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Performance of Weeder in Mechanically Transplanted Rice Cultivation

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ABSTRACT

Field performance of low land weeder was evaluated in mechanically transplanted rice fieldat Bahirbagh and Provakordi representing the silty loam soil under Gopalganj district of Bangladesh during the non-irrigated wet season (Aman) 2016. Twenty-one-day-old seedlings were transplanted by walk behind type 4-rows mechanical rice transplanter (DP480) at a pre-set spacing of 300 × 170 mm. Randomized Complete Block (RCB) design with three replications was applied with weeding practices of BRRI weeder (BW) followed by (fb) one hand weeding (HW), BRRI power weeder (BPW) fb one HW, two HW, pyrazosulfuron-ethyl (PSE) fb one HW, weedy check, weed free and mulching fb two HW (farmers' practice) in two locations. The common weed species were observed in experimental sites. Weeding efficiency (WE) of BPW and BW was 67 and 44, respectively. Field capacity of BPW and BW was obtained 0.07 and 0.03 ha hr^{-1}, respectively. Operator's skill influenced the performance of weeder. During operation, BPW damaged 14-15% tillers in both the locations. However, damaged plants were revived after few days. The labour requirement in BW fb one HW, BPW fb one HW, PSE fb one HW and two HW were 380, 362, 243 and 616 man-hr ha^{-1} respectively. Except weedy check, weed management practices showed identical grain yield in both the locations. The BCR was accounted in PSE fb one HW (1.35), BW fb one HW (1.21), BPW fb one HW (1.20) whereas the lowest BCR was observed in weedy (0.83) and two HW (1.00). It can be concluded that pyrazosulfuron-ethyl, BRRI power weeder followed by one hand weeding and BRRI weeder followed by one hand weeding appeared as the cost effective weed control methods in mechanically transplanted Aman rice production.

Keywords: Transplanter, weeder, herbicide, labour, yield and benefit-cost ratio

INTRODUCTION

Rice is grown in about 11.35 million hectare of land in three distinct rice growing seasons are Boro (Dec-April), Aus (April-July) and Aman (Aug-Nov) (Hussain *et al.,* 2012). The majority of rice area is covered by transplanted Aman rice comprising about 5.53 million hectare of the total rice area (BBS, 2015). Rice is predominantly grown by hand transplanting and required labour of 642-708 man-hr ha^{-1} of which seedlings raising and transplanting consumed 19-22% of the total labour requirement (Islam *et al*., 2016a). Hand transplanting of seedling is the most widely adopted and the most ancient method of rice transplanting. Rice transplanting method is changing from manual to mechanical transplanter due to unavailability of labour, burden to increase yield and save the crops from natural disaster. Mechanical transplanting improves labour efficiency, ensures timeliness in operation, faster transplanting and attains optimum plant density that contributes to high productivity (Islam *et al*., 2016a and Manjunatha *et al*., 2009). Weed is a serious problem in rice cultivation. Weed infestation is a natural and acute phenomenon in rice field. Weed depends on the availability of water supply, soil texture and structure, location of the field, weather and climatic condition of the field, depth of plough pan, and organic matter content of the soil (Hossen *et al*., 2015).

