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Evaluation of a Rice Reaper Used for Rapeseed Harvesting

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Abstract: Introduction of appropriate machinery is one of the major factors for reducing labour requirements and production costs of second crop cultivation after rice especially rapeseed. In this study, performance of power tiller-mounted rice reaper used for rapeseed harvesting was assessed and compared with manual harvesting using sickle. The results showed that the effective field capacity of the reaper was 0.170 ha/h compared to 0.008 ha/h for manual harvesting. Labour requirements for reaper and manual harvesting were 5.88 and 128 man-h/ha, respectively. The grain losses for manual and reaper harvesting were 7.33% and 6.83%, respectively. There were no significant differences between means of losses in the two methods. The cost of harvesting operation (without threshing and handling costs) was 88.88$/ha for manual harvesting and 15.20$/ha for reaper harvesting (mechanical harvesting). The break-even point of the machine is 4.83ha/year; therefore if the machine (power tiller and reaper combined) works less than this amount it is not economical and renting machine should be considered.

Key words: Rapeseed % harvesting machinery % manual harvesting % paddy fields

INTRODUCTION

Rapeseed is the third most important oil-producing crop after soybean and palm. It accounts for 14% of vegetable oil produced in the world. The most important rapeseed producing countries are China, Canada, India and some European countries (France, England and Germany), which produce 89.4% of the total production. Rapeseed cultivation area in Iran is 129229 hectares producing 213000 tonnes rapeseed per year [1].

Special qualities of rapeseed plant and its adaptability to weather condition in most part of the country have increased the cultivation area of this crop. One of the areas that have been encouraged to grow rapeseed after rice harvesting is the paddy field of Caspian Sea, but despite efforts made the anticipated target have not been reached. The unsuitable physical condition of paddy fields soil, lack of desirable drainage system, lack of appropriate machinery and implements, small fields and simultaneous rapeseed harvesting and rice cultivation, are some difficulties for the development of rapeseed cultivation in this area. Rapeseed harvesting is one of the crucial stages with regards to quantity and quality of the produced crop and the production costs is also important. The harvesting time of rapeseed is coincided with the start of rice cultivation (land preparation and rice transplanting) and is faced with lack of labour and high wages which is a major problem. On the other hand low work efficiency with manual harvesting delays harvesting operations of the rice crop. To alleviate the problems concerned with growing rapeseed in the paddy fields after harvesting rice, development of mechanization and introduction of suitable machinery specially harvesting machinery is inevitable.

Combine harvesters are used to harvest rapeseed in most part of the country but are faced with limitation in small paddy fields of Caspian Sea. The small field sizes and low traffic capability of soil to withstand the weight of combine at harvesting, causes an increase in losses and also decrease combine field efficiency and capacity. Then again, because of the weather condition and probable spring rainfall, the increase in soil moisture content and field water clogging make the movement of combine harvester difficult in most fields. Further more the time needed for

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the crop to reach the required moisture content that is necessary for combine harvesting causes delay in the rice transplanting operation and therefore leading to a decrease in rice crop yield.

In most rapeseed growing countries, the swather and windrower are also used for harvesting the crops. The suitable combination of harvesting machinery and threshers is dependent on the economic and climate conditions and type of crop variety in each area. There is no doubt that the cost of machinery and the labour requirement for each method of harvesting are also effective factors that determine the choice of harvesting method. Choice of suitable harvesting method not only reduces production costs but also increases yield and quality of oil produced [2].

Becel and Mayko [3] studied the effect of direct harvesting with combine harvester on rapeseed yield in western Canada. They reported that since 1985 most rapeseed producers in western Canadian replaced the two stages harvesting using swather with combine harvester. The advantages of combine harvesting is the elimination of swathing operation and the cost involved with that and also time saving, but the results from their research on harvesting different varieties with combine and swather indicated that the choice of suitable method of harvesting also depend on the crop variety. The combine harvester was most efficient for some varieties, where as swathers were more efficient for other varieties.

