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Full Length Research Paper

Field performance evaluation of mechanical weeders in the paddy field

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The field performance of four types of mechanical rice weeders including, single row conical weeder (W_1), two rows conical weeder (W_2), rotary weeder (W_3) and power weeder (W_4) was compared to hand weeding (W_5). Two transplanted local and improved rice varieties namely *Hashemi* and *Hybrid*, respectively were selected for this study. The results revealed that among the mechanical weeders, the highest weeding efficiency (84.33%) was obtained with W_4 and *Hybrid* variety and the lowest value (72.80%) was measured with W_3 and *Hashemi* variety. The average of damaged plants in mechanical weeders was obtained as 3.83% compared to 0.13% in hand weeding. The highest effective field capacities of 0.082 and 0.087 hah^{-1} were measured with W_4 and the corresponding lowest values of 0.0084 and 0.0088 hah^{-1} were obtained with W_5 for *Hashemi* and *Hybrid* varieties, respectively. The weeding cost was reduced by 15.70, 38.51, 22.32 and 48.70% for W_1, W_2, W_3 and W_4, respectively as compared to W_5. The highest break-even point (1.24 hayr^{-1}) was obtained with power weeder (W_4). The average break-even point in weedres of W_1, W_2 and W_3 was found to be 0.077 hayr^{-1}. Among the tested weeders, W_4 showed a proper field performance.

Key words: Paddy field, mechanical weeder, weeding efficiency, hand weeding.

INTRODUCTION

Within the worldwide-cultivated cereals, rice (*Oryza sativa* L.) is one of the leading food crops of the world. In Asia where 95% of the world's rice is produced and consumed, it contributes 40 to 80% of the calories of Asian diet. Rice is a major crop in Iran where rice production increased from 1.3 Mt in 1980 to 3.5 Mt in 2007 (Farahmandfar et al., 2009). Main areas of rice cultivation in Iran are located in Mazandaran and Guilan provinces producing 75% of Iran's rice crop. Both local and high-yielding varieties are grown in the rice-cultivated areas in the country (Alizadeh et al., 2006). Weeding is one of the critical stages in rice cultivation and affects yield and quality of rice. Weeds decrease crop yields from 15 to 50% depending on species, density and weeding time through competition with main crop for light, water and nutrition (Hasanuzzaman et al., 2009). It was accounted that losses due to weeds in main crops are more than 40 million tons per year (Singh and Sahay, 2001). Experiments showed that competition of one kind of weed namely *Echinochloa crus-gali* in paddy fields reduced rice yield around 25% (Islam and Haq, 1991). Likewise, presence of weeds would prepare better conditions for pests and diseases improvement in paddy fields and impose heavy losses on farmers consequently. Common ways for controlling weeds include mechanical, chemical, biological and agronomical ones. Mechanical control, which is performed by hand and mechanical weeders have specific importance from agronomical and conformity with environmental condition points of view (Gite and Yadav, 1990). Mechanical control not only eradicates weed between rows, but also softens superficial soil and enhances aeration of soil. Hand weeding is overwhelming and hurts workers who are mostly women. Depending on weed density and species in the field, labor requirement for weeding varied between 10 to 15 persons per hectare in paddy fields. Concerning growing trend of labor wage during recent years, remarkable part of rice production cost is allotted to this stage. Haq and Islam (1985) reported that weeding includes 21.6% of rice production costs in Bangladesh. Row planting technology using rice transplanter and different grain drill machines, prepared the way for

