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Mechanization in Harvesting and Post-Harvest Operation for Paddy in Konkan Region and Its Economic Feasibility

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Rice is primarily a wetland crop and major staple food in Konkan region of Maharashtra state. For rice production the various operations are done manually. The agricultural operations are laborious and require huge manpower. It involves lot of drudgery. The scarcity of labours in these days is resulting into delay in harvesting and threshing operation. The increase in labour cost is resulting into paddy production uneconomical. In order to improve the mechanization status of Konkan region, feasibility of harvesting and threshing machines was studied and operating cost was determined. The different combinations were studied *i.e.* serrated sickle, pedal operated thresher and hand operated winnower as C-1; sickle, pedal operated thresher (wire loop type) and power operated winnower as C-2; self-propelled reaper, pedal operated thresher (wire loop type) and hand operated winnower as C-3; self-propelled reaper, power operated thresher (wire loop type) and power operated winnower in C-4, self-propelled reaper and inverted chain conveyor thresher (DBSKKV design) as C-5; reaper binder and power operated thresher (wire loop type) and power operated winnowing fan as C-6; reaper binder and inverted chain conveyor thresher (DBSKKV Design) as C-7; reaper binder and axial flow thresher as C-8 and combine harvester as C-9. It was found that, the major factor in the cost analysis of the machineries was the variable cost and capacity of the machine. These two factor affects directly on the total cost of operation of the machinery per ha. The majority of farmers (0.2 ha land holders) cannot procure the machines for harvesting, threshing and winnowing due to higher cost of machine and the socio economic status of farmers. The use of reaper and reaper binder can be suitable for the marginal and medium farms in Konkan region. The combinations of machinery involves reaper, reaper binder, power operated wire loop thresher, inverted chain conveyor thresher hand, operated winnowing fan and power operated winnowing fan finds potential in Konkan region. In order to get benefit of mechanization to majority of farmers, the custom hiring services and implement bank schemes needs to promote on massive scale.

(***Key words***: *Cost, Harvesting, Paddy, Threshing, Winnowing,*)

Konkan region is the narrow strip of 40 km width and running 750 km in length from North to South having hilly terrain lying between Sahyadri mountain ranges on the East and Arabian sea in the West in Maharashtra state of India. The region receives heavy rainfall ranging from 2000-4000 mm per annum. The climate is hot and humid almost throughout the year. Rice is the most important staple crop in the tropical and sub-tropical regions of world where most of the developing countries are situated and same is true for India and Konkan region as well. It is the staple food for Asian people. India is one of the major producer accounting 20% of total world production. The total cultivated area under paddy in India is 42.50 m ha against total area of 163.46 m ha, which is the largest in the world. In Konkan, 51 per cent of farmers having land holding 0-0.5 ha followed by 18 per cent and 15.35 per cent under 0.5-1 ha and 1-2 ha respectively (Anonymous, 2014). The contribution of Konkan region in paddy planting is in an area of 0.4 m ha with the production of 1.12 mt.

The intricate steps involved in paddy cultivation i.e. nursery preparation, planting, intercultural operation, harvesting, and threshing requires large human energy consumption. Harvesting constitutes one of the major unit operations among agricultural activities. Paddy is primarily a wetland crop and due to this reason bullock drawn implements are widely used for land preparation in Konkan region. In some part of Konkan cage wheels on small tractors or power tillers are used. Transplanting and harvesting machines are not widely used on small and fragmented farms. Harvesting, threshing and winnowing are the operations which plays significant role in realizing the full benefit of raised crop by reducing post-harvest losses as well as improving quality of milled rice. These operations are laborious involving human drudgery and requires about 30-40 human days per ha for harvesting of paddy alone. Due to the un-availability of workers, crop harvesting is often delayed which exposes the crop to vagaries of nature. Timely harvesting and post-harvest operations are of utmost important, as delay leads to a considerable loss of grain in field.