In some countries, the rice reaper is used for harvesting other crops such as soybean. In Thailand with some modification on rice reaper such as stronger blades, reducing minimum cutting height from 80mm to 40mm, changing distance between star wheels from 30mm to 40mm and increasing blades stroke speed from 437 to 487 rpm, it was used for harvesting soybean. The tests showed that with these modifications, the amount of harvesting losses decreased from 13.2% to 6.27%. The cutting width of the machine was 1.2 m and was powered with a 5.5 horse power petrol engine. The machine field efficiency was 0.083 ha/h compared to 0.005 ha/h of manual harvesting with sickle. The forward speed of machinery was 2.5 km/h. In northern part of Iran the rice reaper is used only for a month in rice harvesting season and is not used in any other part of the year. The objective of this study was to assess performance, grain losses and operational costs of rice reaper which was used for rapeseed harvesting and compare them with manual harvesting method.

MATERIALS AND METHODS

The experiment was conducted in research farm of the Rice Research Institute of Iran (RRII) near the city of Rasht in 2004. The previous crop was rice and rapeseed was planted after rice being harvested. The planting method of rapeseed in this region is usually by broadcasting and row planting. The rapeseed harvesting was performed manually (with sickle) and mechanically (with reaper). The reaper used for harvesting was mounted on a power tiller of 5 kW (Kubota GA-70); the cutting width of the machine was 1.1m. The weight of reaper and power tiller were 70 and 168 kg, respectively. The cutting height of the reaper can be adjusted from 0.2 to 0.55 m. The parameters that were measured during crop harvesting are as follows:

Speed of travel (forward speed): For measuring forward speed of power tiller while harvesting crop, the distance the tiller traveled in 15 seconds was measured and the speed of travel was recorded in terms of km/h.

Time losses and effective operating time: Time losses while harvesting crop is the time for adjustments, turning, fuelling and etc. The start and finish time of harvesting in each plot was also noted.

Field efficiency: Field efficiency is the ratio of effective operating time to total operating time (the ratio of the time a machine is effectively operating to the total time the machine is committed to the operation), in each plot and was determined by the following equation [4]:

$$e = \frac{T_e}{T_t} \times 100 \quad (1)$$

Where,
e = Field efficiency (%)
T_e = Effective operating time (min)
T_t = Total operating time (min)

Effective field capacity: Effective field capacity is the actual rate of performance of land or crop processing in a given time, based on total field time. In other words effective field capacity of a machine is a function of the rated width of the machine, the percentage of rated width actually utilized, the speed of travel and the amount of field time lost during the operation. In order to determine effective field capacity the rated width of implement (cutting width), Speed of travel and field efficiency were measured. The effective field capacity was calculated by the following equation [5]:

$$C_e = \frac{SWe}{10} \quad (2)$$

Where,
C_e = Effective field capacity, in hectares per hour (ha/h)
S = Speed of travel, in kilometres per hour (km/h)
W = Rated width of implement, in meters (m)
e = Field efficiency, in percent (%)

Harvesting losses: In order to estimate harvesting losses in manual and reaper harvesting, first the losses that occur before harvesting (preharvest) must be measured. To do this, in four parts of each plot with the use of a wooden frame with 1m×1m dimensions, all grains fallen within the frame are collected and weighed and the mean of the four measured values are recorded. Harvesting losses include shattering and uncut losses and were determined by the following equation [6]:

$$W_{gt} = W_{gl} + W_{g2} + W_{g3} \quad (3)$$

Where,
W_{gt} = Total losses (g/m^2)
W_{g1} = Preharvest losses (g/m^2)
W_{g2} = Shattering losses (g/m^2)
W_{g3} = Uncut losses (g/m^2)

After measuring the amount of losses at different stages, the percentage of harvest losses were determined by the following equation [6]:

$$H = \frac{W_{gt} - W_{g1}}{Y_g} \times 100 \quad (4)$$

Where,
H = Percentage of harvest losses (%)
W_{g1} = Preharvest losses (g/m^2)
W_{gt} = Total harvesting losses (g/m^2)
T_g = Grain yield (g/m^2)

Harvesting costs: In order to compare harvesting costs in manual and reaper methods, all the costs of wages in manual and the fixed and variable costs in mechanical operations were calculated. A fixed cost are depreciation cost, interest, shelter and taxes and is a function of purchase value, useful life and interest rate [7]. Depreciation was determined from straight-line method by the following equation [4]:

$$D = \frac{P - V_s}{L_u} \quad (5)$$

Where,
D = Mean yearly depreciation ($/y)
P = Purchase value ($)
V_s = Salvage value ($)
L_u = Useful life (Y)