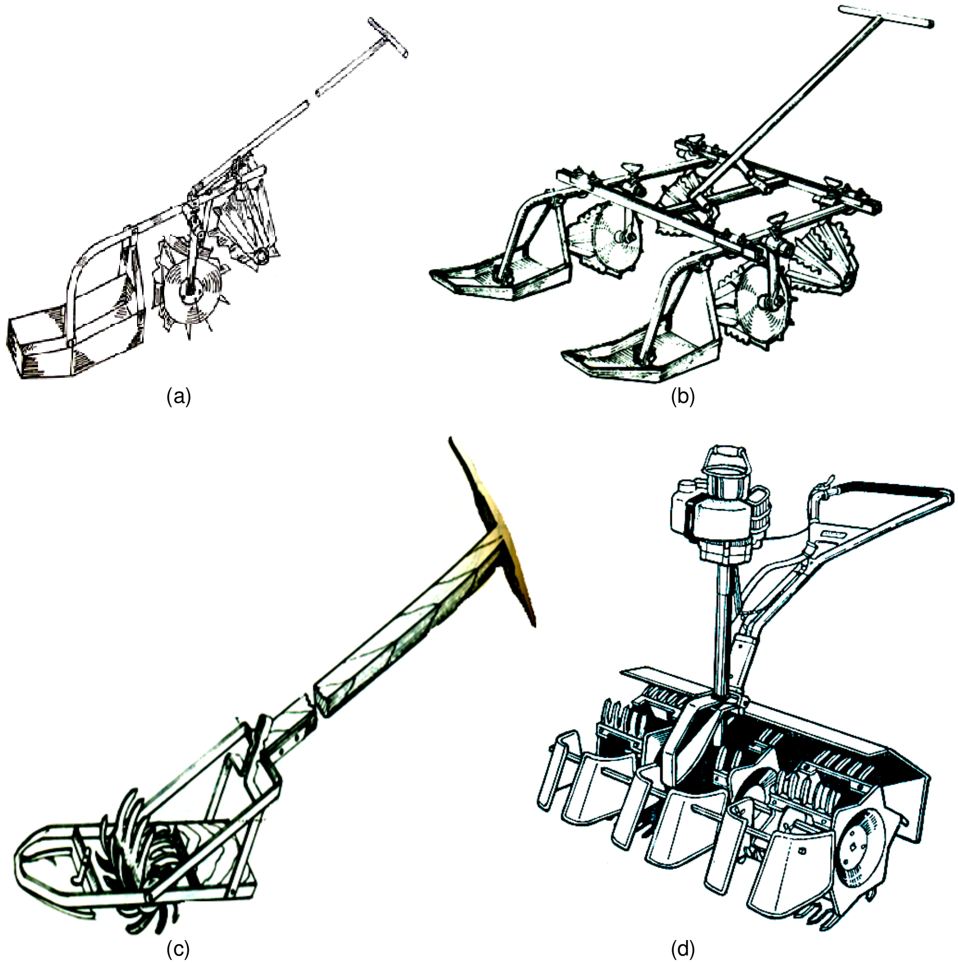

Figure 1. Tested weeders operated in the paddy field. a) Single row conical weeder, b) Two rows conical weeder, c) Rotary weeder and d) Power weeder.

utilization of such plant protection machines as weeders in paddy fields (Tajuddin, 2009). Many researchers have compared field performance and efficiency of weeders with hand weeding method.

Manuwa et al. (2009) designed and developed a power weeder with working width of 0.24 m for weeding in row crop planting. Effective field capacity, fuel consumption and field efficiency of the machine were 0.53 hah^{-1}, 0.7 Lh^{-1} and 95%, respectively. Parida (2002) modified IRRI conical weeder and evaluated its field performance in paddy fields. Results revealed that under experimental conditions, field capacity and field efficiency of the weeder were found to be 0.2 hah^{-1} and 80%, respectively. Other studies in this field showed that the application of weeder would increase field capacity and decrease time and cost of weeding operation (Kumar et al., 2000; Goel et al., 2008; Singh, 1992; Biswas et al., 2000). Review of reports shows that there is a little information on the efficiency of manually operated and power weeders compared to hand weeding in low land paddy fields.

Therefore, the objective of this study was to evaluate field performance of mechanical weeders compared to hand weeding for developing appropriate mechanical control practice in the paddy fields.