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The labour requirement is the main constraint in the paddy harvesting and threshing as it requires 50% of the total labour required for paddy cultivation. Traditionally paddy harvesting and threshing is done manually which is time consuming and involves drudgeries. Due to rapid industrialization and large scale migration to urban area, getting labourers is becoming very difficult and costly day by day. The unavailabity of labours during the peak period of harvesting not only increases the harvesting cost but also indirectly increases the loss incurred. (Khan and Salim, 2005). In Konkan region, threshing of paddy crop is done manually by beating the harvested crop on wooden log or platform. This involves drudgery and labour requirement is 15 man-days ha^{-1}. Winnowing is also done manually. It is time consuming process and many times is depend on wind speed and season. The use of the harvesting, threshing and winnowing machineries can reduce the labour requirement and cost of paddy production. Now a day's few machinery available with farmers and also those have been made available through government subsidy programs. The use of available resources effectively reduces the cost of operation and increases the profit. The mechanization in paddy harvesting, threshing and winnowing can prevent huge loss in the harvesting and post harvesting operations. In order to improve the mechanization status of Konkan region, economic feasibility of harvesting, threshing and winnowing machines was studied and operating cost was determined.

MATERIALS AND METHODS

Selection of the machineries

The commercially available machineries were selected for the study. The major consideration for the selection of the machinery were the availability and the suitability of the machine for the different categories of land holders, capacity of the machine, operating cost and ease of operation. Table 1 shows the specifications of the selected machineries for the study.

Consideration for the study

1. The labour requirement for the manual harvesting with bundling and gathering to the threshing platform, threshing, cleaning and bagging is considered as 25, 15, 8 man-days ha^{-1} respectively (Anonymous, 2015).
2. Labour requirement for the gathering and collection of the crop harvested by reaper and reaper binder to the threshing platform is considered to be 5 and 3 man-days ha^{-1} respectively.

Table 1. *Machineries selected for study*

Sr. No.	Name of the machine	Cost (Rs.)	Power source	Capacity	No of workers required	Remarks
1	Reaper	95,000	3 Hp Petrol start kerosene run engine	0.17 ha h^{-1}	1	Weight: 270 kg
2	Reaper binder	3,50,000	10 Hp diesel engine	0.4 ha h^{-1}	1	Cutting width: 1.22 m
3	Pedal operated wire loop thresher	6,500	Human	35 kg h^{-1}	1	Threshing drum: Wire loop type
4	Power operated wire loop thresher	18,500	2 Hp single phase electric motor	190 kg h^{-1}	4	Threshing drum: Wire loop type
5	Inverted chain conveyor type paddy thresher	45,000	2 Hp single phase electric motor	150 kg h^{-1}	3	Threshing drum: Wire loop type
6	Axial flow thresher	80,000	Tractor = 35/26.5 Hp/kW	1500-1800 kg h^{-1}	5	Type of cylinder: Spike tooth Weight : 950 kg
7	Hand operated winnowing fan	2,500	Human	200 kg h^{-1}	3	Size of fan : 1200-1250 mm Weight : 22 kg
8	Power operated winnowing fan	7,500	1 Hp single phase electric motor	350 kg h^{-1}	1	No. of blades: 9 Diameter of fan : 510 mm
9	Header feed combine harvester	12,50,000	35 hp	1 ha h^{-1}	2	Length of cutter bar: 1.2 m

3. The capacities of the machineries are taken from the performance report or data claimed by the manufactures.
4. Paddy production is assumed to be 35 quintal per ha (Konkan region).

Cost analysis

Paddy harvesting requires different types of machineries to carry out series of operations as harvesting, threshing and winnowing. The main objective for the selection of the proper paddy harvesting methods is the minimization of the cost of harvesting and post-harvest operations. Table 2 shows the different combination of available machineries selected for harvesting, threshing and winnowing. Three main operations considered for the cost analysis are harvesting, threshing and winnowing. The harvesting considered to be using sickle (manual), reaper and reaper binder as machinery. The threshing operation is considered with pedal operated wire loop thresher (PeOT), power operated wire loop thresher (POT), inverted chain conveyor type thresher of DBSKKV design (ICCT) and axial flow thresher (AFT). The winnowing operation is considered with hand operated winnowing fan (HOWF) and power operated winnowing fan (POWF). The cost analysis of the machineries selected is done by B.I.S. procedure (BIS, 1979). The cost analysis consists of the fixed cost, variable cost and operating cost for each of the machine.

RESULTS AND DISCUSSIONS

The cost analysis of the machinery for harvesting and post-harvest operations is considered for one hectare.

