Appropriate Conservation Machinery for Mungbean Cultivation in the Southern Region of Bangladesh

M. A. Hossain[1,*], M. A. Mottalib[2], M. I. Hossain[1], M. N. Amin[1], M. M. Alam[3], C. K. Saha[3]

[1]Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur-1701, Bangladesh

[2]PhD Fellow (FPM), Bangladesh Agricultural University, Mymensingh-2202 & Scientific Officer, Spices Research Centre, Bangladesh Agricultural Research Institute, Bogra, Bangladesh

[3]Professor, Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

Abstract

The study was conducted at Mundopasha, Wazirpur, Barisal during Rabi season of 2017 for testing, adoption and popularization of different conservation machinery (CA) such as zero till planter (ZT), strip till planter (ST), bed planter (BP) and power tiller operated seeder (PTOS) along with conventional tilling and of sowing method for planting of mungbean (BARI Mung-6). The soil type was loamy-sand with bulk density 1.41 g/cc. The effective field capacities of ZT, ST, BP, PTOS and power tiller were found to be 0.104, 0.109, 0.084, 0.109, and 0.074 ha/h, respectively. The field efficiency of ZT, ST, BP, PTOS and power tiller were estimated as 74.68, 76.47, 75.84, 78.16 and 71.52%, respectively. Significantly the highest mungbean grain yields were found from ZT and ST planted plots than those of other plots. Significantly the lowest grain yield was obtained from conventional tillage and broadcasting method. The highest benefit cost ratio (BCR) was obtained from ST planted (2.60) and zero till planted (2.40) mungbean followed by PTOS (2.20), conventional tillage cum broadcasting (1.88) and bed planting (1.82) methods. The lowest BCR was found from traditional tillage and manual line sowing method (1.61) of mungbean. CA planting system saved about 50% planting cost and reduced about 76% carbon dioxide emission. Based on the fuel consumption, grain yield and BCR, ZT planter and the strip till planter may be recommended in Barisal region for cultivation of mungbean.

Introduction

Appropriate farm mechanization has been emphasized as an important policy and development goal in Bangladesh [1,2]. Compared to other South Asian nations, farm machinery use has advanced considerably in Bangladesh [3], particularly for land preparation, irrigation, and post-harvest activities. Use of efficient machines save 20-30% of operation time and labor, 15-20% seed and fertilizer along with 5-20% increase in cropping intensity, 10-15% higher yield and 10-30% reduction of drudgery of farm workers especially that of women [4]. Increasing agricultural production and productivity through sustainable intensification is not an option but could be the only feasible means to feed the alarmingly increasing world population with less detrimental effects to the environment [5]. In this regard, the role of conservation agriculture (CA) as a means of attaining sustainable intensification and promoting productive capacity, soil health and environmental services under diverse agro-ecologies with different soil types has got scientific backings [6]. Conservation Agriculture (CA) includes maintaining permanent soil cover for healthy and living soil, promotes balanced application and precision placement of crop inputs [7]. Conservation agriculture aims to produce crop yields by reducing production costs, maintaining the soil fertility, crop diversity and timeliness of cultivation and conserving water [8]. Barma et al. [9] reported that wheat, maize, pulses, oilseeds, jute, rice can be established and grown successfully in Bangladesh through CA technology. There are about 700,000 two wheel tractors (power tiller) available in Bangladesh [10]. Two wheel tractor operated CA based tillage technologies have been developed by different organizations and promotional activities are being conducted in the farmer's field in Bangladesh for yield gap minimization, water saving, efficient input utilization, soil health improvement and sustainable crop production and crops diversification [11]. CA technologies especially zero tillage and strip tillage technologies are more viable in drought stress areas where seeding operation and initial plants establishment can be done utilizing the residual soil moisture available immediate after monsoon rice harvest [12]. Reduced tillage gave similar yields with the conventional tillage and presented a slightly lower energy productivity indicating that obtain significant environmental benefits [13]. Use of excessive and unnecessary tillage operations is harmful to soil [14]. The zero, strip and rotary till drills recorded effective field capacity of 0.59, 0.46 and 0.49 hah^{-1}; provided savings in time (74 to 79%), labour (64 to 71%), fuel (67 to 85%), cost (65 to 81%) and energy (67 to 85%) compared to conventional sowing [15]. The practices of zero tillage and strip tillage, each of which require specialized machinery, can also reduce time require-ments for planting and costs, largely by saving fuel, compared to conventional full tillage with animal or tractor power and manual planting [16].

