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REVIEW ARTICLE **OPEN ACCESS**

A Review - Mechanical harvesting is alternative to manual harvesting

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ABSTRACT
The mechanical harvesting is done by combiner harvester, which was introduced in the early 1990s. Mechanical harvesting can reduce labour cost and save time to a greater extent. Combined harvester cost about Rs 800 acre-1 within one and half hour but manual harvesting requires minimum of 7-9 man days to harvest one acre and costs about Rs 2022 - 2600 acre-1.The average fuel consumption of the combiner is 15 litres acre^{-1}. This indicated that combiner is an efficient, economical and less labour and time consuming machine.
Keywords: *Mechanical, Manual harvesting, Economics*

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INTRODUCTION

There is less scope for production of Pulses and oilseeds because of many production constraints like non availability of quality seeds of improved, inadequate and imbalanced use of nutrients, losses during threshing and post harvest storage because of unscientific postharvest practices, delay in harvesting which cause shattering of pod, rains during later stage deteriorate quality and create problem in harvesting of crop. Apart from this in recent years, large number of labours migrated from rural to city due to rapid industrialization and urbanization, which created a problem of scarcity of labour during harvesting. To overcome these problems we need to go for mechanical harvesting.

The combiner could harvest 2.4 to 3.0 acres in one hour. Cutting height during combiner harvesting is often higher than with other harvesting methods. The time interval for harvest by combine harvester is often narrow, too early harvesting will result in a high percentage of chaffy kernels, and too late harvesting will result in high shattering losses. Fine tuning forward speed and header height is especially important to minimize field loss [3]. This indicated that combiner is an economical and less labour and time consuming machine, in addition 2 to 3 weeks of saving in harvesting time [41].

EFFECT OF HARVESTING METHODS ON YIELD

The yield from combiner harvesting plots in Etheya was significantly higher (19.3 q ha^{-1}) than from manual harvesting plots (17.2 q ha^{-1}). Similarly, yields differed significantly between combiner harvesting plots (12.2 q ha^{-1}) and manual harvesting plots (9.2 q ha^{-1}) in Asasa [16].

Sorat *et al.* [38] revealed higher rice yield in farmers field by using combiner harvesters compared to manual harvesting. The average yield for combiner harvesters was 0.35 ton rai^{-1} compared to 0.32 ton rai^{-1} for manual harvesting (rai = <4 t ha^{-1}).

Zhang *et al.* [43] reported that the yield appeared in combiner harvester (2,751.5 kg ha^{-1}), was significantly higher than that in manual harvesting (2,641.5 kg ha^{-1}). Further, harvesting loss in combiner harvester was 50 % higher than that of manual harvesting.

Adam *et al.* [2] they revealed that the mechanical harvest representing the highest contribution per cent in total crushing of cane per day (71 %) while manual harvest represents 29 %. The results showed that there was a significant difference between average weights per trailer for manual (6.88 ton/trailer), and mechanical harvesting (9.54 ton/trailer). The weight (ton/trailer) of the manual harvesting represents only 69 % of the mechanically harvested cane. This reflects that mechanical harvesting had an advantage over manual harvesting.

VARIETAL SUITABILITY FOR MECHANICAL HARVESTING

Stieller *et al.* [40] They reported that among *Kabuli* and *desi* Chickpea *(Cicer arietinum* L.) lines obtained from ICRISAT podded well and a number of Kabuli genotypes have a tall growth habit, with 29-67 cm height compared to desi type with 20-59 cm which should make the plants suitable for mechanical harvesting.

Dongkwan *et al.* [14] observed that out of Keuseong and Owool, which were popularized cultivars of mungbean in Korea, Owool was found to be most appropriate for mechanical harvesting. It was favourable for mechanical harvesting because, when compared to Keumseong, It was higher both in plant height (40-57cm) and in pod length (8-10 cm), and also the seed yield was better.

Twenty tall and erect genotypes of chickpea along with two checks (HC 5 and DCP 92-3) were evaluated under normal sown condition for identification of suitable genotypes for mechanical harvesting and with better sunlight interception on crop canopy. Genotypes IPC 2006-11 (2,155 kg ha^{-1}), IPC 2008-83 (1,955 kg ha^{-1}), IPC 2001-28 (1,955 kg ha^{-1}), IPC 20011-85 (1,953 kg ha^{-1}) and IPC 2011-113 (1,933 kg ha^{-1}) out yielded the check varieties HC 5 (1,780 kg ha^{-1}) and DCP 92-3 (1,645 kg ha^{-1}). All 5 genotypes had more than 70 cm plant height with more than 60^0 branch angle and were lodging resistant and suitable for mechanical harvesting [6].

