

Review Article

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Opportunity of Mechanized Harvesting Methods of Cereal Crops in India: A Review

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ABSTRACT

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During harvesting, rain, hail and storm often cause considerable damage to standing cereal crops. Rapid harvest facilitates extra days for land preparation and earlier planting of the next crop. The availability and cost of labor during harvesting is a serious problem. The shortage of labour during harvesting season and vagaries of the weather cause great losses to the farmers. It is therefore, essential to adopt the mechanized harvesting methods so that the timely harvesting could be ensured. The use of mechanical devices for harvesting has increased in the recent years. The use of harvesting machines helps in harvesting the crop at proper stage of maturity, and also reduces human drudgery and operational time. This, in turn, generates spare time for education, social, cultural and political activities, and human development especially in women-headed farming households. The mechanical harvesting would be feasible and economical compared to traditional method in terms of time, labour requirement and money. In this paper, the studies on different types of harvesting machines and techniques have been reviewed and analyzed. The data revealed from different studies showed that up to 85% saving in labor, and approximately 75% reduction in harvesting losses are possible through mechanized harvesting methods. Besides, the cost of harvesting of paddy was reduced by 55% per hectare.

Introduction

It is well known that farm mechanization in the agriculture is an essential input with the potential to transform the lives and economies of millions of rural families. In developing countries with small farms, low productivity, and widespread poverty, mechanization is particularly important to decrease the cost of production, improve farm efficiency, reduce

drudgery, improve crop productivity, intensify cropping and increase farm income. Rice is one of the most important staple foods of millions of people, grown in many countries of the world. The total area planted under rice crop in India is 44.5 million ha, which is the largest in the world as against the total area of 166.1 million ha (FAOSTAT data 2018). Production of rice is increasing, but in most parts of the country the poor post-

harvest management practices impacted quantitative as well as qualitative losses. Currently, India's level of mechanisation is at 40% compared to 90% across the developed nations yet harvesting of rice (70%) and wheat (80%) are highly mechanised (PwC, 2019). Manual harvesting, which is most common in some parts of India, is estimated to consume about 25% of the total labour requirement of the crop. Depending upon the crop yield, 120 to 250 man-hours are required for cutting, bundling and on-farm stacking of one hectare of paddy field by using traditional sickle (Nadeem, 1983). Labour scarcity during peak period of harvesting leads to delay in harvesting and losses of grain in the field. Also, high labour wages during peak harvesting period adds to cost of cultivation. Considering the above-mentioned problem, mechanized method of harvesting may be the better option. Use of scale appropriate machines have an impact on food security through cost and time saving and reducing harvest and post-harvest losses. A study in Bangladesh identifies cost saving of 37% and 52% for using rice reaper and mini-combine harvester over manual operations (Alam *et al.*, 2017).

Harvesting is the operation of cutting/picking/plucking, digging or a combination of these operations for removing the crop from above or under the ground or removing the useful part or fruits / vegetables from plants. In this paper we are mainly focusing paddy harvesting which means cutting of paddy just above the ground. At harvest the quality of rice is the best, and thereafter deteriorates quickly due to poor harvest and post-harvest practices, such as –

Heat buildup from mold and insect development

Discoloration/yellowing from heat build-up

Cracking from re-wetting of dried grains

Loss of vigor

Reduced head-rice yield

Shattering losses

With the ever-increasing population of India, there is huge increment in food, vegetable and fruit demand with increased consumption, calling for the need of farm mechanization. Mechanized agriculture is the process of using agricultural machinery to accomplish the work of agriculture, greatly increasing farm worker productivity. Farm mechanization reduces the cost of different agricultural operations and offers an alternative solution to tackle the above-mentioned problems. Large machineries provide more operations in less time, but they are very costly and beyond the reach of the small and marginal farmers constituting the majority of the farming community in India (86%), as well as at global level (84%), so manually operated machineries/ equipment are the right choice and common in use. As a step towards mechanization of the harvesting operation for cereal crops, the alternatives available were considered such as manual reaper, self-propelled reaper and binder machine, and the modern technology using combine harvester. Reapers are used for harvesting of crops mostly at ground level, and nowadays the height adjustable reapers are available which could harvest the crops at desired statures. Reapers are classified based on conveying of crops and provision of straw which is considered as economic by-product for animal feed and/or industrial applications. An alternative straw-handling and disposal technology needs to be developed and promoted where farmers have adopted combines for harvesting, as burning of straws is creating environmental pollution and farmers are losing valuable animal feed

material. Mechanized harvesting can be done by four actions:

Slicing action with a sharp tool.