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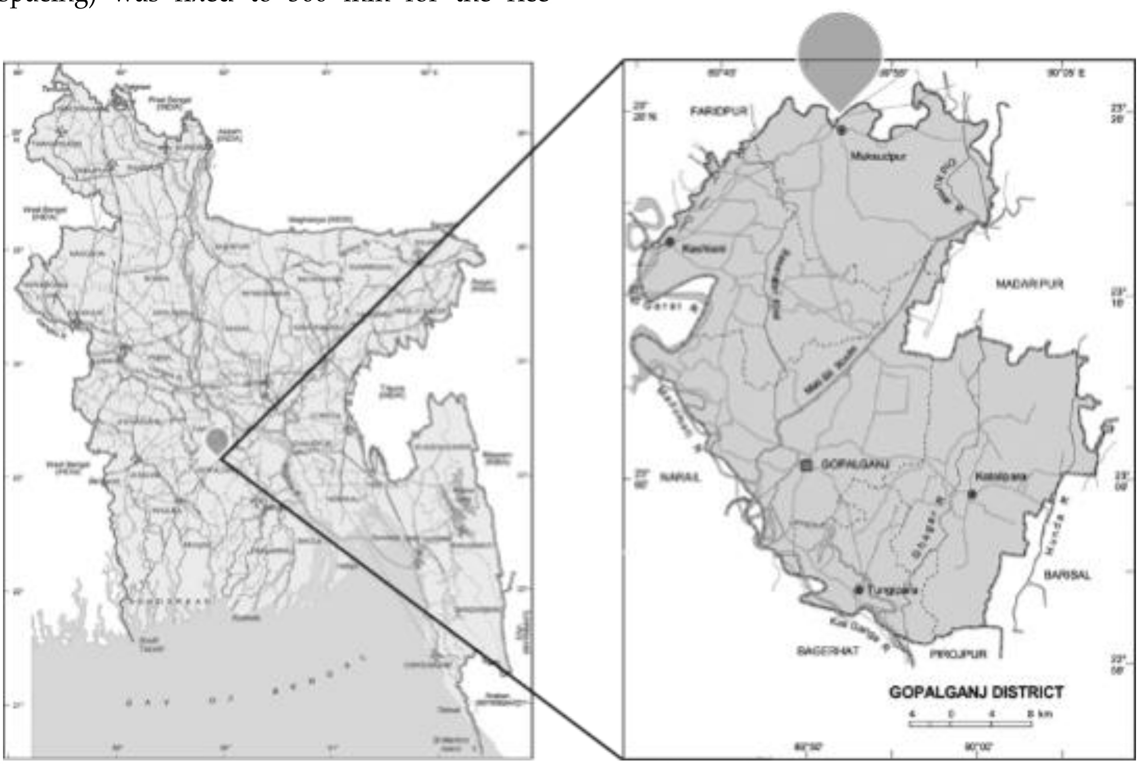
Uncontrolled or improperly controlled weeds compete for soil nutrition with more rapidity in growth and population and cause substantial reduction in yield and grain quality. Severe weed infestation is one of the important factors for such a low yield. The prevailing climatic factors of Bangladesh are highly favourable for luxuriant growth of numerous species of weed, which offer a keen competition with rice crop (Alam *et al.*, 1995). Without weed control, yield losses have been estimated 16 to 48% for transplanted Aman rice (Alam *et al.*, 1996). Weed management requires huge labour resulting in increase of production cost. Lower weeding cost is always preferable from the economic point of view. Weed management is implemented in traditional way by manual labour or in mechanized way by mechanical weeder, power weeder or applying herbicide. Usually, two to three hand weedings are done for growing a transplant rice crop depending upon the nature of weeds and their intensity of infestation. Manual weeding requires 98 man-hr ha^{-1} labour input and there is a great scope of saving up to 78% cost in weeding operation by adopting mechanical means of weeding (Islam *et al.,* 2016b). Mechanical rice transplanting is gaining popularity through the intervention of governmental and non-governmental organizations in Bangladesh as it saved labour, ensured timely transplanting and optimum plant density that contributed to high productivity (Islam, 2016). Many pre-requisite and requisite conditions for successful operation were not identified for Bangladesh condition. Seedling age and plant spacing is also different in mechanically transplanted field compared with the manually transplanted field. Weed management is thus an issue of reconsideration to suit with the mechanical interventions involved with the modern cultivation practices. Different weeding methods especially BRRI weeder and BRRI power weeder were evaluated in manually transplanted rice field. However, there is little understanding of their efficacy for mechanically transplanted rice. Therefore, a study was conducted to evaluate the performance of different low land weeder in mechanically transplanted rice in the farmers' field during the non-irrigated wet season.

METHODOLOGY

The experiment was conducted in the farmers' field at Bahirbagh and Provakordi under Muksudpur upazila, Gopalganj district of Bangladesh during wet season 2016 (Map 1). The soils of the experimental locations represented the silty loam soil. Experimental plots were designed considering the ease of rice transplanter (4-row walking type rice transplanter, model: DP 480) operation. Average sub-plot size of the experimental field was 238 m^2 (17.0 m long and 14.0 m width) in Bahirbagh, whereas, it was 210 m^2 (20.0 m long and 10.5 m width) in Provakordi. Buffer spacing between treatments was 0.5 m. The following seven weeding treatments were arranged in a randomized complete block (RCB) design with three replications. Each of the replication represented a block in the experiment. The treatments were T_1 = BW fb one HW, T_2 = BPW fb one HW, T_3 = Two HW, T_4= Pyrazosulfuron-ethyl (PSE) fb one HW, T_5= Weedy check, T_6 = Weed free and T_7 = Mulching fb two HW (Farmers' practice).