MATERIALS AND METHODS

This study was carried out in the experimental paddy field of the Rice Research Institute of Iran (RRII), Rasht during the rice-growing season of 2009. Five weeding methods including, single row conical weeder (W_1), two rows conical weeder (W_2), rotary weeder (W_3), power weeder (W_4) and hand weeding (W_5) were examined. Two transplanted paddy varieties, namely *Hashemi* and *Hybrid* that are local and high-yielding varieties, respectively were chosen in the experiment. The schematic representations of the mechanical weeders used in the experiment are presented in Figure 1. The paddy field was prepared using conventional tillage practice, which is first plowing once followed puddling and harrowing twice under the flooding conditions by a power tiller. To raise mat-type seedlings for transplanting, sprouted paddy seeds were sown uniformly over the plastic trays. The seedlings trays were covered with fine soils, stacked and covered with polyethylene sheet for germination process. After the germination stage was completed, the seedling trays were transferred to main nursery in the field for the greening and hardening stages. The mat seedlings were ready to transplant when they had 2 to 3 leaves and 20 days old with 15 cm height. Transplanting was done in rows at 30 cm fixed intervals. The hill spacing on each row for the varieties of *Hashemi* and *Hybrid* was 15 and 20 cm, respectively. Because of short hill spacing, the weeds between them were removed by labors and weeding machines were used in controlling weeds between the rows.

To determine the weeding efficiency in four places of each plot wooden frame of 1 × 1 m was thrown in the field randomly and the number of weeds was counted. The weeding efficiency of the weeders was calculated by the following equation (Remesan et al., 2007):

$$WE = \frac{N_1 - N_2}{N_1} \times 100 \quad (1)$$

Where, WE is the weeding efficiency of the weeders (%), N_1 and N_2 are the number of weeds before and after weeding, respectively.

In order to determine the damaged plant, as a quality of work done (Tewari et al., 1993) in four positions of each plot, wooden frame of 1 × 1 m was thrown in the field randomly and the number of damaged plants in the frame were counted. Then, the percentage of damaged plants was obtained by the following equation:

$$DP = \frac{Q_1}{Q_2} \times 100 \quad (2)$$

Where, DP is the damaged plants (%), Q_1 and Q_2 are the total number of plants and damaged plants per m^2, respectively.

To determine the travel speed of the machines during operation, the needed time for covering 10 m between two planting rows was recorded. Four measurements were recorded in each plot. Effective field capacity (C_e), field efficiency (F_e) and work capacity (W_c) were calculated by the following equations (Hunt, 1995):

$$C_e = \frac{S \cdot W \cdot e}{10} \quad (3)$$

$$F_e = \frac{T_e}{T_t} \times 100 \quad (4)$$

$$W_c = \frac{1}{C_e} \quad (5)$$

Where, C_e is the effective field capacity (hah^{-1}), S is the travel speed of the weeder (kmh^{-1}), W is the width of work (m), F_e is the field efficiency of the weeder $(\%)$, T_t and T_e are the total and useful working time (h), respectively and W_c is the working capacity (hha^{-1}). Also, the total time for job fulfillment and wasted time in each plot was recorded.

In order to compare weeding cost in mechanical and hand methods, all the cost wages in hand weeding and the fixed and variable cost in mechanical operations were calculated. The fixed costs are including depreciation, interest, insurance, shelter and taxes. Depreciation was determined from straight-line method by the following equation (Alizadeh et al., 2007):

$$D = \frac{P - V_s}{L_u} \quad (6)$$

Where D is mean annual depreciation cost $(Rialyr^{-1})$, P is purchase value $(Rial)$, V_s is the salvage value $(Rial)$ and L_u is useful life (yr). Interest is an actual cost in agricultural machinery and was determined from straight-line method by the following equation (Alizadeh et al., 2007):

$$I = \frac{P + V_s}{2} \times i \quad (7)$$

Where, I is the mean interest $(Rialyr^{-1})$ and i is interest rate $(\%)$. In this study, the costs of insurance, taxes and shelter are considered negligible. Variable costs include fuel, lubricant, repair and operator costs and are directly related to the amount of work done by the machine. Repair cost for the weeders was considered 5% of purchase value and lubricant cost was accounted to be 30% of fuel cost (Remesan et al., 2007). The wages of labor in hand weeding method was considered based on the 2009 wages price list with 8 h of work per day. The machine operational cost is sum of the fixed and variable costs and was calculated by the following equation (Hunt, 1995):