Agriculture in the southern area is characterized by low productivity due to salinity, water logging, less practice of modern technologies, inadequate control over water resources and repeated crop losses due to natural calamities. Most of the CA based tillage and seeding methods are practiced in the northern and west-northern regions of Bangladesh. But, limited CA is practiced in the southern region where soils and environment are quite different from other regions of the country. Therefore, it is necessary to test the CA machineries in the agro-ecological conditions of west-southern areas of Bangladesh to enhance crop productivity. This study has been under taken to adapt and promote appropriate-scale agricultural mechanization of conservation agriculture for sustainable intensification for smallholder farming systems in the southern delta of Bangladesh

Materials and Methods

Experimental Design

The field experiment was conducted in the farmers' field in Mundopasha village of Wazirpur,upazial, Barisal during Rabi season of 2017 for testing, adoption and popularization of different conservation machinery such as strip till planting method (ST), and PTOS method along with traditional tilling and sowing method.The existing cropping pattern in the study area was Transplanted aman rice-mungbean/lentil-fallow'. The soil type was clay-loam with bulk density 1.46 g/cc. The date of sowing of mungbean was 23 January 2017. The number of participating farmers was nine. The unit plot area was 10-15 decimal (423-485 m^2). The total land area was 3600 m^2. The following six treatments

were taken to conduct the experiment. The design of the experiment was RCBD with four treatments and three replications. The treatments were-

CT= Conventional tillage with manual line sowing

ZT= Zero till planting

ST= Strip till planting

BP= Bed planting

PTOS= Planting by power tiller operated seeder

CT_L= Conventional tillage and manual line sowing

CT_B= Conventional tillage and broadcasting (Farmers' practice)

Before planting, seed germination was tested at laboratory. Germination of seed was found 99%. Sunup (Glyphosate) herbicide was applied in zero tillage method and strip tillage method before 10 DAS (Days after sowing). Provex (Azoxystrobin) was mixed with mungbean seeds to protect soil born disease of seed for zero tillage method. The seeds were sown continuously in 30 cm row to row distance. Thinning and other intercultural operations were done. The fertilizers were used @ $N_{20}P_{40}K_{20}S_{10}$ kg/ha as basal for bed planting, PTOS method, conventional tillage and line sowing (CT_L) and conventional tillage and broadcast method (CT_B). But same amount of fertilizers was applied as top dress 15 DAS for zero tillage method and strip tillage method. One irrigation was applied during vegetative stage at 25 DAS at farmer's field. No weeding was done due to less infestation of weeds at farmer's field. Three times spraying were applied with Imitaf (Imidachloropide), Veertako (Thiamethoxam + Clorantraniliprol), Proklem (Amamektin Benzoate), Actara (Thiamethoxam) during flowering stage up to pod filling stage, starting from 35 DAS to 49 DAS against thrips and pod borer.

Field Performance of Selected Machinery

Theoretical field capacity was calculated by equation [17].

$TFC = S_w/10$, h_a/h (1)

Where, S =Forward speed km/h, w= Width, m

Effective field capacity was determined by equation [17].

$EFC = A/t$, h_a/h (2)

Where, EFC = Effective field capacity (ha h^{-1}), A= Actual operational area (ha), t= Total operating time (h)

The field efficiency was determined by equation [17].

$E_f = (EFC/TFC)*100$ (3)

Fuel consumption was measured by equation.

Fuel consumption= F/A   (4)

Where, F = Amount of fuel (l), A = Area covered (ha)

Seed rate was determined through calculation by using equation [18].

$S_d = 10W_s/A$ (5)

Where, S_d = Seed rate (kg ha^{-1}), Ws = Total weight of seed (g), A = Measured area (m^2)

Economic Analysis

A simple economic analysis was done based on total production. Production cost included input cost. The input cost was calculated by considering cost of seed, fuel, fertilizers, weedicide, insecticide and hiring charges of labour. The gross return and net return were calculated on the basis of local market price. The capital consumption (CC) method of calculating depreciation is widely used. The useful lives of CA machines and power tiller were assumed to be 8 years and 5 years, respectively. The annual working hours of zero till planter, strip till planter, PTOS, Bed planter and power tiller were 120, 120, 240, 160 and 720 hours, respectively. Annual interest rate was considered 14% of the capital price of the machine. In calculation of fixed cost is assumed and the following equation was used:

Fixed cost, FC= CC+T   (6)

Where, CC= Capital consumption, T=Shelter cost, Tk

Capital consumption, CC =(P-S)CRF+S*i   (7)

$CRF = i(1+i)^L/(1+i)^L-1$ (8)

Where, P=Purchase price, Tk, S = salvage value, Tk, CRF= Capital recovery factor

Where, i= Rate of interest 14%, L=Useful working life of the machine, yr.

