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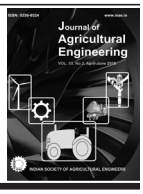

A Systematic Assessment of Paddy Losses at Various Stages from Harvest to Storage in the State of Goa

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ABSTRACT

Paddy, the main field crop of Goa, is not profitable due to small and fragmented landholdings, inaccessible fields, lack of farm work force and mechanization. A study was conducted to assess the post-harvest practices and losses of paddy in Goa using the methodology developed by AICRP-PHT, ICAR to estimate losses by enquiry and actual observation methods. The study indicated that traditional methods of manual harvesting, threshing, winnowing, sun-drying on road side, parboiling in brass pots and storage in woven polybags with *Vitex negundo* (lingur leaves) or neem leaves for unprocessed paddy and boric powder for milled rice, were practiced in the state during 2011-13 with a slight shift towards mechanization during 2013-15. Most of the rice mills in Goa needed modernization and product diversification. Data indicated total losses of 19.26±14.63 % and 11.31±12.09 % by enquiry, and 5.92±2.62 % and 9.04±9.74 % (excluding parboiling by observation) in various unit operations of paddy production in the year 2011-13 and 2013-15, respectively. No on-farm value addition by farmers was practiced. Interventions in terms of infrastructure and mechanization, sensitization through trainings on modern methods of harvesting, processing, value addition, and improved storage methods are required to reduce the postharvest losses in Goa, and ensure better profit margin for farmers.

Agriculture with ₹ 188.96 crores GSDP from crops alone is the second most important profession, next to tourism (GSDP of ₹ 543.41 crores) in the State of Goa since the cancellation of all mining leases (GSDP of ₹ 108.58 crores) from 2018-19 (Anon., 2019a; Anon., 2020). The state policy makers are trying to attract its population towards agriculture through various remunerative schemes and incentives. Disappearing farm manpower and dwindling farm returns, however, have made the profession less attractive.

Paddy is the main field crop and staple food of Goa. It is cultivated in total area of 36,384 ha under three unique land profiles *viz. morod* or lateritic uplands (16.67 % of total paddy area), *kher* or sandy midlands (33.33 % of total paddy area), and *khazan* or salt affected coastal lowlands (50 % of total paddy area in the state) (NABARD, 2019a,b). It is being cultivated both in *Kharif* (*Sod*) and *Rabi* (*Vaigon)* seasons, in approximately 67 % and 33 % of the total paddy area, respectively. The average paddy productivity of *Rabi* season is relatively higher (2,759 kg.ha^{-1}) as compared to *Kharif* season 2,719 kg.ha^{-1}) (NABARD, 2019a, b;Anon., 2019a). Paddy area has been rapidly falling as the profits in paddy farming are dwindling due to high labour cost, lack of mechanization and reducing yields of the traditional varieties (Anon., 2012;Anon., 2019b). Farmers adopting new varieties sell it as unprocessed paddy, or take it to neighbouring states of Karnataka or Maharashtra for milling, thus losing their profit margins (Gupta *et al.,* 2013). The post-harvest losses in paddy further reduce the profit of the farmers (Kiaya, 2014).

Paddy crop undergoes a series of operations such

as harvesting, threshing, winnowing, bagging, transportation, processing and packaging before it reaches the consumer. At each of these stages, there are considerable losses due to various factors (DMI, 2002; DMI, 2005; Nanda *et al.,* 2012; Jha *et al*., 2015). According to a study by AICRP-PHT, ICAR-CIPHET, total loss of paddy in farm operations at national level was 4.67 %. The loss during storage in different channels at national level was 0.86 %, and total losses were 5.53 % (Jha *et al*. 2015). Post-harvest losses have impact at both the micro- and macro-levels of the economy (DMI, 2002; DMI, 2005; Basavaraja *et al.,* 2007; Nanda *et al.,* 2012; Jha *et al.,* 2015). The study on post-harvest losses in food grains at different stages of their handling would help assess the extent and magnitude of the losses, and identify the factors responsible for such losses (Grolleaud, 2002; FAO, 2011). This, in turn would help develop proper measures to reduce these losses. Evolving correct policies for minimizing post-harvest losses would crucially depend on reliable and objective estimates of such losses at different stages. This information is important for scientists, technologists, policymakers, administrators and industrialists. Hence, a study was undertaken on harvest and post-harvest losses of paddy in the state of Goa to identifying the reasons for these losses, and to suggest remedial measures for minimizing them at farmer, marketer, researcher and policy maker's level. The long-term objectives of the study were to reduce the post-harvest losses of Goa by appropriate interventions at farmer, research scientists, and state policy makers' level.