Hugo *et al.* [17] revealed that the cowpea genotypes 'BRS Carijó' and 'BR14 Mulato'. The differences between the parents ranged from 1.13 to 2.70 times for the traits like main branch length (MBL) 4.36; secondary vegetative branch length (SVBL) 2.5; number of secondary vegetative branches (NSVB) 1.7; number of nodes (NN) 2.1, and number of days to grain maturity (NDGM) 3.0. Broad and narrow sense heritability estimates were either close to or above 50 % for all traits under evaluation. Therefore, these developed cultivars with combined set of traits were more suitable for mechanical harvesting.

Munirathnam *et al.* [17] carried out field experiment, at Nandyal, Andhra Pradesh, during *rabi* seasons of 2012 - 2014 and reported that chickpea cultivar 'NBeG47' suitable for mechanical harvesting due to its higher plant height (53.6 cm).

Mamta *et al.* [22] Results indicated that most of the genotypes were suitable for mechanical harvesting as they possess tall plant height, erect growth habit, acceptable branch angle ($70\text{-}80^0$) and first pod height at more than 30cm height. However, based on seed yield potential five genotypes namely GL12021 (2,313 kg ha^{-1}), GL13016 (2,204 kg ha^{-1}), ICCV13604 (2,146 kg ha^{-1}), ICEL3 (1,713 kg ha^{-1}) and ICCV11605 (1,638 kg ha^{-1}) were identified as promising genotypes.

LOSSES IN YIELD DUE TO MANUAL AND MECHANICAL HARVESTING

Chandrakanthappa and Batagurki [13] conducted an experiment at the Bangalore, Karnataka, India, on four methods of threshing *viz.,* manual beating with a stick, passing a bullock drawn stone roller, passing a tractor drawn stone roller and using a rasp bar type mechanical thresher for two ragi varieties (MR-1 and HR-911). Output, threshing efficiency, mechanical damage and cost of operations for different threshing methods were evaluated and compared. It was found that the rasp bar type mechanical thresher was the best among the four methods. It had an output of 138.46 kg per hour, threshing efficiency of 79.61 per cent, mechanical damage of 2.95 per cent and low operation cost of ₹ 18.43 per quintal.

Harvest loss of a rice combiner harvester was 1.68 % for a local variety in Malaysia compared to conventional method was 0.98 % [34].

Abdul *et al.* [1] tested combiner harvester (Class Denominator- 68) for wheat at Faisalabad and revealed that, the crop with less moisture content (7.5 %) had greater threshing loss (about 6 %) as compared to crop with higher moisture content (9.5 %). The crop with low moisture content had more broken grains (5.7 %) than crop with high moisture content which had about 1.5 % of broken grains. The reason of more breakage losses may be narrow concave clearance, which needed to be increased as crop gets dried. But the header loss (unthreshed pods) was more (19.15 kg ha^{-1}) when crop was with high moisture and in low moisture its about 14.4 kg $acre^{-1}$.

Bora and Hansen [12] examined field performance of a portable reaper for rice harvesting and compared it with manual harvesting. Their results showed that field capacity and fuel consumption of that reaper were 0.15 ha h^{-1} and 0.25 litres h^{-1}, respectively. Harvest duration of that device was 7.8 times less as compared to manual harvesting. They reported that grain loss was 2.3 % and 1 % for reaper and manual harvesting, respectively.

Khazaei [20] reported that impact velocity (at 5, 7.5, 10, and 12 m/s) and beans moisture content of beans (at 5, 10, 15 and 20 % wet basis) significantly influenced the physical damages to seeds of kidney beans. Increasing the impact velocity from 5 to 12 m/s caused an increase in the mean per cent of physical damages to seeds which varied from 3.25 to 37.5 %. With increasing the moisture content from 5 to 15 %, the mean values of percentage of damaged beans decreased by 1.4 times. However, with increase in the moisture content from 15 to 20 %, the mean values of physically damaged beans showed increasing trend and was non significant.

Loveimi *et al.* [21] investigated losses of two rice combined harvesters equipped with spike-tooth and rasp-bar threshing units. In direct harvesting (mechanical harvesting), average crop loss was 1.73 and 3.68 % for spike-tooth and rasp-bar combiner, respectively. In indirect harvesting (manual harvesting), it was 3.45 %.