Shelter cost, Tk/h; T= 0.5% of P

Variable cost,   VC = L_b +F+L+R+M_n (9)

Where, L_b= Labour cost (Tkh^{-1}), F= Fuel cost (l h^{-1} × Tk l^{-1}), Tk., L= Lubrication oil cost (15% of fuel cost) and R&M= Repair and maintenance cost per year (3.5% of purchase price)

Annual cost (AC) = FC+VC   (10)

Where, AC= Annual cost, FC= Fixed cost, Tk. and VC= Variable cost, Tk.

Production cost, $C_p=C_s+C_m+C_h+C_{fr}+C_{pp}+C_{ir}+C_{th}$ (11)

Where, C_p= Production cost (Tkha^{-1}), C_s= Cost for seed (Tkha^{-1}), C_m= Machine operating cost (Tkha^{-1}), C_h = Cost for human labour (Tkha^{-1}), C_{fr}= Cost for fertilizer (Tkha^{-1}), C_{pp}= Cost for plant protection (herbicide and pesticide) (Tkha^{-1}), C_{ir}= Irrigation cost (Tkha^{-1}), C_{th}= Threshing cost with custom hire rate of threshing machinery (Tkha^{-1}).

Gross return, GR= $(Y_g \times P_g) + (Y_b \times P_b)$ (12)

Where, GR= Gross return (Tkha^{-1}), Y_g= Yield of grain (kgha^{-1}), P_g= Price of grain (Tkkg^{-1}), Y_b= Yield of bi-product (kgha^{-1}), P_b= Price of bi-product (Tkkg^{-1})

Net return, NR= GR-C_p (13)

Where, NR= Net return (Tkha^{-1}), GR= Gross return (Tkha^{-1}), C_p= Production cost (Tkha^{-1})

Benefit cost ratio, BCR=GR/Cp   (14)

Where, BCR= Benefit cost ratio, GR= Gross return (Tkha^{-1}), C_p= Production cost (Tkha^{-1})

Statistical Analysis

Data were analyzed by using statistical softwear Mstat-C. Means was compared using list Duncan's Multiple Range Test (DMRT).

Results and Discussion

Machine parameters of jute planting

Field performance of different machines at Mundopasha, Wazirpur, Barisal is shown in Table 1. It was observed that the width of tilling for ZT, ST and PTOS was found 1.20 m and 0.60 m for BP and power tiller, respectively. A low speed (gear I) was selected for ZT, ST and PTOS methods and higher speed (gear II) was selected for BP and power tiller. The tilling depth from soil for ZT, ST, BP, PTOS and power tiller were 2.41, 4.76, 12.06, 6.03 and 7.88 cm respectively. The top width of bed of BP method and strip width of ST method were found 25.50 cm and 6.24 cm respectively.

It was also observed that the effective field capacity of ZT, ST, BP, PTOS and power tiller were found to be 0.104, 0.109, 0.084, 0.109, and 0.074 ha/h, respectively. The field efficiency of ZT, ST, BP, PTOS and power tiller were estimated as 74.68, 76.47, 75.84, 78.16 and 71.52%, respectively. The fuel consumptions for operation of all machines were similar except power tiller. Power required at least three passes for complete land preparation and by other machines land preparation and seeding was done by single pass. So ZT, ST, BP, PTOS saved about 60% fuel than that of power tiller. The fuel consumptions for operation of ST and PTOS were same (13.90Lha^{-1}). Fuel consumptions in power tiller for dry land preparation and wet land preparation were 56.60 and 41.10 Lha^{-1}, respectively. Single pass was enough for tilling and mungbean seeds planting in ZT, ST and PTOS methods. So, ST and PTOS saved about 66% and 75% fuels than and dryland preparation for mungbean planting. Fuel consumption in PT for dry land tillage was higher due to more passes (3-4) required for land preparation.