$$A_c = F_c + R_m + H[(F + O + L)] \quad (8)$$

Where, A_C is annual operational cost of the machine $(Rialyr^{-1})$, F_c is annual fixed cost $(Rialyr^{-1})$, R_m annual repair cost $(Rialyr^{-1})$, H is annual operational hours (h), F is fuel cost $(Rialh^{-1})$, O is lubrication cost $(Rialh^{-1})$ and L is the labor cost $(Rialh^{-1})$. The break-even point, the area that a machine has to work per year in order to justify owning the machinery was determined by the following equation (Alizadeh et al., 2007):

$$B_e = \frac{F_c}{V_c - V_{cm}} \quad (10)$$

Where, B_e is the break-even point (haY^{-1}), F_c is the annual fixed cost $(Rialyr^{-1})$, V_c is the cost of customary method $(Rialha^{-1})$ and V_{cm} is the variable cost of the machine $(Rialha^{-1})$.

This experiment was conducted in split-plot with the variety as

Table 1. Means comparison for weeding efficiency and damaged plants in different weeding methods.

	Weeding efficiency (%)		Damaged plants (%)	
Methods[1]	***Hashemi***[2]	***Hybrid***[2]	***Hashemi***	***Hybrid***
W_1	73.2[d]	74.4[d]	3.82[abc]	3.13[c]
W_2	73.8[d]	77.5[c]	4.45[a]	3.84[abc]
W_3	72.8[d]	74.6[d]	4.26[ab]	3.53[bc]
W_4	82.6[b]	84.3[b]	4.03[ab]	3.68[abc]
W_5	96.7[a]	97.5[a]	0.27[d]	0[d]

[1]W_1: Single row conical weeder, W_2: two rows conical weeder, W_3: rotary weeder, W_4: power weeder , W_5: hand weeding; [2]values in the same columns followed by different letters are significantly different ($p<0.05$).

main plot and the weeding method in sub-plot based on randomized complete block design (RCBD) with three replications for each treatment. Data were analyzed using the ANOVA and the mean comparisons were determined using Duncan's multiple range tests.

RESULTS AND DISCUSSION

Weeding efficiency

Means comparison for weeding efficiency in the experimental treatments is demonstrated in Table 1. Results showed that for each type of variety, there is a significant difference ($P<0.01$) between various methods. Amongst mechanical weeders (W_1, W_2, W_3 and W_4), the highest weeding efficiency (83.45%) was belonged to W_4 and the lowest value (73.8%) was obtained in W_3. This could be attributed to utilized active rotors mechanism in the power weeder. It means that the engine would provide the needed power for rotor caused better blades grips with soil, resulting in higher weeding efficiency of the weeder. The results also showed that for each type of mechanical weeder, the weeding efficiency in *Hybrid* variety was more than *Hashemi*. This may be due to differences in canopy pattern of the tested rice varieties in vegetative stage. *Hybrid* as a high-yielding variety grow straightly so that there is enough space between rows for operation of weeder and the operator is able to control better while weeding. On the contrary, because of plant shading in the local variety of *Hashemi*, the movement of machine would face difficulty. Generally, weeder efficiency depends on the weeder type, weed species and the weeding time. If weeding is delayed, the weeder efficiency will be decreased for excessive growth of weeds in soil and improper involvement of machine blades in soil depth. Different results have been reported about mechanized and hand weeding efficiency. Ramesan et al. (2007) reported that the weeding efficiency of conical and rotary weeders were around to be 79 and 72.25%, respectively.

The weeding efficiency of modified IRRI conical weeder was 80% (Parida, 2002). Likewise, Subudhi (2004) reported that the efficiency of different types of hand-operated weeders is between 76 to 91%, which is matched results of the current experiment.