Tearing action with a rough serrated edge

High velocity single element impact with sharp or dull edge.

Two-element scissor type action.

Goals of good harvesting is to

Maximize grain yield (minimize losses)

Minimize grain damage

Minimize quality deterioration

Keeping these points in view, work was reviewed to find out improved mechanized methods for harvesting of cereals with the evidence of some important parameters such as effective field capacity, time taken, labor requirement, harvesting losses and cost of operations.

Traditional harvesting technique

In India, most of the farmers still adopt manual harvesting method for reaping paddy. During manual harvesting process, they are mostly using sickle having serrated type or regular type of blades. Mostly serrated type sickles are used for harvesting paddy and wheat. Scientists in different regions studied the performance of sickle along with the difficulties in traditional method of harvesting. In this paper, we have attempted to compile the results of all relevant studies on these aspects.

Harvesting of field crops is generally done manually with the help of sickle. The shape and size of the sickles vary with the region. It was found that a sickle with serrated surface gave better performance than a plain one with shearing force at the cutting edge (Singh and Singh, 1978). Devnani and Pandey (1981) evaluated the field performance of the newly

designed sickle having the size of 255 mm, made from 1.27 mm thick carbon steel, having elliptical shaped blade with eccentricity of 0.7, compared to local sickle. The blade was riveted to the reinforcing strip, which in turn was riveted to the handle. The result showed that the performance of the improved sickles was better as compared to other sickles. The improved sickle with serrated edge reduced drudgery of farm women by about 16.5% as compared to local sickle for harvesting wheat crop (Gite and Agarwal, 2000). The comparison of performance of Naveen and Vaibhav sickles with the local sickles for harvesting paddy crop with 12 farm women, showed that their respective output was 47.3, 60.7 and 65.4 m²/h, with corresponding mean rate of heart-beat/min at 103, 107 and 106, respectively while working in operation using these sickles. The workload was under acceptable limit for day-long work with normal rest pause for the studied sickles (Singh *et al.*, 2012). Another study involving twenty volunteer non-pregnant farm women using serrated and non-serrated sickles showed that the total cardiac cost of work was 290 beats, the physiological cost of work was 7.45 beats/min, the average working heart rate was 115 beats/min and the average energy expenditure was 8.26 KJ/min during the harvesting activity performed by improved tool, the Naveen serrated sickle. It was found that the improved tool was ergonomically good and women-friendly, that reduced drudgery and thus was helpful in improving the efficiency of women (Verma *et al.*, 2016). A study was conducted to determine the physical fitness, time and activity profile and physiological stress of farm women during wheat harvesting activity. The results revealed that 19.5% of working efficiency is increased by using serrated sickle, as an average one farm woman harvested 50 bundles of wheat by using serrated sickle while only 39 bundles of wheat were

harvested through local sickle, and using serrated sickle, with average working heart rate of women to be 110 beats/min. Similarly, energy expenditure was found to be 12 kJ/s, and about 19% saving in cardiac cost of workers per unit of output in comparison to the traditional practice of local sickle was recorded (Singh *et al.*, 2014).

Why mechanized harvesting

Sickle is the main equipment used for manual harvesting having several issues. Manual harvesting is mainly labor-intensive and time-consuming operation. Many studies revealed that drudgery is one of the major issues of manual harvest, and mostly women farmers are involved in this operation. In this section, efforts have been made to focus mechanized harvesting of cereals, as timely harvesting not only has larger implications on quality and quantity of harvested produce, but also on sowing and preparedness of the succeeding crops in sequence.