Yield and Yield contributing parameters

Effect of different tillage systems on yield and yield contributing parameters of mungbean at Mundopasha, Wazirpur, Barisal is given in Table 2. In farmers' field two types of conventional tillage and seeding were followed. The conventional methods were three passes of tillage by power tiller then manual line sowing and manual broadcasting of seeds. Significantly the lowest grain yields were found from broadcasted plots than manual line sowing plots. Statistically the highest plant populations were found from ZT, PTOS and strip till planted plots followed by other plots. Significantly the highest numbers of pods per plant were obtained from zero till, strip till and PTOS planted plots than other plots. There were no significant differences of number of pods per plant between bed planting and PTOS planting plots. The lowest pod per plant was found from CT. The reason might that in strip till and zero till plots, more nutrients were up-taken by plants due to the non-disturbance in soil. Finally, significantly the highest grain yields were found from zero till and strip till planted plots than those of other plots. Significantly the lowest grain yield was obtained from conventional tillage and planting system. Intermittent yields of grain were found from bed planting and conventional (line sowing)

| | | | | | Table 1. Field performance of different machines at Mundopasha, Wazirpur, Barisal | | | | |

Treatment	Width of tilling (cm)	Forward speed (km/h)	Fuel consumption (l/h)	Tilling depth (cm)	Top width of bed (cm)	Theoretical field capacity (ha/h)	Effective field capacity (ha/h)	Field efficiency (%)
ZT	120	1.16	1.30	2.41		0.139	0.104	74.68
ST	120 (Strip width 6.24)	1.18	1.25	4.76		0.142	0.109	76.47
BP	60 (Top width 25.5	1.86	1.33	12.06 (Bed depth)		0.111	0.084	75.84
PTOS	120	1.16	1.31	6.03		0.139	0.109	78.16
Power tiller	60	1.96	3.40 (for 3 passes)	7.88		0.104	0.074	71.52

Table 2. Effect of different planting methods on plant establishment, yield and yield contributing parameters of mungbean in farmer's field at Mundopasha, Wazirpur, Barisal

Treatment	Plant population / (m²)	Plant height (cm)	Pod length (cm)	No. of pod/ plant	100 Grain weight (g)	Grain yield (kg/ha)
ZT	37.76 a	35.2	5.7	18.8 a	3.9	1166 a
ST	34.56 b	38.6	5.9	18.3 a	3.8	1160 a
BP	30.24 c	39.2	5.4	16.8 b	3.8	944 b
PTOS	34.48 b	38.7	5.2	16.8 b	3.8	1132 ab
CT_L	31.32 c	40.1	5.2	17.3 b	3.9	989 b
CT_B	27.08 d	36.8	5.4	15.4 c	3.9	788 c
CV(%)	4.78	8.77	8.18	6.33	2.63	11.2
F-test	**	NS	NS	*	NS	**

planting methods and they were statistically alike. The highest grain yields were obtained from strip till and zero till planting plots because of the highest number of pods and the highest weight of grains were found from these plots. Hossain et al. [8] presented similar results for zero and strip till planting treatments than conventional tillage and sowing methods.

The temperature and rainfall in Barisal during mungbean growing period is given in Fig. 1. Both the maximum and minimum temperatures increased during the mungbean growing period. The reason was that the season proceeding toward summer and hence temperature was increasing. From the month of March there was some rains. Small rain is good for the vegetative growth of mungbean. So, the vegetative growth and pod formation of mungbean were good. But, there was heavy rains (24.4 mm) during the last week of April. So, mungbean fields were temporally flooded with rain water.

Comparatively lower grain yields were found from all the plots because heavy rains occurred during ripening stage (Last week of April 2017) and the all the plots were submerged into water for five days. Only one picking (pod harvesting) was possible due to flooded water although the vegetative growth was good. Hence, the sudden rain reduced the yield of mungbean.