Cost economics of the machineries :

The operating cost and economics of paddy harvesting, threshing and winnowing was calculated. Table 3 shows the cost economics of the selected machineries. The operating cost for one hectare area was calculated for the study. The major factors affecting on the cost of operation was labour requirement, time of operation and capacity of the machine. The harvesting cost of different harvesting tool/machinery is as shown in (Fig. 1). Manually harvesting with sickle has highest harvesting cost (Rs. 4500) than other methods. Reaper and reaper binder has the lower harvesting cost than manual harvesting with sickle which saves Rs. 2483 (55.17%) and 3160 (70.22%) per ha respectively compared with manual harvesting.

Threshing cost (Rs ha^{-1}) of different threshing machineries is as shown in (Fig. 2) Threshing cost for

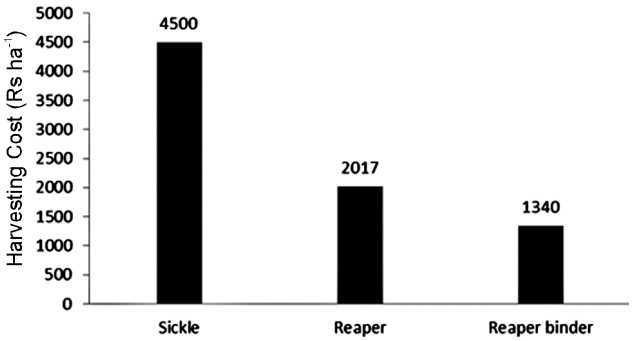

Fig. 1. *Harvesting cost of different tool and machinery*

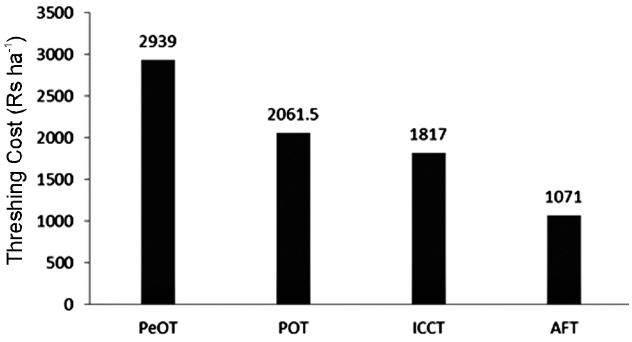

Fig. 2. *Threshing cost of different machinery*

Table 2. *Different combinations of tools/machineries selected under study*

Combination	Harvesting	Threshing	Winnowing
C-1	Sickle	Pedal operated wire loop thresher	Hand operated winnowing fan
C-2	Sickle	Power operated wire loop thresher	Power operated winnowing fan
C-3	Reaper	Pedal operated wire loop thresher	Hand operated winnowing fan
C-4	Reaper	Power operated wire loop thresher	Power operated winnowing fan
C-5	Reaper	Inverted chain conveyor type thresher	–
C-6	Reaper binder	Power operated wire loop thresher	Power operated winnowing fan
C-7	Reaper binder	Inverted chain conveyor type thresher	–
C-8	Reaper binder	Axial flow thresher	–
C-9	Combine harvester (Header feed)	–	–

Table 3. *Cost economics of the selected machineries*

Sr. No.	Name of the machine	Annual use, h	Variable cost, Rs h^{-1}	Operating cost, Rs h^{-1}	Capacity of the machine	No of hours ha^{-1}	Cost of operation, Rs ha^{-1}	Custom hire charge, Rs h^{-1}
1	Reaper	360	146	191.86	0.17 ha h^{-1}	5.88	2017[a]	260
2	Reaper binder	500	201	320	0.4 ha h^{-1}	2.50	1340[b]	430
3	Pedal operated wire loop thresher	250	25.1	29.39	35 kg h^{-1}	100	2939	40
4	Power operated wire loop thresher	250	99.7	111.91	190 kg h^{-1}	18.42	2061.5	150
5	Inverted chain type paddy thresher	360	57.25	77.87	150 kg h^{-1}	23.33	1817	105
6	Axial flow thresher	1000	330.25	479.08	1500 kg h^{-1}	2.33	1071	650
7	Hand operated winnowing fan	250	67.5	70.8	200 kg h^{-1}	17.5	1239	96
8	Power operated winnowing fan	350	49.5	53.10	300 kg h^{-1}	11.67	619.5	70
9	Header feed combine harvester	600	402.21	698.75	1 ha h^{-1}	1	699	1100