Damaged plants

The means comparison for damaged plants in the experimental treatments is shown in Table 1. Results indicated that the least percentage of damaged plants (0.13%) was obtained in hand weeding (W_5), while the most one (4.14%) was registered in two rows conical weeder (W_2). The power weeder caused less damaged plant, although it had high efficiency rather than other experimental weeders. The results also revealed that in each weeding method, the percentage of damaged plant in *Hashemi* variety was significantly ($P<0.01$) more than *Hybrid*. This could be related to that as mentioned in the previous section, the movement of weeder machines encounters difficulties in *Hashemi* variety because of the distribution pattern and shading of plant over spaces between the rows and percentage of damaged plant will be increased consequently. In the other hand, *Hybrid* variety grows erectly and let weeder move easily between the rows caused fewer damages of plants through weeding.

Field capacity and field efficiency

Means comparison for effective field capacity (C_e), field efficiency (F_e) and working capacity (W_c) of the tested weeders are illustrated in Table 2. It was observed that among mechancal weeders, the most C_e (0.084 hah^{-1}) belonging to W_4 and W_2 was in the second rate. Besides, the least C_e (0.0086 hah^{-1}) was related to W_5. In power weeder, travel speed of operator fallows the peripheral speed of weeder rotor (Figure 2). Regarding high speed of rotor, the operator has to trail rapidly. On the other hand, power weeder compared to other tested weeders

Table 2. Field performance of the mechanical and hand weeding methods in the paddy field.

	$C_e(hah^{-1})$		W_c (hha^{-1})		F_e (%)	
Methods	***Hashemi***	***Hybrid***	***Hashemi***	***Hybrid***	***Hashemi***	***Hybrid***
W_1	0.018^{cd}	0.020^{bcd}	54.79^{b}	49.20^{bc}	82^{a}	84^{a}
W_2	0.036^{bc}	0.038^{b}	27.83^{cd}	26.50^{cd}	78^{a}	80^{a}
W_3	0.020^{bcd}	$0.024b^{bcd}$	48.41^{bc}	41.71^{bc}	81^{a}	83^{a}
W_4	0.082^{a}	0.087^{a}	12.16^{d}	11.40^{d}	82^{a}	85^{a}
W_5	0.0084^{d}	0.0088^{d}	126.18^{a}	116.17^{a}	ND	ND

Ce: effective field capacity, Wc: work capacity, Fe: field efficiency, ND: not defined; W1: single row conical weeder, W2: two rows conical weeder, W3: rotary weeder, W4: power weeder, W5: hand weeding. Values in the same columns followed by different letters are significantly different (p<0.05).

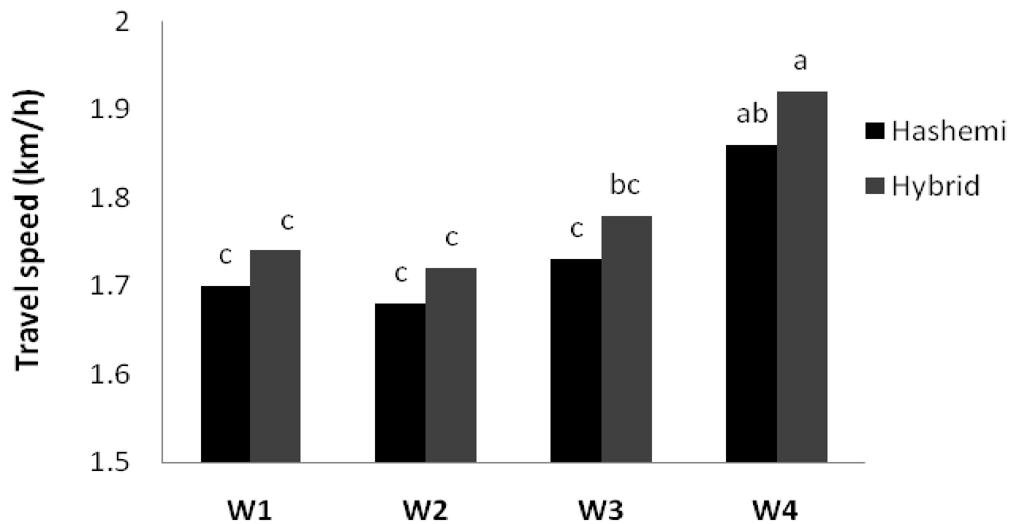

Figure 2. Comparison of travel speed of the tested weeders in paddy field (W_1: single row conical weeder, W_2: two rows conical weeder, W_3: rotary weeder, W_4: Power weeder and W_5: hand weeding).