Useful life for power tiller and reaper was considered to be 10 and 5 years, respectively. The machine salvage value was considered to be 10% of purchase value [7]. Interest is an actual cost in agricultural machinery and was determined from straight line method by the following equation [4]:

$$I = \frac{(P + V_s)}{2} \times i \quad (6)$$

Where,
I = Mean interest ($/y)
P = Purchase value ($)
V_s = Salvage value ($)
I = Interest rate (%)

The insurance and shelter costs were 25% of purchase value [8].Variable costs include fuel, lubricant, repair and operators costs and are directly related to the amount of work done by the machine. Repair cost for power tiller and reaper was considered to be 5% of purchase value for every 100 hours of effective operation. [7]. Lubricant cost is 25% of fuel cost. The operator wages was 1.11 $/h (on the basis of the 2001 wages price list). The wages of labour in manual method of harvesting using sickle was also calculated and it was 5.55 $/day (eight hours of work per day).

The break-even point, the area that a machine has to work per year in order to justify owning the machinery is determined by the following equation:

$$B_e = \frac{F_c}{V_{ct} - V_m} \quad (7)$$

Where,
B_e = Break-even point (ha/y)
F_c = Fixed costs ($/y)
V_{ct} =Variable costs for manual method ($/ha)
V_m =Variable costs for machinery method ($/ha)

RESULTS AND DISCUSSION

Plant specification: Some of the agronomical specifications measured while harvesting rapeseed are shown in Table 1. Each measurement in the Table 1 is a mean value of 10 measurements that were obtained randomly in each plot. It can be seen that, the first secondary stem is just above the ground, this caused the cutting height of blade to decrease to the minimum possible level of 25 mm. The stem thickness in broadcast and row crop planting was on average 14.2 mm but stem thickness differences were large. So that some of the stem thickness was more than 20 mm and some were less than 7 mm.

Reaper performance: Measures of the reaper performance are the rate and quality at which the operations are accomplished. The mean value of some of the parameters that include time losses; total operating time, cutting width, forward speed, effective field capacity and field efficiency are shown in Table 2. The cutting width was 1.1 meter and the forward speed of the machine was 2.14 and 2.23 km/h for broadcast and row crop planting methods, respectively and the mean forward speed for the two methods was 2.18 km/h. Studies carried out by Alizadeh [9] showed that forward speed of reaper mounted on a power tiller for harvesting rice was 2.41 km/h which is higher than the rapeseed harvester.

The results showed that the machine field efficiency is less than its stated field efficiency that is quoted by the manufacturer. The reason for low field efficiency is small fields and increase in time losses. Field efficiency for broadcast and row planting were 68.7% and 73.7 %, respectively. The field efficiency for rapeseed reaper was less than rice reaper. The studies by Alizadeh [9] showed that the mean field efficiency for mounted rice reaper was 82% compared to 71% for the same reaper for rapeseed harvesting.

The effective field capacity of the reaper for broadcast and row planting methods was 0.161 and 0.180 ha/h, respectively and there was no significant difference. The effective field capacity of machine is a function of speed of travel, field efficiency and cutting width. In manual harvesting with sickle, a labourer on average can harvest 80 m^2/h, but this amount can differ with respect to crop condition, labourer ability and climate condition. The required time for harvesting one hectare of rapeseed in manual harvesting was 128 man-h/ha compared to 5.88man-h/ha for the reaper harvesting (Table 2).

Harvesting losses: The measured values of preharvest and harvesting losses in manual and reaper methods are shown in Table 3. The results revealed that the preharvest losses were considerably high and that harvesting was carried out at lower moisture content than normal limit. Delay in harvesting caused grains to shatter due to natural factors (rain and wind) and therefore losses increase. Measurements showed that the moisture content at harvesting time was between 15-18 % and this is not suitable for indirect harvesting (reaping and threshing). If harvesting is carried out at suggested moisture content (25%-30%), the amount of preharvest losses and cutting and handling losses are significantly reduced. Therefore it is necessary to assess the most suitable moisture content for harvesting and its relation to the amount of losses.