[a]5 man-day ha^{-1} additional required for the gathering and transportation purpose @ Rs. 180 day^{-1}
[b]3 man-day ha^{-1} additional required for the transportation purpose @ Rs. 180 day^{-1}

pedal operated wire loop thresher was lowest and has lowest capacity (35 kg h^{-1}). Pedal operated wire loop thresher is manually operated machine and requires more time and increased cost of operation. The power operated wire loop thresher has higher capacity and lower operating cost (Rs 2061.5 ha^{-1}). The power operated wire loop thresher and inverted chain conveyor thresher has the higher capacity of 190 kg h^{-1} and 150 kg h^{-1} respectively and less time requirement than pedal operated wire loop thresher. The axial flow thresher has the highest threshing capacity of 1500 kg h^{-1} and the highest operating cost (Rs 479.08 ha^{-1}) and requires less time to complete the operation and hence resulted into least total cost of operation (Rs 1071 ha^{-1}).

Winnowing is done using hand operated and power operated fan. The cost of operation per ha is shown in (Fig. 3). Power operated winnowing fan requires 5.83 h less time than that of hand operated winnowing fan which can saves Rs. 620 ha^{-1}. Using header feed combine harvester (harvesting, threshing and winnowing simultaneously), the cost of operation was lesser by Rs. 699 ha^{-1} than the above tool/machinery for individual harvesting and post-harvest operations.

Cost analysis of operations

The cost economics data of selected machineries was used for the calculation of the cost per ha of paddy harvesting, threshing and winnowing. Table 4 shows cost of different combinations of harvesting, threshing and winnowing operations. The same is presented through graph also (Fig. 4).

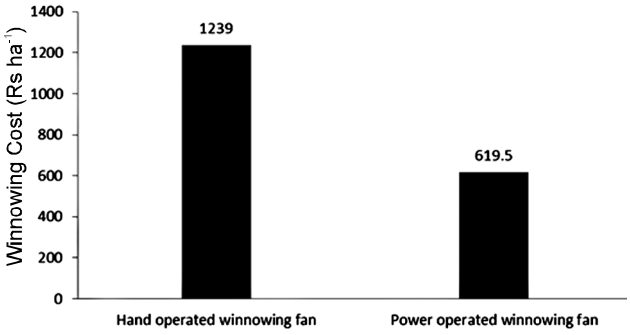

Fig. 3. *Winnowing cost of different machinery*

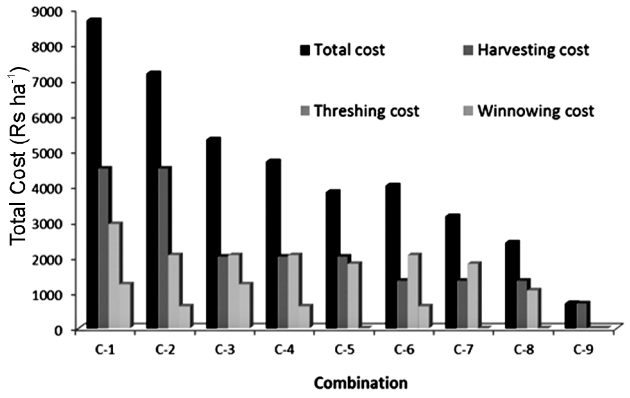

Fig. 4. *Comparative cost of different operations under different combinations*

Table 4. *Total cost of harvesting, threshing and winnowing operation using different combinations*

No	Combination	Harvesting (%)	Threshing (%)	Winnowing (%)	Total cost (Rs ha^{-1})
1	C-1	4500 (51.86)	2939(33.87)	1239(14.28)	8678
2	C-2	4500 (62.67)	2061.5 (28.71)	619.5(8.63)	7181
3	C-3	2017 (37.93)	2061.5 (38.77)	1239(23.30)	5318
4	C-4	2017 (42.93)	2061.5 (43.88)	619.5(13.19)	4698
5	C-5	2017 (52.61)	1817(47.39)	–	3833
6	C-6	1340 (33.33)	2061.5 (51.27)	619.5(15.41)	4021
7	C-7	1340 (42.45)	1817(57.55)	–	3157
8	C-8	1340 (55.58)	1071(44.42)	–	2411
9	C-9	699 (100.00)	–	–	699