Financial Analysis

Benefit cost ratio of mungbean cultivation by different tillage and planting methods is shown in Fig. 2. Costs of all tillage and planting methods were calculated assuming fixed cost and variable cost. Components of fixed costs were capital consumption, interest, shelter costs, etc. The components of variable costs were costs of seed, fertilizers, pesticides, herbicides, labour, fuel, oil, irrigation, etc. The highest benefit cost ratio (BCR) was obtained from strip till planted (2.40) and zero till planted (2.60) plots followed by plot planted by power tiller operated seeder (2.20), conventional tillage cum broadcasting (1.88) and bed planting (1.82) methods. The lowest BCR was found from traditional tillage and manual line sowing method (1.61). Higher mungbean grain yield was obtained in traditional tillage cum line method than traditional tillage cum broadcasting method. But the lowest BCR was found in traditional tillage cum line sowing method because this method required higher labours in manual line sowing method. Traditional tillage cum broadcasting method is usually followed by most of the farmers in Bangladesh. All BCRs are comparatively lower for mungbean production because the crop was partially damaged by heavy rains. Based on the BCR, the strip till planter, zero till planter and PTOS may be recommended in Barisal region for mungbean planting. The cost of planting and cost saving of different planting methods over conventional tillage and seeding method are given in Table 3. The overall cost saving by CA machinery over conventional tillage and seeding method was about 50%. Fuel saving and CO_2 emission in CA system over conventional methods are shown in Table 4. Diesel fuel saved per hectare was 45.78 liter that also saved planting cost of BDT 3021.48. Due to less fuel used about 76% carbon dioxide can be reduced using CA planting methods.

Conclusion

The conservation machinery such as ZT, ST, BP and PTOS were tested for cultivation of mungbean in Wazirpur upazila of Barisal district. The effective field capacities of zero till planter (ZT), strip till planter (ST), bed planter (BP), power tiller operated seeder (PTOS) and power tiller were found to be 0.104, 0.109, 0.084, 0.109, and 0.074 ha/h, respectively. The field efficiency of ZT, ST, BP, PTOS and power tiller were estimated as 74.68, 76.47, 75.84, 78.16 and 71.52%, respectively. Fuel saving by ZT, ST, BP, and PTOS was about 60% than that of power tiller. Significantly the highest mungbean grain yields were found from ZT and ST planted plots than those of other plots. Significantly the lowest grain yield was obtained from conventional tillage and broadcasting method.