Table 1: Some of the estimated agronomic specification of rapeseed in manual and reaper harvesting

Planting method	Height of Main stem (mm)	Height of First secondary stem from ground (mm)	Number of sub-main stems	Plant density (Numbers/m^2)	Thickness of main stem (mm)
Broadcast	1022	29.7	4.4	113.5	13.8
In row	1044	31.3	4.6	102.7	14.6

Table 2: Mean values for the manual and mechanical methods of rapeseed harvesting

Harvesting method	Planting method	Time losses (min)	Total operating time (min)	Cutting width (m)	Forward speed (km/h)	Field efficiency (%)	Effective field capacity (ha/h)
Reaper	Broadcast	3.75	13.0	1.1	2.14	68.7	0.1610
Reaper	In row	3.34	10.6	1.1	2.23	73.7	0.1800
Manual	Broadcast	6.00	55.0	na	na	na	0.0074
Manual	In row	5.00	51.0	na	na	na	0.0086

na = not available

Table 3: Estimated losses in two manual and reaper methods of harvesting

	Manual planting (broadcasting)						Row planting					
	Harvesting with reaper			Manual harvesting			Harvesting with reaper			Manual harvesting		
Re P.	W_{g1}	W_{g2+3}	W_{gt}	W_{g1}	W_{g2+3}	W_{gt}	W_{g1}	W_{g2+3}	W_{gt}	W_{g1}	W_{g2+3}	W_{gt}
1	1.67	8.93	10.60	1.35	7.82	9.17	1.27	7.63	8.90	1.17	6.93	8.10
2	0.97	8.38	9.35	1.76	8.35	10.11	1.53	8.32	9.82	1.47	7.67	9.14
3	1.43	7.72	9.15	1.51	6.87	8.38	1.77	7.52	9.29	1.86	8.16	10.02
4	1.82	9.26	11.08	1.47	8.73	10.20	1.08	8.83	9.91	1.62	7.40	9.07
Ave.	1.47	8.57	10.04	1.52	7.94	9.46	1.41	8.07	9.48	1.53	7.55	9.08

Table 4: Percentage* of preharvest and harvesting losses for manual and reaper harvesting in manual planting (broadcasting)

	Manual harvesting			Reaper harvesting		
Re P.	W_{g1}(%)	W_{g2+3}(%)	W_{gt}(%)	W_{g1}(%)	W_{g2+3}(%)	W_{gt}(%)
1	0.99	5.98	6.98	0.84	5.00	5.84
2	1.24	6.76	7.98	1.15	6.04	7.20
3	1.32	5.62	6.94	1.37	6.02	7.40
4	0.89	8.16	1.30	6.00	7.32	7.27
Ave.	6.93	5.77	1.16	7.51	6.40	1.11

* Average of four measurements

Table 5: Percentage* of preharvest and harvesting losses for manual and reaper methods in row planting

	Manual harvesting			Reaper harvesting		
Re P.	W_{g1}(%)	W_{g2+3}(%)	W_{gt}(%)	W_{g1}(%)	W_{g2+3}(%)	W_{gt}(%)
1	1.21	6.50	7.72	0.91	5.27	6.18
2	0.71	6.20	6.91	1.31	6.25	7.56
3	1.00	5.42	6.42	1.00	4.51	5.51
4	1.26	6.40	7.66	1.11	6.62	7.73
Ave.	1.04	6.12	7.16	1.08	5.66	6.74

* Average of four measurements

Table 6: Calculation for costs of the reaper machine in rapeseed harvesting

Case	Power tiller*	Reaper	Total
Purchase value($)	1000	611.11	1611.11
Machine life (year)	10	5	-
Annual use (hours)	700	480	-
Salvage value ($)	100	61.11	-
Fixed costs			
Depreciation ($/h)	0.128	0.229	0.357
Interest ($/h)	0.125	0.112	0.237
Shelter and insurance ($/h)	0.028	-	0.028
Total fixed costs ($/h)	0.281	0.341	0.622
Variable costs			
Labourer	1.11	-	1.11
Fuel	0.035	-	0.035
Oil	0.008	-	0.008
Repairs	0.500	0.305	0.805
Total variable costs	1.653	0.305	1.958
Effective field Capacity (ha/h)	-	0.170	-
Harvesting time (h/ha)	-	5.88	-