Figures in parenthesis shows per cent of total cost

Amongst the different combinations, C-1 has highest cost of Rs. 8678 ha^{-1}, followed by C-2 (Rs. 7181 ha^{-1}). In both C-1 and C-2 manual harvesting by sickle was considered and it contributes to 51.86 per cent and 62.67 per cent respectively, of the total cost of operation i.e. harvesting, threshing and winnowing. Combination C-3, C-4 and C-5 resulted in the cost of Rs 5317.5, Rs. 4698 and Rs. 3833 per ha respectively. It is depicted that harvesting cost contributed maximum in the total cost. As compared to combination C-3 and C-4, the cost of C-5 was found to be less due to the non-requirement of winnowing. Further in descending order of the cost, combination of C-6, C-7 and C-8 with Rs. 4021, Rs. 3157 and Rs. 2411. In C-6, the cost of threshing was maximum with contribution of 51.27 per cent followed by harvesting 33.33 per cent and winnowing 15.41 per cent in the total cost. Among the different methods, the least cost of Rs 699 ha^{-1} was required for combination C-9 i.e. header feed combine harvesting.

Looking at each harvesting and post-harvest combinations studied each individual system has some pros and cons. It is observed that the winnowing increases the total cost of the operation. Moreover, manual harvesting was highly inefficient compared to machine harvesting (reaper/reaper binder). These machinery operations have limitations like small plot size, bunds height, difficulty in transport to terrain and one plot to another plot etc. Although, C-9 (combine harvester) has the least cost ha^{-1}, but it is not easy to work in the undulating and hilly terrain of Konkan region. Moreover, the small farm makes it difficult for turning and results in loss. On custom hiring basis it can be used in some of pockets of Konkan region where plot size is bigger and plane land is available. Hence the choice remains with the other combinations.

It is observed that among the harvesting machineries operating cost of reaper and reaper binder is less by Rs. 1340 ha^{-1} as compared to manual harvesting method. In Konkan region, particularly in Ratnagiri district most of the paddy fields are small and on hill side and farmers follow manual harvesting. Under this situation it is advised to go for improved sickle for reducing the drudgery involved and get benefit of mechanization. Threshing cost was lowest among threshing machinery for axial flow thresher. Axial flow thresher has high capacity, weight, and bigger size. For small and marginal farmers it might not be the better solution. It could be suitable for custom hiring. Inverted chain conveyor thresher (DBSKKV design) does threshing and winnowing both, which saves the energy as well as cost (Rs. 1817 ha^{-1}). This thresher gives straw of full length. The straw is useful as fodder for animals, which is one of the important animal feed in this region. It will be suitable option for the medium farmers having plain land where plot size is big, particularly in Sindhudurg, Raigad and Thane district of Konkan. This machine has a better potential. Looking into the cost limitation, this machine can be promoted on custom hiring or group farming.

Least cost was observed in the case of the combination C-9. Farmers could have another choice of C-8 combination with reaper binder and axial flow thresher with cost of operation is Rs. 2411 ha^{-1}. For individuals there can be risk of idleness of machines. However, the high cost of both machines necessitates going for custom hiring or co-operative framing. The limitation with this combination is getting the paddy straw (used for animal feed) in the form of bhusa/chopped instead of bundles. The combination C-7 (reaper binder with inverted chain conveyor thresher) registered the cost of operation Rs. 3157 ha^{-1}. For this

combination winnower is not required and the paddy straw was obtained in bundles which makes it suitable for further handling. In the same way combination C-5 (reaper and inverted chain conveyor thresher) can also be another choice having cost of Rs. 3833 ha^{-1}. In both C-7 and C-5 combination also, the farmers can go for custom hiring/co-operative farming. For small to medium farmers this could be better combinations. C-6 and C-4 are the next combination with operating cost of Rs. 4021 ha^{-1} and Rs. 4698 ha^{-1} respectively. Here the power operated wire loop thresher and power operated winnowing fan is common, which can be owned by individual farmer or co-operative farming. But the reaper and reaper binder are needed to make available on custom hiring basis. These two can also be machines suitable for small to medium farmers. C-3 combination with reaper, power operated wire loop thresher and hand operated winnowing fan has resulted cost of Rs. 5317.5 ha^{-1}. Here farmers can purchase power operated wire loop thresher and hand operated winnowing fan as they are comparatively cheaper but not reaper. In C-2 (manual harvesting with sickle, power operated wire loop thresher and power operated winnowing fan) combination cost is Rs. 7181 ha^{-1} which is higher than C-3 by Rs. 1863.5 ha^{-1}. Farmers can have their own power operated wire loop thresher and power operated winnowing fan but they have to spend 62.67% of total cost on manual harvesting with sickle under C-2 combinations.