The need for introduction of efficient harvesting equipment for the cereal crops seems to minimize the time of harvesting and the grain loss suffered due to slow rate of work in process of manual harvesting. About 5-15% loss may occur, if proper care was not taken during harvesting and specifically during manual harvesting (Ojha and Nath, 1980). The various paddy harvesting methods i.e. sickle, power tiller-operated Vertical Conveyor Reaper (VCR) and tractor operated VCR have different costs of operation. It was found that the average harvesting cost was Rs. 520/ha, Rs. 251/ha and Rs. 351.8/ha for sickle, power tiller-operated vertical conveyor reaper and tractor-operated VCR, respectively (Pradhan *et al.*, 1998). In a study on tractor-front mounted reaper-windrower with vertical conveyor belts for harvesting wheat and rice, the unit harvested 0.4 ha/h, and unlike combine, harvester did not destroy the straw,

important for cattle fed, and the labor requirement was reduced by two-third as compared to conventional manual harvesting with sickles (Garg and Sharma, 1991). The study conducted on cost-comparison of mechanized harvesting of paddy showed that the actual field capacity of the power reaper was found to be 0.29 ha/h with a field efficiency of 70% at an average operating speed of 3km/h, with the fuel consumption rate of 0.8 l/h. Thus, the cost of mechanical harvesting was 690 Rs/ha compared to 2,500 Rs/ha in traditional method of manual harvesting using local sickle. Hence, the mechanical harvesting would be feasible and economical compared to traditional method in terms of time, labour requirement and money (Murumkar *et al.*, 2014).

The performance of tractor operated combine harvester was evaluated for harvesting of paddy crop. The average value of effective field capacity of the machine was found to be from 0.64 to 0.81 ha/h with field efficiency of 67 to 77%. The harvesting losses were in the range of 2.9 to 3.6% during paddy harvesting. The cost of operation was lesser for tractor operated combine harvester as compared to manual method by 57.6 to 65.5% (Veerangouda *et al.*, 2010).

Improved harvesting technique

Above two section clearly indicate that farm mechanization is very much essential for harvesting. Different R & D institutes tried to design different type of manual and powered harvesting equipment for harvesting of paddy and wheat. It can be mainly divided into three categories such as, manual operated harvesting equipment, self-propelled machine and tractor/power tiller-operated machine. The scientists also studied their performance and compared with the traditional method of harvesting. The results of different studies have been revealed for better understanding.

Manual-operated harvesting equipment

A manual operated vertical conveyor reaper weighing 45kg with 25cm effective cutting width was fabricated at a cost of around Rs 4,740, and its performance was compared with Naveen and local sickle for harvesting paddy crop. Its field capacity and field efficiency were 0.03 ha/h and 62% respectively, whereas the average field capacity for Naveen and local sickle was 0.0083 ha/h and 0.0066 ha/h, respectively. The harvesting cost for developed reaper, Naveen and local sickle were Rs 619/ha, Rs 1500/ha and Rs 1875/ha, respectively (Singh *et al.*, 2009).

The newly developed manual operated reaper was high labor-saving equipment, requiring

only 20 man-h/ha. The field efficiency was satisfactory (66%), with much lower cost of harvesting (Rs 1250 /ha) than traditional method (Rs 2000 /ha) (Chavan *et al.*, 2015). Focusing on ease of harvesting operation to the small landholders for harvesting wheat crop, a low-cost machine was designed and fabricated to harvest the crop more efficiently. The machine included handle, main frame, cutter bar, crop divider and lifter, star wheel, ground wheel and supporting wheel. Cutter bar operated directly by ground wheel power. The optimum forward speed of the machine to obtain maximum field capacity was 1.7 km/h, the effective field capacity of the machine was found to be 0.048 ha/h and the field efficiency was 71 % (Sinha and Jogdand, 2019).