has more width of work, so based on Equation 3, it has also more C_e. There were no significant differences between the means of C_e in W_1 and W_3. The field efficiency, which indicates ratio of useful working time to the total working time was maximum in W_4 and it was minimum in W_2, however there were no significant differences between the treatments. As shown in Table 2, the greatest working capacity (W_c) of 121.17 hha^{-1} was measured in W_5. This could be attributed to lower C_e in hand weeding method. The W_c in the treatment of W_1, W_2, W_3 and W_4 were 52, 27.17, 45.06 and 11.78 hha^{-1}, respectively. The weeding operation time in W_1, W_2, W_3 and W_4 was decreased by 57.07, 77.57, 62.8 and 90.27%, respectively as compared to hand weeding method. Different results were reported by other researchers. Field capacity of an IRRI modified hand-operated weeder was 0.2 hah^{-1} (Parida, 2002). Tajuddin (2009) developed a power weeder and reported that the effective field capacity of weeder was around 0.75 hah^{-1} in Indian paddy fields. The effective field capacity of rotary weeder, conical weeder and hand weedering were found to be 0.021, 0.024 and 0.003 hah^{-1}, respectively. The field efficiency of rotary and conical weeders was 72.5 and 79% respectively (Remesan et al., 2007).

Field performance of four types of hand-operated weeders were evaluated in India and results showed that the field capacity of these machines were varied from 0.17 to 0.89 hah^{-1} (Subudhi, 2004).

Cost analysis

The items for evaluating and comparing weeding costs in mechanical and hand methods are illustrated in Table 3. Annual operation of the weeders was determined for 160 h based on 20 days actual annual use in paddy field and daily 8 h useful operation. Annually coverage area was obtained from multiplication of the effective field capacity

Table 3. Basic calculations of weeding cost in different methods.

Methods	Initial cost (rials)	Salvage value (rials)	Useful life (year)	Annual operation (h)	Effective field capacity (hah^{-1})	Area coverage (hayr^{-1})
W_1	500000	50000	4	160	0.019	3.04
W_2	1000000	100000	4	160	0.037	5.92
W_3	500000	50000	4	160	0.022	3.52
W_4	15000000	1500000	5	160	0.084	13.44
W_5	ND	ND	ND	ND	0.0086	1.37

W1: single row conical weeder, W2: two rows conical weeder, W3: rotary weeder, W4: power weeder, W5: hand weeding and ND: not defined.

Table 4. Weeding cost in different weed control methods.

Methods	Fixed cost (Rialha^{-1})	Variable cost (Rialha^{-1})	Machine operating cost (Rialha^{-1})	Labor input[1] (Man-hha^{-1})	Labor cost (Rialha^{-1})	Total cost (Rialha^{-1})	Cost reduction compared to hand weeding (%)
W_1	47862	1652947	1700809	40	1250000	2950809	15.70
W_2	49155	853027	902182	40	1250000	2152182	38.51
W_3	41335	1427545	1468880	40	1250000	2718880	22.32
W_4	274553	520678	795231	32	1000000	1795231	48.70
W_5	ND	ND	ND	112	3500000	3500000	Base

W1: single row conical weeder, W2: two rows conical weeder, W3: rotary weeder, W4: power weeder, W5: hand weeding; 1Labor cost for weeding on rows in mechanical methods and ND: not defined.