* Power tiller with necessary equipments

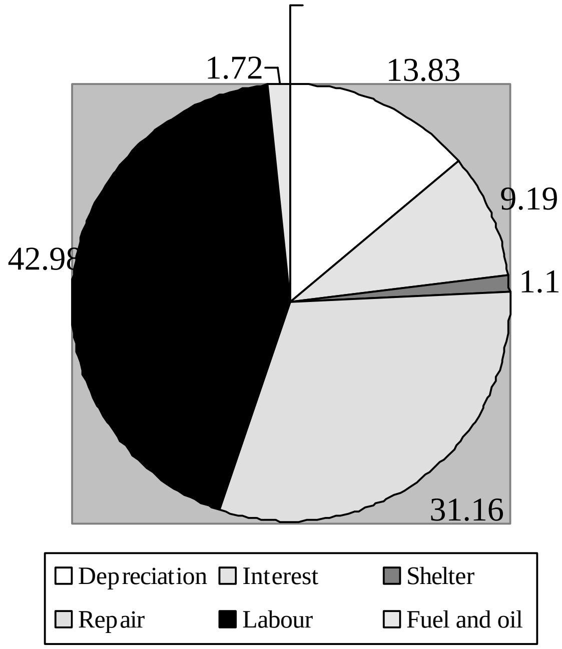

Fig. 1: Comparison of fixed and variable costs of the reaper

The percentage of preharvest, harvesting and total harvesting (preharvest and harvesting) losses in broadcast and row planting are shown in Tables 4 and 5, respectively. The mean preharvest losses in manual and reaper harvesting were 1.07% and 1.12% respectively and there is no significant difference between them. The harvesting losses in manual and reaper harvesting were 6.26% and 5.71% respectively. The total harvesting losses in manual and reaper harvesting were 7.33% and 6.83%. There was no significant difference in harvesting losses in the two broadcasting and row planting method.

Harvesting costs: The fixed and variable costs for harvesting rapeseed with reaper are shown in Table 6. The comparison of fixed and variable costs per hectare are shown in Fig. 1. The fixed cost accounts for 24% of machine cost and the reason for this is high purchase value of the reaper and power tiller. Also due to high interest rate, the interest cost is a major part of fixed cost. Repair and labour costs account for 31% and 43% of total machine cost, respectively. The high cost of spares and repair rate increases repair cost. Lack of authorized repair shops and suitable after sale services are also a reason for high repair rate and spare costs (Fig. 1). Labour requirement for reaper harvesting was 5.88 man-h/ha compared to128 man-h/ha for manual harvesting. The cost of harvesting operation (without threshing and handling costs) in manual method was 88.88 $/ha and that of reaper harvesting was 15.20 $/ha.

The break-even point of the machine was 4.83 ha/year; therefore if the machine (power tiller and reaper combined) works less than this amount then it is not economical and renting machine should be considered. The cost of renting a reaper is 11.10 $/h and the time needed for harvesting is 5.88 h/ha; therefore the cost of renting reaper is 65.27 $/ha and comparing it with manual method there is about 27% reduction in cost.

CONCLUSION

From the analysis of the results the following can be concluded:

- The effective field capacity of the reaper for rapeseed harvesting was 0.170 ha/h compared to 8×10^{-3} ha/h in manual operation.
- The average labour requirements for reaper and manual harvesting were 5.88 and 128 man-h/ha, respectively. Therefore in fields where the use of reaper is possible, it will play an important role in reducing production costs.
- The average grain losses for reaper harvesting were 6.83% compared to 7.33% in manual method. In two stages harvesting of rapeseed with reaper, assessment of the most suitable moisture content at harvesting time is necessary in order to reduce percentage of losses.

- The cost of harvesting operation (without threshing and handling costs) in manual method was 88.88 \$/ha and in reaper harvesting was 15.20 \$/ha; a reduction of about 83% in harvesting cost. Fixed cost is a major part of total machine operation, bank loan facilities with low interest rate and long repayment time can effectively reduce this cost.
- For economical justification of machine application, the yearly capacity of machine must not be less than about 5ha. Therefore facilities should be given to farmers to increase cultivation area especially where the lands have been consolidated, which can increase machine field efficiency.
- In order to increase the reaper performance, studies should be carried out on the machine working parameters and the appropriate rapeseed crop conditions in harvesting operation.

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