It has been observed that combinations C-9 and C-8 are not much feasible in most of the Konkan region, while combination C-1 and C-2 are more expensive and involves drudgeries. For combinations C-4, C-5, C-6 and C-7 there is the scope for adoption. The cost of total operation for these combinations is also high i.e. Rs. 4698, Rs. 3833, Rs. 4021 and Rs. 3157 per hectare respectively (Table 4). These combinations definitely have the potential for custom hiring in the region. These combinations involves use of reaper, reaper binder, power operated wire loop thresher, inverted chain conveyor thresher hand, operated winnowing fan and power operated winnowing fan. The harvesting cost contributes in these combination ranges from 33.33 per cent to 55.58 per cent. However threshing cost contributes in these combinations ranges from of 43.88 to 55.55 per cent. Their contributions are quite substantial as far as total costs of operation are concerned. If equipments like reaper, reaper binder, power operated wire loop thresher, inverted chain conveyor thresher are made available on custom hiring, their custom hiring charges (rent) can be affordable to the farmers as estimated rental charges are less i.e. Rs. 260 h^{-1}, Rs. 430 h^{-1}, Rs. 150 h^{-1}, Rs. 105 h^{-1}, Rs. 95 h^{-1} and Rs. 70 h^{-1} respectively (Table 5). Total cost of operation for small plots of 0.2 ha and 0.5 ha is calculated and shown in Table 6. These costs are very less as compared to big size machine and their higher operating costs. Considering the majority group i.e. 0.2 ha land by 51 per cent farmer, cost for paddy harvesting and post-harvest operation for combinations is summed up to C-4, C-5, C-6 and C-7 was Rs. 1022, Rs. 796, Rs. 934 and Rs. 705 respectively (Table 6).

At present there is urgent need to go for agricultural mechanization in Konkan region for marginal and small farmers whose contribution is more than 50 per cent. Considering the socio-economic status, it is not worthwhile to procure this machinery by individual farmers. To get direct benefits of mechanization, use of machineries in the farm should be enhanced. This can be possible by large scale promotion of custom hiring services through implementation of bankable schemes of state government. At present, Government of

Table 5. *Cost of operation for custom hired machineries*

Sr. No.	Machine	Custom hire rate, Rs. h^{-1}	Cost of operation, Rs.	
			0.2 ha	0.5 ha
1	Reaper	260	306	780
2	Reaper binder	430	215	538
3	Pedal operated wire loop thresher	40	800	2000
4	Power operated wire loop thresher	150	553	1382
5	Inverted chain type paddy thresher	105	490	1225
6	Hand operated winnowing fan	95	333	831
7	Power operated winnowing fan	70	163	613

Table 6. *Cost of operations for different combinations by custom hiring*

Sr. No.	Combination	Cost of operation, Rs.	
		0.2 ha	0.5 ha
1	C-4	1022	2310
2	C-5	705	2005
3	C-6	934	2533
4	C-7	705	1763

Maharashtra has implemented this scheme on small scale. This scheme can be promoted by identifying more groups of farmers, non-government organizations, unemployed rural youth forum or social organizations in Konkan region. This will regain the interest and faith of farmers in agriculture of Konkan and can prevent the shifting of youths and farmers on large to the urban areas.

CONCLUSIONS

Based on the above studies, the following conclusions are drawn.

1. The major factor in the cost analysis of the machineries was the variable cost and capacity of the machine. These two factor affects directly on the total cost of operation of the machinery per ha.
2. Harvesting is the most dominating cost factor i.e. 51.86 per cent and 62.67 per cent respectively for combinations C-1 and C-2. The use of reaper and reaper binder is suitable for the marginal and medium farms in Konkan region.
3. The combinations of machinery involving reaper, reaper binder, power operated wire loop thresher, inverted chain conveyor thresher hand, operated winnowing fan and power operated winnowing fan has potential in Konkan region.

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