MATERIALS AND METHODS

Methodology

Paddy crop was transplanted from end of May to July during the *Kharif* season, during which this study was conducted across the state under the aegis of the ICAR-Central Coastal Agricultural Research Institute, Old Goa. The data was collected both by (i) enquiry, and (ii) by actual observation on field from farmers using questionnaires and forms used by Vishwakarma *et al*. (2007), Basavaraja *et al.*(2007), Nanda *et al.* (2012), Jha *et al.* (2015).

Sampling

A multi-stage sampling design as followed by Vishwakarma *et al*. (2007), Basavaraja *et al.* (2007), Nanda *et al.* (2012), Jha *et al.* (2015) was used to select the paddy farmers in the 2 (North, South) districts of Goa. A total of ten villages, five each from the North Goa and South Goa districts were chosen by simple random sampling for the study. In the study period (2011-12), five farmers from each village were chosen for data collection. During the second study period (2013-15), ten farmers from each village were chosen. Wherever possible, earlier sample of farmers were retained and the remaining chosen by simple random sampling. Thus, the total sample size for 2011-12 and 2013-15 were 50 and 82(17 of the chosen farmers did not go beyond sowing or transplanting), respectively.

The data collection by enquiry and observation, sample plot size, sample size, collection protocol, questionnaires, etc. were as per the methodology adopted by Vishwakarma *et al*. (2007), Basavaraja *et al.* (2007), Nanda *et al.* (2012), and Jha *et al.* (2015), which also followed the methodology for post-harvest losses estimation given by Harris and Lindblad (1978), and similar to many of the post-harvest losses methodologies reported by Aulakh and Regmi (2013).

The data on losses during harvest, threshing, winnowing, parboiling, and milling were collected during *Kharif* season (which is the major paddy cropping season in Goa) of 2011 and 2013. For storage, stored rice or paddy (50-100g) was collected from each farmer at intervals of three months from the month of storage up to one year after storage, or till end of storage period. Rice samples from the farms were brought to the Institute, and examined under Stero Zoom Microscope (Leica S8 APO, 8:1 Zoom, 75 mm working distance) to calculate percentage of infested grains. A total of 18 rice mills (only those used by the sampled farmers in the data set) and 6 godowns were also surveyed.

Analytical Techniques

Post-harvest losses per farm were calculated for each unit operation *viz.* harvesting, threshing, winnowing, parboiling, milling, and storage and expressed as percentage losses as:

$$\text{Harvest loss, \%} = \frac{\text{Weight of paddy collected from a randomly selected 5m} \times \text{5m plot on farmers land, kg}}{\text{(Production in 5m} \times \text{5m area of farmers land), kg}} \times 100 \quad \ldots (1)$$

$$\text{Threshing loss, \%} = \frac{\textit{Weight of paddy remaining on threshed stalk from a 5m} \times \textit{5m plot, kg}}{\text{(Production in 5m} \times \text{5m area of farmers land), kg}} \times 100 \quad \ldots (2)$$

$$\text{Winnowing loss, \%} = \left(\frac{\textit{Weight of paddy grains in 250 g of chaff, g}}{250\ g}\right) \times \frac{\textit{(Weight of calculated chaff in 5m} \times \textit{5m area), kg}}{\text{(Production in 5m X 5m area of land), kg}} \quad \ldots (3)$$

Milling loss, %= Per cent of total rice in husk outlet* ... (4)

*All values were converted to percentage of paddy using (20 % as husk and 68 % as total rice yield of paddy milled (Samaddar *et al*., 2017)

$$\text{Storage loss, } \% = \frac{\text{Weight of infested grains in 100 g of grain, g}}{100} \times 100^{**} \quad \ldots (5)$$

**If stored produce was rice, the quantity was converted to equivalent paddy (68 % of rice yield per kg of paddy)

$$\text{Parboiling loss, } \% = \frac{\text{Weight of paddy grains in 100 g of discarded waste from parboiling pot, g}}{2500} \times 100^{***} \quad \ldots (6)$$

***It was assumed that 4 % of parboiled paddy was removed as unfilled and immature grains

The values of percentage post-harvest losses during each unit operation for individual farmers were averaged (Basavaraja *et al*., 2007). The total on-farm post-harvest losses was the sum of the average losses during each unit operation.

Moisture Content

Moisture content of paddy was estimated by taking samples of paddy in three replications, and using standard hot air oven (Galaxy instruments, Panaji, Goa; Range: 50-300 ^{o}C) drying method at 105^{o}C for 72 h.

Sample weight in laboratory was determined using an analytical balance (Atco T210AB0021/W, range: 0.001- 200g, least count: 0.001 g).