The highest benefit cost ratio (BCR) was obtained from ST planted (2.60) and zero till planted (2.40) mungbean followed by PTOS (2.20), conventional tillage cum broadcasting (1.88) and bed planting (1.82) methods. The lowest BCR was found from traditional tillage and manual line sowing method (1.61) of mungbean. CA planting system saved about 50% planting cost and reduced about 76% carbon dioxide emission. Based on the fuel consumption, grain yield and BCR, ZT planter and the strip till planter may be recommended in Barisal region for cultivation of mungbean.
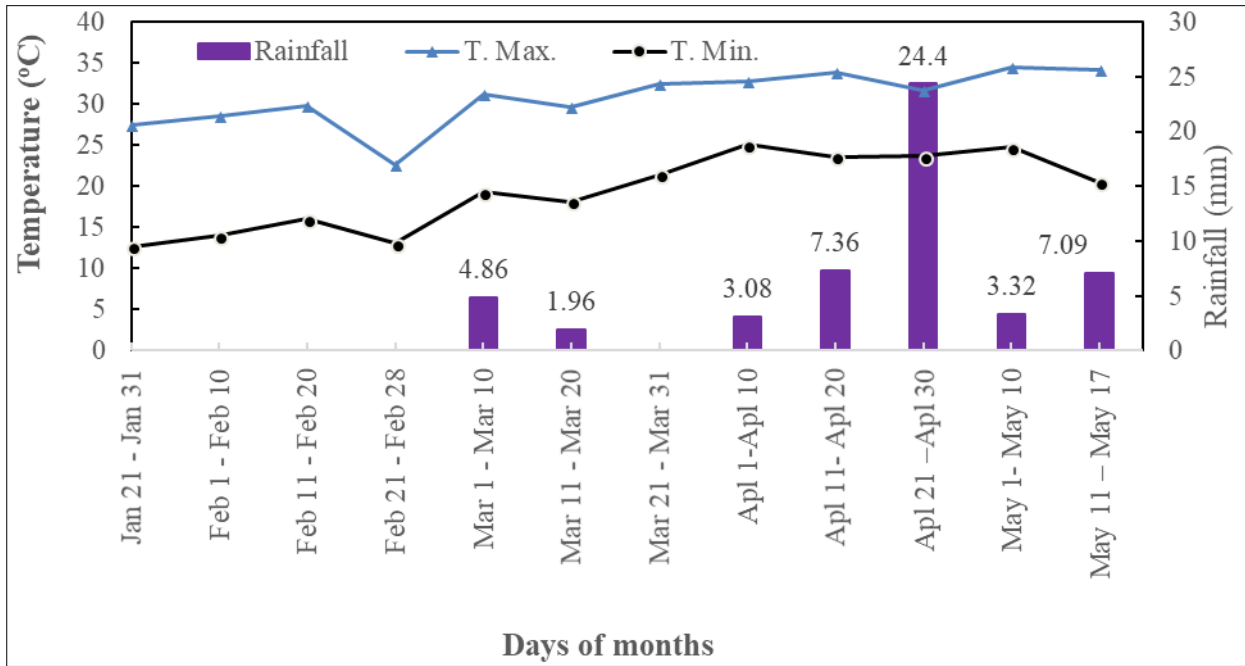
Fig. 1. Temperature and rainfall in Barisal during mungbean growing period.
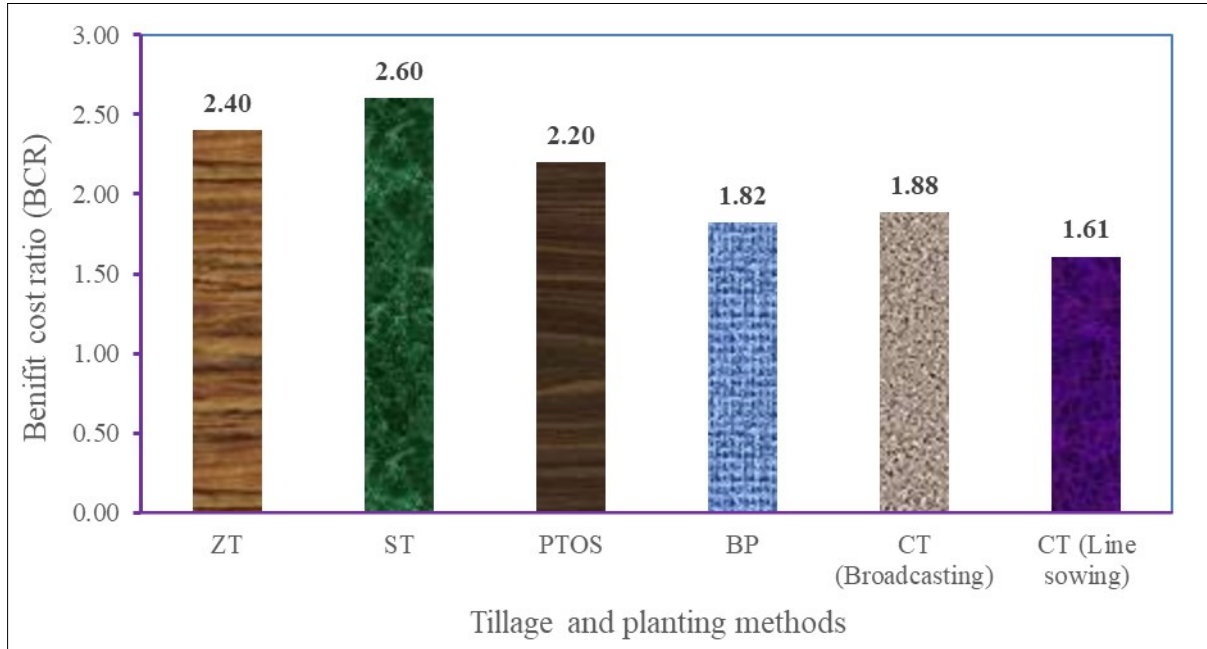

Fig.2. Benefit cost ratio of mungbean cultivation by different tillage and planting methods.

Table 3. Cost of planting in different CA methods over conventional methods

Seeding methods	Cost of seeding (Tk[*]./ha)	Cost saving (%)
PTOS	1673.30	51
ZT	1686.30	51
ST	1747.90	49
BP	1658.60	52
Conventional method	3420.00	-

* 1US$ = 80 BDT

Table 4. Fuel saving and CO_2 emission in CA over conventional methods

Tillage option	Diesel used (l/ha)	Diesel saved (l/ha)	Money saved for fuel (BDT[*]/ha)	CO_2 emission (kg/ha)
CA system	14.00	45.78	3021.48	36.40
Traditional method	59.78			155.42

* 1US$ = 80 BDT

Acknowledgement

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