High yielding inbred rice variety BRRI dhan39 was transplanted as variety in Aman season. Twenty-one-day-old seedlings were transplanted in the experimental plots on 19 July 2016 in Bahirbagh and 17 August 2016 in Provakordi respectively. A rotary tiller powered by 2-WT was used for land preparation. Three rotary tillage passes in saturated soil, followed by one leveling, were the operations for land preparation. Plastic tray (580 ×280 × 25 mm) was used for raising mat type seedlings. Clod-free sandy loam soil collected from the respective field was used to fill-up the trays. A total of 130 g of pre-germinated seeds were spread uniformly on each tray. When the radicals and coleoptiles elongate to 1/3 of seed length is desired for pre-germinated seed to broadcast. After sowing, fine and loose soil was spread over the seeds to 3-5 mm depth. Sprinkling water was applied twice a day until complete emergence of seedlings. Seedlings of 125 to 150 mm height with 2-3 leaves were used in the experiment of Bahirbagh and Provakordi respectively. Walk behind 4-rows mechanical rice transplanter (model- DP480) was operated at a pre-set spacing of 300 × 170 mm. There are three options in the rice transplanter (DP 480) to adjust the hill spacing (plant-to-plant spacing). The transplanter was set to maintain 170 mm distance between hills spacing in the row. Spacing between rows (line to line spacing) was fixed to 300 mm for the rice transplanter. The transplanting depth control lever was adjusted to the medium mode during field operation to maintain 20-30 mm depth of seedlings placement. Number of seedlings hill^{-1} were adjusted based on the seedling density setting. There were nine options to select number of seedlings hill^{-1}. The picker was set at point 4 to maintain similar numbers of seedlings hill^{-1} in all treatments for both the locations. During transplanting, minimum standing water was maintained in the field to reduce the floating hills as well as missing hills. Bunds around the individual plots were repaired as and when necessary to control the water flow between the plots. Hill to hill distance of the transplanted seedlings was measured randomly in three places of each sub-plot from 1.0 m of length. Number of plants hill^{-1} was collected after transplanting from 0.25 m^2 of area of each sub plots.



Map 1. Location of the experimental site.

Weed management

Weeds were managed according to the design and treatments. BW and BPW were operated at 25 DAT (Days after transplanting) in both the locations. Pyrazosulfuron–ethyl was applied to control weeds in T_4 at 7 DAT at the rate of 150 g ha^{-1}. One hand weeding was done at 45 DAT to control the weeds of T_1, T_2, T_3 and T_4 plots. Whereas, T_6 (weed free) was weeded at 22, 30, 40 and 50 DAT to keep the field weed free throughout the crop growing period. In case of T_7, weeds were controlled by the farmers manually at 15, 25 and 40 DAT.

Weeding efficiency

Weeding efficiencies (WE) of the BRRI weeder and BRRI power weeder were measured by counting the number of weeds of the pre-selected area before and after weeding. At each sampling time, three quadrates of 0.5 m × 0.5 m were placed randomly in each sub-plot and weeds were collected from each quadrate before and after weeding. Weeding efficiency was calculated using the following equation (Remesan *et al.*, 2007).

$$WE=\frac{W_1-W_2}{W_1}\times100 \qquad (1)$$

where,

WE= Weeding efficiency, %

W_1 = Weed population before weeding, no.

W_2 = Weed population after weeding, no.

Tiller damage

It is the measure of damage on crop plants while weeding operation done and it depends on the uniformity of plant to plant spacing, skill of the operator, field condition and standing water of the experimental fields. Minimum standing water (around 10 mm) was maintained during weeding. In order to determine the damaged plant, bamboo frame of 0.50 × 0.50 m was thrown in the field randomly in three places of each plot and the number of damaged plants in the frame was counted (Tewari *et al.*, 1993). Number of tiller damage during weeding practices was calculated by the following equation:

$$DTR = \frac{Q_2}{Q_1}\times100 \qquad (2)$$

where,

DTR = Damaged tiller ratio, %

Q_1 = Plants in 1 m^2 area before weeding, no.