and annual hours of operation. The comparison of weeding costs in the experimental treatments is shown in Table 4. In mechanical weeders, the cost of machine operation is the sum of fixed and variable costs. The total cost of weeding is gained from all machine operation cost and labor cost for weeding between the hills on row. In hand weeding treatment (W_5), the total cost of operation is just related to the labor cost. Among the weeders, the greatest fixed cost of 274553 $Rialha^{-1}$ was associated with W_4 and the least one with 41335 $Rialha^{-1}$ pertained to W_3. However, in case of variable cost, the results were varied in such a manner that the least cost was associated with W_4 (520678 $Rialha^{-1}$) and the most cost was related to W_1 (1652947 $Rialha^{-1}$) which due to low field capacity of conical weeder compared to other tested weeders. The average labor input in mechanical weeder was 36 man-hour ha^{-1} compared to 112 man-hour ha^{-1} in hand weeding. In mechanical weeder, labor just controls the weeds between the hills on rows and the weeding operation between the rows is done by the machine. Based on the obtained results, weeding cost in W_1, W_2, W_3 and W_4 was reduced by 15.7, 38.51, 22.32 and 48.70%, respectively compared to hand weeding method. Among the mechanical weeders, the lowest total weeding cost was associated with W_4 (1795231 $Rialha^{-1}$) and the most one belonged to W_1 (2950809 $Rialha^{-1}$). The cost of hand weeding was accounted for 3500000 $Rialha^{-1}$. Similar results were also reported by other researchers indicating significant decrease in the mechanized methods over hand weeding (Goel et al., 2008; Remesan et al., 2007; Tajuddin, 2009; Parida, 2002).

The break-even point (BEP) analysis was done considering the actual cost of operation of the weeders and prevailing cost of the hand weeding. As shown in Figure 3, the highest BEP (1.24 hayr^{-1}) was obtained with power weeder (W_4). This could be attributed to higher annual fixed cost (F_c) of this type of weeder than the other tested implements. The average BEP in manually-

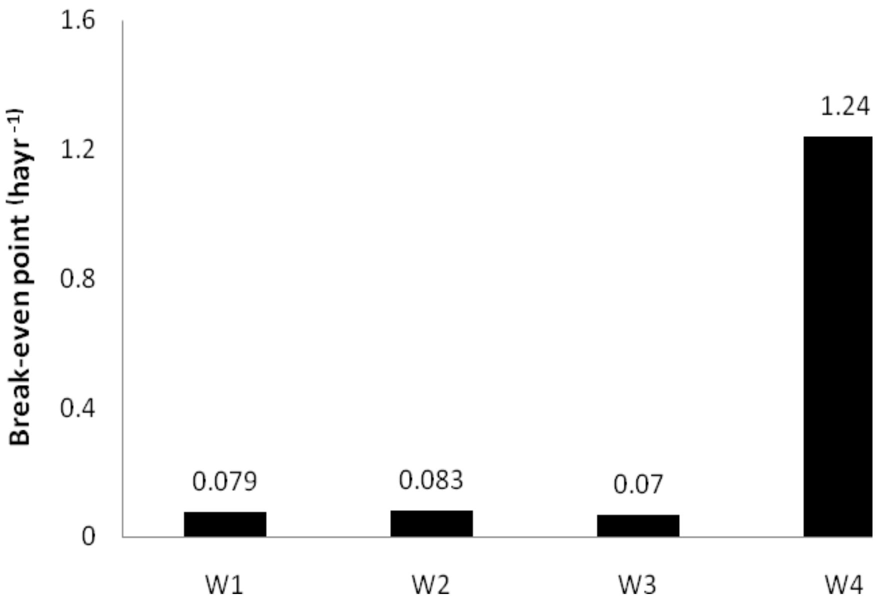

Figure 3. The break-even point of different mechanical weeders in paddy field (W_1: single row conical weeder, W_2: two rows conical weeder, W_3: rotary weeder, W_4: Power weeder and W_5: hand weeding).

operated weeders of W_1, W_2 and W_3 was found to be 0.077 $hayr^{-1}$.

Conclusions

The following conclusions were drawn from the results of this study:

1) Among the tested weeders, the highest weeding efficiency and effective field capacity were registered in the power weeder.
2) The weeding operation time in single row conical weeder, two rows conical weeder, rotary weeder and power weeder was decreased by 57.07, 77.57, 62.8 and 90.27%, respectively compared to hand weeding method.
3) Weeding cost in single row conical weeder, two rows conical weeder, rotary weeder and power weeder was reduced by 15.7, 38.51, 22.32 and 48.70%, respectively compared to hand weeding method.

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