Fig.1 Labor saving in mechanical method over traditional method of harvesting

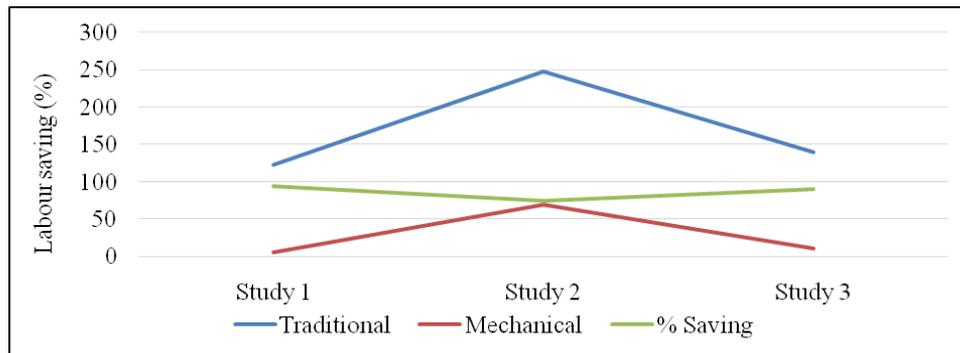


Fig.2 Loss of paddy in harvesting with mechanical method and traditional method

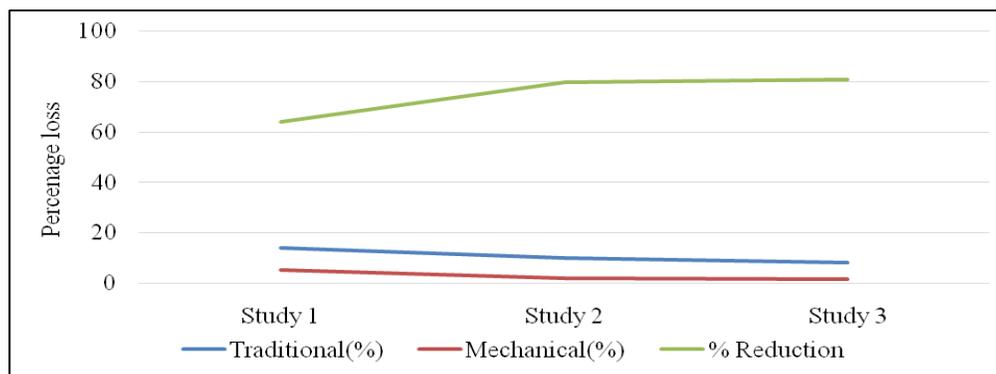
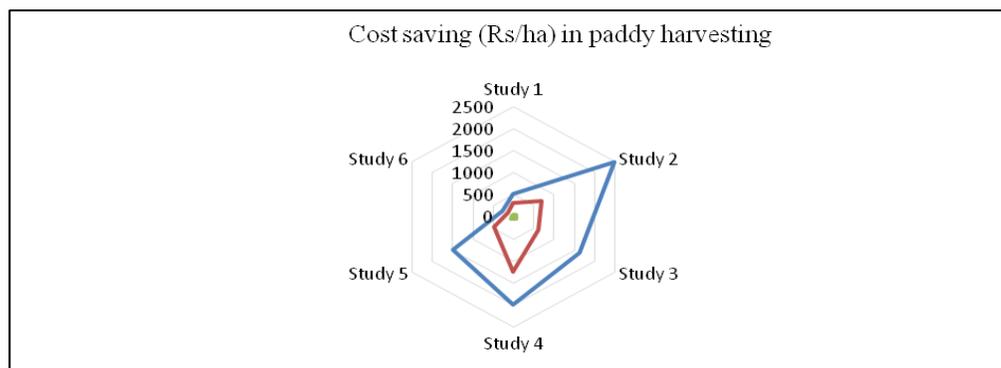


Fig.3 Saving in cost by mechanized paddy harvesting



Self-propelled harvesting equipment

The field performance of a vertical conveyor reaper was evaluated and compared with the conventional method of harvesting. Optimum machine-performance obtained with forward speed was 4.2 km/h. The harvesting losses increased rapidly as harvesting was delayed which impacted sowing time of succeeding crop(s). The effective field capacity of reaper was 0.43ha/h with 3.4km/h forward speed, and 0.47 ha/h with 4.2 km/h forward speed having field efficiency of 76% and 70%, respectively, whereas manual harvesting has capacity of 0.008 ha/h. Reaping by machine required only 6.5 man-h/ha compared to 122.6 man-h/ha required for hand reaping. (Amjad and Gee, 1983). The performance of newly developed self-propelled vertical conveyor reaper was compared with the traditional method of harvesting. It was found that the reaper gave 0.2 ha/h average effective field capacity and 80% field efficiency with minimum labor requirements of 5 man-h/ha. The cost of operation was found to be Rs 375/ha which was the lower than traditional (Rs 1125/ha) with a saving of Rs 750 /ha and reduced harvesting losses (2%) (Gawali, 2005).The actual field capacity of the power reaper was 0.3 ha/h with a field efficiency of 73% at an average operating speed of 3.2 km/h, with the fuel consumption rate 5.5 l/ha.