Q_2 = Damaged plants in 1 m^2 area after weeding, no.

The recommended fertilizer doses for Aman season (cv. BRRI dhan39) were applied at the same rate for all treatments (BRRI, 2013). Diammonium phosphate (DAP), muriate of potash (MoP), zinc sulphate ($ZnSO_4$) and gypsum fertilizers were applied in the soil before transplanting as basal. Urea (N) was broadcast in three equal splits at seven days after transplanting, vegetative stage and before panicle initiation. Pest attacked the plants severely during the study period. However, pests were controlled by two applications of Furadan 5G and Theovit 80 WG along with Virtako 40 WG pesticide to control yellow stem borer and other insect infestation at 28 and 48 DAT in both the locations. Pesticide was mixed with 500-600 liter of water to spray in one hectare of land. Experimental plots were irrigated as and when needed.

General performance parameters

The performance parameters of the low land weeders are common (i.e. forward speed, theoretical and actual field capacity, effective operating time, field efficiency and fuel consumption) as discussed sequentially (Hunt, 1995). All these parameters were used to calculate cost of production and benefit-cost ratio of rice production under different weeding practices.

The time required by a machine to travel certain distance in the field was recorded and then machine forward speed was calculated using the following equation:

$$S = \frac{D}{t} \times 3.6 \quad (3)$$

where,

S = Machine forward speed, km hr^{-1}

D= Distance, m

t = Time required to cover the distance D, sec

Theoretical field capacity was calculated as a function of speed and operating width by the following equation:

$$C_0 = \frac{W \times S}{C} \quad (4)$$

where,

C_0 = Theoretical field capacity, ha hr^{-1}

W = Operating width of the machine, m

C = Constant, 10

Actual field capacity was calculated as a function of total area and total field time by the following equation :

$$Ca = \frac{A}{T} \quad (5)$$

where,

Ca = Actual field capacity, ha hr^{-1}

A= Total area covered, ha

T= Total operating time required for transplanting, hr

The effective operating time of the machine, as a function of time required by it to cover a unit of area performing its task successfully, was measured by the following equation;

$$E_T = \frac{1}{Ca} \quad (6)$$

where,

E_T = Effective operating time, hr ha^{-1}

The field efficiency, as a function of theoretical and actual field capacity was calculated by the following equation :

$$Ef = \frac{Ca}{C_0} \times 100 \quad (7)$$

where,

Ef = Field efficiency, %

The fuel consumption was measured from the amount of refill after finishing an operation and was calculated by using the following equation:

$$F = \frac{Ft}{T} \quad (8)$$

where,

F = Fuel consumption rate, l hr^{-1}

Ft = Total fuel used during operation, l

T = Total time needed for operation, hr

Operating cost of weeder

Operating cost of weeder was calculated considering the fixed cost and variable cost using the method mentioned in Hunt (1995). Depreciation, interest on investment, tax, insurance and shelter are the components of fixed cost and calculated using the following equations:

Depreciation, $D = \frac{P - S}{L}$ (9)

Interest on investment, $I = \frac{P + S}{2} xi$ (10)

where,

D = Depreciation, Tk yr^{-1}

P = Purchase price of the weeder, Tk

S = Salvage value, Tk

L = Working life of the weeder, yr

i = rate of interest

Fixed cost, FC (Tk yr^{-1}) = Depreciation + Interest on Investment + Tax (3% of purchase price) + insurance and shelter cost.

In variable cost calculation, the cost of fuel, lubrication, daily service, power and labour were considered. These costs increase with the increase of machine use and vary to a large extent in direct proportion to days of use per year.

Variable cost, VC (Tk hr^{-1}) = Labour cost + Fuel cost + Oil cost (3% of fuel cost) + Repair and maintenance cost (3.5% of purchase price).

Yield and yield contributing character

Excess water was drained out from the plots before 15 days of harvest to enhance maturity of the crop. Crops were harvested on 2 November 2016 in Bahirbagh and 27 November 2016 in Provakordi respectively. Rice grain yield was recorded from a pre-selected 10 m^2 harvest area and was determined with the adjustment to 14% moisture content.