Pawar *et al.* [32] conducted experiment on combine harvester at MPKS Rahuri in wheat crop. They observed that total field loss of combiner harvester (4.20 %) was less than the combination of reaper with thresher (10.57 %).

Ponican *et al.* [33] investigated on different aspects of threshing machine used for maize crop. They concluded that peripheral speed and clearance between cylinder and concaves were the most important factors affecting the crop quality. Their experiment results with the tangential threshing mechanism showed that with increasing the cylinder peripheral speed from 9.4 to 21.4 m/s, the grain damage increased from 3.8 to 6.01 %.

Alizadeh and Khodabakhshipour [4] studied moisture content at harvest and usage of combined harvester on yield loss and seed damage at RRI, Iran. Study revealed that, 0.68 % of damaged grains recorded at drum speed of 850 rpm and paddy moisture contents of 17 % and the least value was obtained at drum speed of 450 and 550 rpm at 23 % moisture content of paddy. The cracked grains increased from 7.0 to 37.0 %, 6.67 to 25.0 % and 14.0 to 17.30 % at paddy moisture contents of 17.0, 20.0 and 23.0 %.

The combiner harvester not only minimizes the post-harvest losses but also helps in shortening the harvesting period [36].

Mirasi *et al.* [23] from Iran, measured grain losses of different wheat varieties with different models of combiner harvester. They observed that average pre harvest losses in all fields of study were 31.4 kg ha^{-1} accounting for 12.71 per cent of total losses.

Feizollah *et al.* [15] conducted experiment in Lorestan University, Iran. Result revealed that increasing the impact velocity from 10 to 25 m/s caused a significant increase in the mean values of damage from 0.53 to 31.78 %. The mean values of physical damage decreased significantly (from 22.41 to 11.24 %) with increase in the moisture content from 9.54 to 20 %. However, by further increase in the moisture from 20 to 25 %, the mean value of damage showed a non significant increasing trend. There was an optimum moisture level of 20 %, at which seed damage was minimized. An empirical model composed of seed moisture content and velocity of impact developed for accurately describing the percentage of physical damage to mungbean seeds.

A field experiment conducted in Iran by Salari *et al.* [35], revealed that the effect of cylinder speed was the most significant factor, followed by the moisture content for the grain damage. With increasing cylinder speed in the range of 9 to 15 m/s, the grain damage increased from 4.98 to 47.97 %, Optimized point was determined which was observed at the cylinder speed of 10.63 m/s, concave clearance of 13.74 mm, feed rate of 240 kg h^{-1}, and moisture content of 12 % (wet basis).

Mohammad *et al.* [24] at Amol, Iran studied three indirect harvesting methods of (i) hand cutting + threshing by a tractor driven thresher (ii) rice reaper + threshing by a tractor driven thresher (iii) rice reaper + threshing by universal combiner harvester equipped with pickup type header, and two direct harvesting methods of head-feed rice combiner, and whole-crop rice combiner. Quantitative losses (grain and panicle shattering) in harvesting and threshing were 2.58 % and 2.33 % in indirect harvesting and direct harvesting, respectively, which were not significant statistically. The average qualitative losses (broken, husked and cracked grains) were 2.30 % for indirect harvesting and 0.61 % for direct harvesting that showed a decline of 63.3 % compared to indirect harvesting. Total harvesting losses were 5.07 % to 2.74 %. The harvesting method affected percentage of broken rice after milling significantly. The average broken rice for indirect method was 23.72, 23.28 and 24.56 %, respectively which were significantly higher than head-feed rice combiner (21.05 %) and whole-crop rice combiner (20.87 %).

Afshin *et al.* [3] conducted an experiment at University of Tabriz, Iran and reported that the total per cent of yield loss of chickpea in manual and mechanical harvesting was 3.49 % and 20.23 %, respectively. Optimum forward speed of 1.8km h^{-1}r and soil moisture content of 19.9 % was recorded for higher efficiency in mechanical harvesting with corresponding decrease in cost of operations.

Bawatharani *et al.* [10] carried out a study at Peradeniya, Sri Lanka and reported that threshing unit tip velocity of the combine harvesters were found to be in the range of 10.35 – 39.51 m/s. The tip velocity of 10.35 m/s gave the lowest broken percentage of 15.38 % and a higher head rice yield of 49.45 %. Relatively low percentages of broken rice of 19.32 % and 27.45 % were obtained at high forward speeds of 1.36 and 2.5 m/s, respectively. The lowest grain moisture content of 15.9 % yielded relatively high broken rice percentage of 33.98 kg ha^{-1} at the tip velocity of 24.64 m/s. The highest grain damage of 39.94 kg ha^{-1} was obtained during milling at the tip velocity of 39.51 m/s at the moisture content of 20.9 %.