Cost of mechanical harvesting was Rs.420/ha as compared to Rs 800/ha in manual harvesting (Manjunatha *et al.*, 2009). Evaluation of self-propelled reaper-binder for harvesting of wheat and paddy crop revealed that average forward speed, field capacity, field efficiency and shattering loss was 3.22 km/h, 0.359 ha/h 92% and 0.23%, respectively. The average cost of operations was found to be Rs 1725 /ha(Karahle *et al.*, 2013). The evaluation of performance of self-propelled riding-type vertical conveyor reaper indicated an average effective field capacity of 1.7 km/h with 60% efficiency. It was found suitable for reaping the crops up to 55 to 60cm crop height with an operating cost of Rs 115/h (Mehetre *et al.*, 2014). Aung *et al.*, (2014) compared to manual harvesting by sickle and machine harvesting by power reaper with effective cutting width of 1.2m, for rice harvesting and revealed that the actual field capacity of the reaper was 0.24 ha/h compared to 0.05 ha/h for manual harvesting. Labor requirements for reaper and manual harvesting were 4 and 28 man-h/ha, respectively. The fuel consumption, knife speed, field efficiency and cutting efficiency were 1.89 l/h, 1.223 m/s, 92% and 98%, respectively. The cutting cost of power reaper was 67% less compared to manual harvesting, and the grain loss was less than 0.5%.

A newly developed self-propelled reaper was compared with the Chinese reaper and manual harvesting, and their respective field capacity was 0.250 ha/h, 0.203 ha/h and 0.004 ha/h, whereas the corresponding labour requirements (man-h/ha) for rice harvesting including bundle making were 248, 69 and 68, respectively. Harvesting costs were saved by self-propelled reaper and Chinese reaper by about 68 and 61%, respectively over manual harvesting (Zami *et al.*, 2014).

Another study on the harvesting of wheat and paddy using a self-propelled vertical conveyor reaper revealed that the actual field capacity for paddy harvesting was 0.276 ha/h, whereas for wheat it was found 0.311 ha/h with fuel consumption 6.12 l/ha and 5.29 l/ha, respectively. Cost of mechanical harvesting with reaper was found lower by 47.1% and 44.4% for paddy and wheat, respectively, in comparison to the manual harvesting (Dangeet *et al.*, 2015).

Tractor and power-tiller operated harvesting equipment

Garg *et al.*, (1985) developed and evaluated field performance of a tractor-front-mounted vertical conveyor-reaper-windrower with 1.9 m cutting width, operated by a tractor of about 25 HP, which could effectively harvest wheat and rice and place the harvested crop on the ground in neat windrows that could be easily collected. Its average effective field capacity was 0.29 ha/h, and the total grain losses were only 0.72-1.51%. When compared with traditional manual methods, the machine could save 131 man-h/ha. A tractor-drawn side-mounted reaper was designed to cut the green crops and form crop bunches.

The machine's field efficiency was 66.7%, shattering losses were 2–5%, and non-recoverable loose stalk losses were 4.1 and

3.5% for 2 varieties at 15 % moisture content. The cost of harvesting soybean crop by this machine was Rs 150/ha as compared to Rs 216/ha for manual harvesting (Yadav, 1985).

A study of a tractor-front-mounted reaper–windrower with vertical conveyor belts for harvesting wheat and rice showed that the unit was capable of harvesting 0.4ha/h, and unlike combine harvester did not destroy the straw, important for cattle feed. The labor requirement was reduced by two-third with the new unit as compared to conventional manual harvesting with sickles (Garg and Sharma, 1991). The performance of newly developed power tiller-operated vertical conveyor reaper was evaluated for wheat crop. The average field capacity and fuel consumption were 0.284 ha/h and 0.5 L/h, respectively. The total grain losses were very low (~ 1%). Labour savings and financial savings were 129 man-h/ha and Rs 226/ha with machine harvesting compared to the traditional method (Garg *et al.*, 1984).

In conclusion based on the review and analysis of foregoing studies at different locations it may be concluded that the performance of power-operated reapers is better than manual harvesting method. The evidence of the studies showed that 85% of labour saving and approximately 75% reduction in harvesting losses are two major benefits of mechanized harvesting method. The reduction in cost of harvesting of paddy per hectare was found 55% (Fig 1,2,3). Moreover, saving in operational time helps early clearance of the field making way for early/ timely sowing of succeeding crop, leading to increase in cropping intensity as well as system productivity. It implies that self-propelled reaper, and tractor/power-tiller operated reapers (mechanized harvester) are better alternative options for harvesting of cereal crops.

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