Cost estimation

Cost of rice production under different weeding practices was calculated based on total production cost. Rental charge of the land and input costs were the components of production cost. Seedling raising, land preparation, fertilizer, labour, herbicides, weeding, transplanter, intercultural operation, irrigation, harvest and post-harvest costs were the components of input cost. Market price of the crop was collected from local markets. Price of the product and production costs were used to calculate gross return, gross margin and benefit-cost ratio. The benefit-cost ratio (BCR) was computed as the gross return divided by production cost. Gross margin was also calculated by subtracting the total inputs from gross return.

Statistical analysis

Data were analyzed as a single factorial design according to Gomez and Gomez (1984) using Statistix 10 programme (Statistix 10 software, 2013). Means were compared with the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Plant spacing and seedling dispensed per stroke

The ultimate productivity of a crop is determined by plant population (Baloch *et al.*, 2007). Before operation of the transplanter, plant to plant spacing was set at 17 cm, and seedling density was set at 4. In actual field condition, plant to plant spacing was obtained 17.1 and 17.4 cm in Bahirbagh and Provakordi respectively (Fig. 1). Islam *et al.* (2017) mentioned that the variation was caused by the slippage and skidding of the transplanter.

Weed species

There are nine common weed species were observed in the experimental sites. The weed species in the experimental plots were *Cyperus rotundus* , *Cynodon dactylon, Digitaria ischaemum, Eleusine indica, Alternanthera philoxeroides, Monochoria vaginalies, Cyperus difformis, Nicotiana plumbaginifolia and Ranunculus scleratus.*

Weeding efficiency

Weeding efficiency (WE) of weeder was depended on the severity of weed, soil moisture and weeding regime. WE of BPW and BW was obtained 66 and 44%, respectively (Fig. 2). The WE of BW was lower than BPW because BW eliminated weeds within 20 cm of spacing as the width of BW was 20 cm and 10 cm space remained unweeded in mechanically transplanted rice field. BW having the width of 20 cm is not suitable for mechanically transplanted rice. Therefore, the width of BW should be increased to get the better WE. On the other hand, BPW exerted the sufficient power in rotor and caused better blades grips with soil, resulting in higher WE of the weeder. Islam *et al.* (2016b) and Islam *et al.* (2017) tested the WE of BW and BPW in two types of soil in wet season rice cultivation and found the WE of BPW was higher than BW. Alizadeh (2011) tested the WE of two types of weeder in low land rice cultivation in Iran and found that WE of power weeder (84%) was higher than the rotary weeder (73%). Ramesan *et al.* (2007) observed that the WE of rotary weeder was 72%. Subudhi (2004) reported that the WE of different types of hand operated weeder was 76 to 91%. Islam *et al.* (2017) reported that the WE of BPW and BW was 78% and 73% in hand transplanted plot. These findings are not consistent to the results of the present experiment due to weeder was operated in sandy loam soil and weed infestation was severe. Generally, WE depended on the weeder type, weed species, weeding time and soil condition. If weeding is delayed, the WE will be decreased for excessive growth of weeds in soil and improper involvement of machine blades in soil depth.

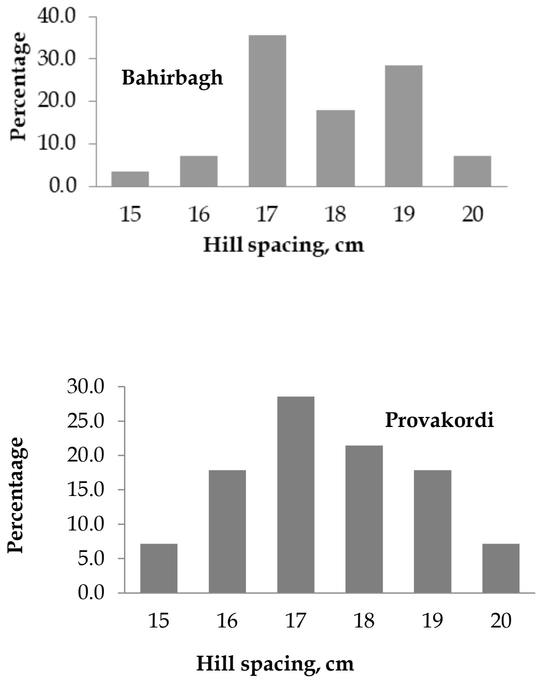


Fig. 1. Plant spacing at Bahirbagh and Provakordi.