Study was conducted to measure wheat losses during pre-harvest and harvest stages in Chaharmahal and Bakhtiari province of Iran. Results showed that higher amount of losses were in the genotypes Omid and JD 955 with total loss of 6.83 % (307.4 kg ha^{-1}) of which 10.5 % was attributed to the cleaning, 34 % to Header, 16.5 % to Drum, 21 % to impurity and 18 % to broken grain losses. The lowest losses of 3.97 % (178.66 kg ha^{-1}) were recorded by genotype JD 1165 and Alvand and 10 % of which was attributed to the cleaning, 38 % to Header, 13 % to Drum, 22 % to impurity and 17 % to broken grain losses (Asadullah *et al.,* 2014).

Muhammad *et al.* [27] studied grain losses of wheat as affected by different harvesting and threshing techniques at Adaptive Research Farm, Vehari. Three methods of harvesting and threshing *i.e.* i) manual plus thresher ii) reaper plus thresher and iii) combiner harvester were used in the study. The data revealed that total grain losses during harvesting and threshing processes of wheat with manual plus thresher, reaper plus thresher and combiner harvester were 222.63 kg ha^{-1}, 199.41 kg ha^{-1} and 149.87 kg ha^{-1}, respectively, which were 4.28 %, 3.85 % and 2.92 % of the total yield, respectively. The minimum amount of waste belonged to reaper plus thresher (0.82 %) by providing 42.58 kg ha^{-1} broken grains and inert material in the produce. The cleaning efficiency of combiner was a bit poorer (98.90 %) as compared to other harvesting and threshing techniques.

Upasana *et al.* [41] reported that the average loss of pegion pea grains per hectare in traditional method and mechanical method were 57.54 kg ha^{-1} and 74.84 kg h^{-1} in Vijayapur district, 56.61 kg ha^{-1} and 81.97 kg ha^{-1} in Bagalakote district, respectively. Which indicated that 30.06 per cent higher loss in mechanical harvesting than that of the traditional method.

Soybean seeds of cultivar 'ND 4910' was harvested at two moisture levels *i.e.,* 16.6 % moisture and 13.7 %. Higher mechanical injury with lower seed quality was recorded at 13.7 % compared to 16.6 % moisture content [30].

Keerti *et al*. [29] revealed that mechanical harvesting showed significantly higher threshing loss (4.21 %), damaged grains (0.65 %) and unthreshed pods (3.37 %) than manual method of harvesting (2.73 %, 0.50 % and 2.16 %, respectively). But the paraquat spray reduces mechanical damage of grains to a greater extent.

EFFICIENCY OF MECHANICAL V/S MANUAL HARVESTING

Anwar [8] reported field performance of a chickpea thresher in comparison to conventional practices by using bullock and tractor treading followed by manual winnowing. Thresher intake capacity was 1000 to 1500 kg per hour with a cleaning efficiency of 94 per cent, 2 per cent grain breakage and 3 per cent grain losses. The total grain losses for bullock and tractor treading methods ranged from 10 to 12 per cent.

Kalsirislip and Singh [18] reported that for a combinerr equipped with a 3m working width head stripper, field capacity and field efficiency were o.66 ha h^{-1} and 74 % for standing crop and 0.3 ha h^{-1} and 72 % for lodged crop, respectively.

Roy *et al.* (2001) expressed that field capacity and field efficiency of a whole-crop rice combiner harvester were 1.05 ha h^{-1} and 72 %, respectively for a common rice variety in Malaysia.

Padmanathan *et al.* [31] conducted an experiment in Tamil Nadu Agricultural University, Coimbatore and observed higher harvesting efficiency of 92.30 per cent, threshing efficiency of 82.30 per cent, cleaning efficiency of 72.30 per cent and minimum percentage of broken pods of 4.43 for prototype tractor operated groundnut combiner harvester compared to manual method.

The time required for completing the operation of harvesting and threshing with traditional practice (manual harvesting + threshing with mechanical thresher by manual labour) was about 20 hr. Whereas with combiner + straw reaper was 3.5 hr [7].

