	PTOS system	Conventional method
Speed of operation (km/hr)	2.5	2.5	5
Effective width (m)	0.8	1.2	0.8
Line to line distance (cm)	20	20	scattered
Depth of planting (cm)	3-4	3-4	uneven
Effective field capacity (ha/hr)	0.12	0.18	0.27
Field efficiency (%)	55	60	67
Seed rate (kg/ha)	120	120	150
Fuel consumption (l/ha)	12.3	9.45	15.50*

*Plowing operation

(a) Conventional method (b) PTOS system (c) Zero-tillage system

Fig. 3: Photographic view of growing stage of wheat with different sowing method

3.3 Economic performance evaluation

The yield of wheat in Zero-tillage, PTOS and conventional method were 3.3, 3.5 and 3.1 t/ha, respectively. The planting cost of wheat in Zero-tillage, PTOS and conventional method were Tk. 1575/ha, Tk. 1321/ha and Tk. 4160/ha, respectively (shown in Table 4). From the Table 4, it is observed that the establishment cost saving for wheat was Tk. 2585/ha and Tk. 2839/ha using zero-till drill and PTOS method, respectively over conventional method. In addition, total cultivation cost of wheat for Zero-tillage, PTOS and conventional method were found Tk. 26435/ha, Tk. 29691/ha and Tk. 37790/ha respectively. Therefore, 42% cost was saved under Zero-tillage system over the conventional system which produced the similar trend of profits obtained by Pandey *et al.* (2003). Again, net saving for wheat production from Zero-tillage, PTOS and conventional method were found Tk. 26365/ha, Tk. 26308/ha and Tk.11810/ha respectively. Therefore, the benefit cost ratio (BCR) of the zero-till drill was 2.0 which indicated that zero-till drill was profitable than PTOS (BCR = 1.88) and conventional method (BCR = 1.31). Furthermore, during experiment, it was found that Zero-tillage and PTOS system minimized turn-around time to 8-10 days as conventional method needed about 10-12 days from rice harvesting was to seeding.

Table 3: Yield contributing character of wheat in different tillage method

Methods	Number of plants/m^2	Number of tillers/m^2	Number of spike/m^2	Grain yield (t/ha)
Zero-till drill	187	360	350	3.3
PTOS	202	335	330	3.5
Broadcasting	214	300	295	3.1

Table 4: Economics of operation in wheat establishing methods

Parameters	Wheat establishing method		
	Zero-Till	PTOS	Broadcasting
Land condition	No plough	No plough	ploughed
Seed rate (kg/ha)	120	120	150
Grain yield (t/ha)	3.3	3.5	3.1
Total cost of production (tk/ha)	26435	29691	37790
Production cost saving (%)	42.8	38.2	-
Total output (tk/ha)	52800	56000	49600
Net saving (tk/ha)	26365	26308	11810
Benefit cost ratio (BCR)	2	1.88	1.31

4. Conclusion

The performance evaluation test of zero-till drill machine showed distinct advantages over conventional wheat establishment method. From the results it was observed that fuel consumption and effective field capacity of the zero-till drill was 1.5l/hr and 0.12 ha/hr, respectively. The Zero-till drill and PTOS system saved 30 kg of seed per hectare and maintained uniform line to line spacing and depth of seeding. Number of effective tiller and effective spike were more in Zero-tillage system than in conventional method. Wheat yield under Zero-tillage and PTOS planting methods were 6.5% and 13% higher than conventional system. Also zero-till drill saved production cost by Tk. 11355/ha which was 42% less than that of conventional method. The benefit-cost ratio (BCR) of zero-till drill was 2.0, which indicated that the drill was profitable than conventional method. Therefore, it can be concluded that wheat establishment using zero-till drill and power tiller operated seeder (PTOS) are better than conventional method. From the point of view of benefit-cost ratio Zero-tillage system is better than power tiller operated seeder.

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