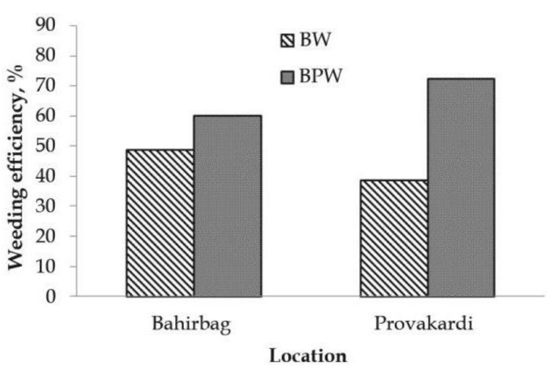


Fig. 2. Weeding efficiency of two types of weeder.

Field capacity

Field capacity is an important factor for any kind of machine operation. Field capacity of BPW and BW was obtained 0.07 and 0.03 ha hr^{-1} respectively (Fig. 3). Islam *et al.* (2016b and 2017) studied the field capacity of BW and BPW in other soil types and obtained almost similar results due to variation of soil types. Operator's skill influenced the weeder performance. At the end of each pass, operator lifted the machine, placing it in another new rows and started operation. This increased the turning time loss, which reduced the field capacity of the BPW.

Tiller damage

Plant spacing is an important factor for successful weeding operation. Results indicated that 14-15% plants were damaged during operation of the BPW in Bahirbagh and Provakordi respectively (Fig. 4). The damaged plants were revived after few days. Similar results were obtained by Islam *et al.* (2016b and 2017). The movement of weeder machines encountered difficulties in BPW because of the distribution pattern and shading of plant over spaces between the rows.

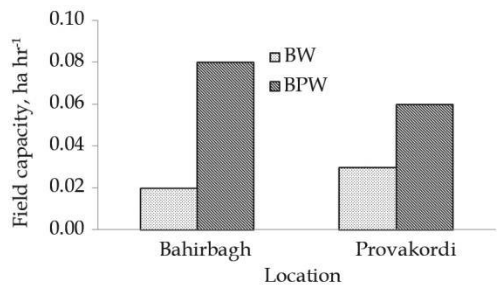


Fig. 3. Field capacity of BW and BPW.

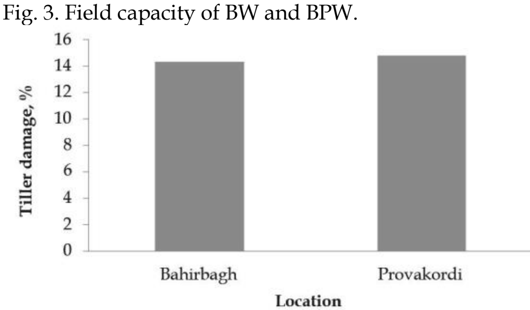


Fig. 4. Tiller damage by BPW.

Labour requirement and weeding cost

Labour requirement and cost of weeding in rice production is one of the major input cost. Both the labour requirement and cost for weeding were varied significantly with the weeding practices (Table 1). In Bahirbagh, the highest number of labourer was required for mulching fb two HW, which was similar to two HW whereas the lowest number of labourer was required in PSE fb one HW, which was similar to BPW. Weeding cost is linearly proportional with the labour requirements for different weed management practices. In Provakordi, significantly higher labour was required in making the rice field weed free, which was similar to mulching fb two HW whereas the lowest and similar labour was required for the rest of the weed management practices. On average, BW fb one HW, BPW fb one HW and PSE fb one HW reduced 38, 41 and 61% labour compared to hand weeding. Islam *et al.* (2016a) stated that BRRI weeder, BRRI power weeder and herbicide application reduced 74, 91 and 98% labour and 72, 63 and 82% cost compared to hand weeding. Alizadeh (2011) mentioned that the labour input in mechanical weeder was obtained 36 man-hr ha^{-1} whereas 112 man-hr ha^{-1} in hand weeding. These values were lower than the present finding. This might be due to the variation in weed density, type of weed and weeding regime.