Pawar *et al.* [32] evaluated combiner harvester (SWARAJ 8100) and combination of self propelled vertical conveyer reaper with thresher ((SAECO) for different cylinder speeds at MPKS Rahuri in wheat crop. Comparative evaluation of both the machines showed that the total field loss of combiner harvester (4.20 %) was less than combination of self propelled vertical conveyer reaper with thresher (10.57 %).

Veerangouda *et al.* [42] reported that field capacity for a tractor operated combiner harvester was varied from 2.88 to 3.60 ha h^{-1} in chickpea.

Zhang *et al.* [43] reported that the working efficiency of combined harvester was 0.2-0.3 ha h^{-1}, *i.e.*, 50 times higher than that of manual harvesting in rapeseed crop.

Mohammad *et al.* [24] conducted a study at Amol, Iran in paddy crop and revealed that the higher and minimum effective field capacity were 0.361 and 0.009 ha h^{-1} for combined harvesting and manual harvesting, respectively. Time requirement to harvest one hectare was 111.10 h ha^{-1} for manual harvesting but it was 3.64 h ha^{-1} for mechanized treatments, which was 96.70 % less.

Different experiments on sugarcane were conducted to compare and contrast between the two harvesting systems in Sudan. Infield cane losses represent 4.72 % and 4.22 % of the actual yield for the manual harvesting and mechanical harvesting systems, respectively. On average the cane weight (ton/trailer) was 6.88 for manual harvesting and 10.12 for mechanical harvesting. The trash per cent was only 3.66 % for manually harvested cane while it reached 9.49 for the mechanically harvested cane. About 1 % increase in trash will lead to decrease in sugar recovery by 0.1 % (Adam, 2013).

Keerti *et al.*[19] Comparative evaluation of both method showed that mechanical harvesting recorded significantly higher field efficiency and harvest efficiency (444 kg h-1 and 86.14%) than manual method of harvesting (8 kg h-1 and 72.64 %). Whereas mechanical harvesting showed significantly lesser harvest per cent and grain purity (96.6 % and 96.0 %) than manual harvesting (97.8 % and 97.3 %).

Economics of manual and mechanical harvesting

Hassena *et al.* [16] conducted experiments at Chilalo Agricultural Development Unit (CADU) of Etheya and Asasa and reported that in Asasa and Etheya, the cost per quintal of manual harvesting and threshing was 21 % and 25 % higher than the cost of combiner harvesting, respectively. Net benefit of combiner harvesting was about 38 % and 16 % higher in Asasa and Etheya, respectively, compared to manual harvesting and threshing.

Abdul *et al.* [1] tested combiner harvester (Class Denominator- 68) at Faisalabad and concluded that the manual and reaper harvesting methods cost about the same (`2400 acre$^{-1}$) while combiner harvester costs only ` 860 acre^{-1}. A benefit of about ` 1600 acre^{-1} may be realized by using combiner harvester when compared to conventional methods of wheat harvesting. The combiner harvester does not make bhoosa which is a by product of other two methods of harvesting, even after debiting the cost of bhoosa the minimum benefit of using combiner harvester was ` 731 acre^{-1} over other methods of harvesting.

Padmanathan *et al.* [31] conducted an experiment in Tamil Nadu Agricultural University, Coimbatore and observed the operation of groundnut combiner harvester resulted in saving cost and time (39 % and 96 %, respectively) compared to conventional method (manual digging and stripping).

Mohammad *et al.* [24] conducted a study at Rice Research Institute of Iran. They reported that the effective field capacity of the reaper was 0.170 ha h^{-1} compared to 0.008 ha h^{-1} for manual harvesting. Labour requirements for reaper and manual harvesting were 5.88 and 128 man-h ha^{-1}, 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 these two methods. The cost of harvesting operation (without threshing and handling costs) was 88.88$ ha^{-1} for manual harvesting and 15.20$ ha^{-1} for reaper harvesting (mechanical harvesting).

Moussa [26] reported that combiner harvester reduced the cost of harvesting by 32 and 36 % compared to semi mechanical system (mower + transportation + thresher) and traditional system (manual + transportation + thresher), respectively.

Pawar *et al.* [32] evaluated combiner harvester (SWARAJ 8100) and combination of self propelled vertical conveyer reaper with thresher ((SAECO) for different cylinder speeds at MPKS Rahuri in wheat crop. Comparative evaluation of both the machines showed that the cost of combiner harvester was 817.84 ` ha^{-1} which was less than the combination of self propelled vertical conveyor reaper with thresher (1816.79 ₹ ha^{-1}). Thus, the combiner harvester and combination of self propelled vertical conveyor reaper with thresher were more suitable for large fields and small fields respectively.

Sorat *et al.* [28] of Nakhon Phanom, Thailand, reported that manual harvesting had higher costs (1,550 baht rai^{-1}) and lower gross returns (3,200 baht rai^{-1}) than combiner harvester which costs 1,350 baht rai^{-1} and gave a gross return of 3,500 baht rai^{-1}. Therefore, the net benefit of using the combiner harvester was 2,150 baht rai^{-1} compared to 1,650 baht rai^{-1} for manual harvesting, the net benefit of combiner harvesting was about 30.3 % higher compared to manual harvesting and threshing. Boaz *et al.* [11] recorded the significant increase in cost of manual harvesting of olives which was about 60 % of the farmer's income, and where as in mechanical harvesting it was 25 % of the income.

Economic profit analysis demonstrated that mechanical sowing/combiner harvesting (MS/CH) showed an input/output ratio of 1:1.6, and it was 1:1.2 in mechanical sowing m^{-1}anual harvesting (MS/MH). Labour-cost accounted for more than 70 % of the total cost in MS/MH, which led to low profitability to a great extent [43].

Adam *et al.* [2] conducted experiments to compare and contrast between the two harvesting systems at Sudan. They revealed that manual harvesting was more expensive (8.98 SDG which equivalent to USA $ 4.38.) than mechanical harvesting (4.95 SDG = USA $ 2.41.) the wages for the cane cutting labour represent 74.14 % of the total cutting cost, 46 % of the total manual harvesting cost, and 18.9 % of the total harvesting cost.

Mundinamani *et al.* [29] studied the economics of manual versus mechanical harvesting and threshing of chickpea in north Karnataka. Multistage sampling procedure was adopted and tabular and budgeting techniques were employed to analyze the data. The cost incurred per acre of chickpea harvesting engaging labour was found to be 1255.83 and the cost of threshing with machine was 1110.83; the total cost of manual harvesting and mechanical threshing per acre summing up to 2366. The cost incurred in harvesting and threshing of chickpea with machine was 1050 per acre. The net return realized by mechanical harvesting and threshing of per acre of chickpea was around 1300.

Shinde *et al.* [37] evaluated the economic efficiency of mechanization of harvesting in sugarcane in Kolhapur district of Maharashtra. Which is highly labour intensive consuming about 850 to 1000 man hours ha^{-1}. Huge investment of ₹ 113 lakh was made on the sugarcane harvesting unit. The variable cost of the unit was to the tune of ₹ 20.15 lakh out of which, 60 per cent was on diesel. The quantity harvested by the harvester was 14300 tonnes and income generated by the machine was ₹ 43.15 lakh. The economic efficiency of marketing of sugarcane was enhanced due to mechanical harvesting. They also forecasted that the state can earn ₹ 19.67 crores per annum by bringing only 5 per cent of existing sugarcane area under mechanical harvesting. Muhammad *et al.* [27] revealed that cost of manual plus thresher and reaper plus thresher was ₹ 18,315 ha^{-1} and ₹ 17,206 ha^{-1} while combiner harvester cost ₹ 11590 ha^{-1} only. A benefit of about ₹ 6725 ha^{-1} may be realized by using combiner harvester when compared to manual harvesting of wheat. Further it was concluded that minimum benefit of ₹ 2867 ha^{-1} and ₹ 1196 ha^{-1} were obtained by using combiner harvester over manual plus thresher and reaper plus thresher, respectively.

Upasana *et al.* [41] studied the economics of mechanical harvesting and threshing in comparison to manual harvesting and mechanical threshing in Vijayapur and Bagalakote districts, Karnataka. Result revealed net additional benefit of mechanical harvesting cum threshing over manual harvesting and mechanical threshing per hectare was 3041 for Vijayapur district and 2960 for Bagalakote district. The average area of Tur harvested and threshed annually was 2657.60 acres. The average harvesting cum threshing charges was 760.00 per acre. The annual net returns from the combined harvester was ₹ 9 lakh.

CONCLUSION

Main aim of the mechanical harvesting is to harvest at the right time and at optimum moisture content. Compared to manual harvesting, mechanical harvesting will reduce the labour requirement and cost of cultivation. The grain recovery in combined harvester was increased by application of paraquat, which intern reduced the pre and post-harvest losses and saved the time and labour.

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