Yield and yield contributing characters

Weed management practices showed significant effect on grain yield in Bahirbagh. Weedy check gave significantly lower yield followed by mulching fb two HW while yield of paddy in other weeding practices gave statistically similar yield (Table 2). In Provakordi, except weedy check, all other treatments produced statistically similar yield. Averaged over two locations, PSE fb one HW gave higher yield followed by BPW fb one HW, BW fb one HW and weed free.

Economic analysis

Economic analysis included cost of production and return from paddy and straw (Table 3). PSE fb one HW (1.35), BW fb one HW (1.21) and BPW fb one HW (1.21) accounted for the highest BCR while weedy check (0.94) and two HW (1.06) gave the lowest BCR in Bahirbagh. Similar pattern of BCR was observed in Provakordi.

Table 1. Labour requirement as affected by weed management practices.

Weeding method	Labour (man-hr ha^{-1})			Cost (TK ha^{-1})		
	Bahirbagh	Provakordi	Average	Bahirbagh	Provakordi	Average
BW fb one HW	538	222	380	20436	9667	15052
BPW fb one HW	402	322	362	16519	15406	15963
Two HW	897	335	616	33622	14676	24149
PSE fb one HW	278	207	243	10413	9046	9730
Weedy check	0	0	0	0	0	0
Weed free	737	580	659	23042	25358	24200
Mulching fb two HW	1074	345	710	40260	15079	27670
Mean	561	287	380	20613	12747	16680
$LSD_{0.05}$	194.14	242.43	-	7368.2	10732	-
CV, %	19.46	47.43	-	20.09	47.32	-

Note: BW=BRRI weeder, BPW= BRRI power weeder, PSE = Pyrazosulfuron-ethyl, fb=followed by, HW=hand weeding, NS=Not significant

Table 2. Grain yield(t ha^{-1}) as affected by weed management practices.

Weeding methods	Location		Mean
	Bahirbagh	Provakordi	
BW fb one HW	5.7	4.7	5.2
BPW fb one HW	5.5	5.0	5.3
Two HW	5.4	4.7	5.0
PSEfb one HW	5.7	5.2	5.4
Weedy check	3.0	3.6	3.3
Weed free	5.6	4.8	5.2
One mulching fb two HW	4.6	5.2	4.9
Mean	5.1	4.7	4.9
$LSD_{0.05}$	0.75	0.50	-
CV, %	12.55	9.01	-

Note: BW=BRRI weeder, BPW= BRRI power weeder, PSE = Pyrazosulfuron-ethyl, fb=followed by, HW=hand weeding, NS=Not significant

Table 3. Benefit-cost ratio as affected by weed management practices in mechanically transplanted rice.

Weeding method	Input cost (Tk ha^{-1})		Gross return (Tk ha^{-1})		Gross margin (Tk ha^{-1})		BCR		Mean
	L1	L2	L1	L2	L1	L2	L1	L2	
BW fb one HW	97,985	85,427	120,840	101,050	22,855	15,623	1.23	1.18	1.21
BPW fb one HW	94,765	91,854	116,600	107,500	21,835	15,646	1.23	1.17	1.20
Two HW	113,920	91,037	114,480	101,050	560	10,013	1.00	1.11	1.06
PSEfb one HW	87,925	84,732	120,840	111,800	32,915	27,068	1.37	1.32	1.35
Weedy check	76,263	74,600	63,600	77,400	-12,663	2,800	0.83	1.04	0.94
Weed free	102,070	103,001	118,720	103,200	16,650	199	1.16	1.00	1.08
One mulching fb two HW	93,908	91,488	97,520	111,800	3,612	20,312	1.04	1.22	1.13

Note. L1= Bahirbagh, L2= Provakordi, BW=BRRI weeder, BPW= BRRI power weeder, PSE = Pyrazosulfuron-ethyl, fb=followed by, HW=hand weeding, NS=Not significant
Petrol: Tk 90 L-1, Labour (normal) Tk 300 day-1, Labour (skilled): Tk 400 day-1, Paddy:Tk 20 kg-1, Straw: Tk 1.88 kg-1.

CONCLUSION

Considering weeding efficiency and cost as well as benefit-cost ratio pyrazosulfuron-ethyl, BRRI power weeder and BRRI weeder followed by one hand weeding were found more suitable in mechanically transplanted rice field.

RECOMMENDATIONS

The width of BRRI weeder should be modified for operating in the wider spaced mechanically transplanted rice field.

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