Head Rice Yield

It was calculated by taking paddy samples of 100 g (in triplicate) from the mill outlet, and manually separating rice with length greater than 75 % of whole grain length, and averaging it.

Sample weight was measured in field using an weighing machine (Make Essae Teraoke Pvt. Ltd., model: DS-852, range 0.05-30 kg, least count: 1g)

RESULTS AND DISCUSSION

Land Holding Patterns of Sample Sets

Land holding pattern of the farmers in the sample set indicated that during the year 2011-13, 72 % of the farmers had landholdings between 0.4 ha to <2 ha, while 22 % of the farmers had less than 0.4 ha of land. Just 6 % farmers had land holdings of ≥ 5 ha.

In the sample set of the year 2013-15, there were 53.66 % farmers with land holdings of <0.4 ha landholding, followed by 34.15 % farmers with 0.4< 2 ha land holdings, 8.54 % with 2<4 ha landholdings, and 3.66 % farmers with ≥ 4 ha landholdings.

Paddy Cultivation and Processing Operations

Cultural practices in paddy production and harvest
Morod

These are terraced fields at the foothills of Goa (Fig. 1). With the onset of monsoon, land was generally

Paddy for harvest in *Khazan* (salt affected coastal lowland)

Morod(lateritic upland)

Kher (midland plains)

Fig. 1: Different types of land topography in Goa

ploughed, bunds formed and puddling done using power tillers or bullock drawn plough. Method of sowing was transplanting or broadcasting (usual varieties being *Jaya*, *Jothi*, *Kazat 3*, *Kazat 5*). Other operations after transplanting like weeding, fertilizer application were manual. The crop was then harvested manually using sickle, left on the field for a couple of days, and then collected and stacked on the field (Fig. 2). After about 2-3 weeks, the stacked crop was threshed by treading under tractor wheel, cement roller attached with power tiller, beaten by sticks or beaten over bench.Threshed grains were collected, manually winnowed, dried, parboiled, milled, and stored in woven sacks as rice with boric power (@ 50g per sack of 50 kg rice) for personal use. Excess paddy was sold without milling to the local mills or authorized procuring agency at MSP.

Fig. 2: Paddy with weeds harvested and threshed using combine harvester

Kher

These are well drained, sandy midlands of Goa (Fig. 1). With onset of monsoon, the land was ploughed, levelled, puddled and paddy sown by either manual transplanting or broadcast method. The varieties commonly used were *Jaya*, *Jothi*, *Karzat* 3 or *Karzat* 5. Intercultivation and fertilizer top dressing were done manually. The crop was mostly harvested and threshed using combine harvester, except in fields where access to the combines was not possible. Paddy was generally sun-dried and stored in woven sacks for personal use, and the surplus produce sold as paddy at MSP. The farmers parboiled and milled the paddy for their personal use at the local mills whenever needed.

Khazan

These are low-lying salt affected coastal lands near the river basin (Fig.1), and are submerged for most part of the paddy growing season. Paddy seed was usually broadcast sown. Traditional submergence tolerant varieties of *Korgut*, *Jaya* or *Jothi* were sown. No inter-culture operation was done as the crop was submerged for weeks. Towards the end of the monsoon, the water was drained by opening community-based bund gates, and wherever possible crop was harvested using combine harvester. Manual harvesting was done in areas still under submergence. Manually harvested paddy was then threshed, dried, and stored.

There were wide variations in the time of harvest and methods of harvest and operations, as indicated in Table 1-2. The monsoon in the year 2011 started on June 5, 2011 and ended on September 22, 2011; whereas in the year 2013 it extended from May 30, 2013 to October 14, 2013. The variations in harvest time were due to vagaries of the monsoon, lack of labour or delay in arrival of custom-hired combine harvesters. Manual labour was the main method of harvesting in the *morod*, and inaccessible areas of *khazan* topography areas due to lack of mechanization options for the fragmented and inaccessible landholdings either on slopes or under submergence due to ingress of sea water during monsoons. The Government of Goa had supplied power tiller to the farmers through its subsidy programme. The State Government had also purchased many self-operated, crawler combine harvesters and had been supplying them to the farmers at subsidized hiring rates. Hence, higher mechanization of harvesting operation was noticed in the year 2013(42.7±3.7 %) as compared to the year 2011 (32 %). During the period 2011-13, it was found that 32.0 % of sampled farmers with average land holding of 7829.41 ± 6363.74 m^2 used combine harvesters; while during the period 2013-15 mechanized harvesting (using combines, self-propelled reapers and brush cutter with paddy harvesting attachment was 43.7 % with average landholding of 7950.68±13230.41 m^2. During the period 2011-13, the use of machinery for harvesting was 0 % in *morod* lands, 100 % in *Kher,* and 36.7 % in *Khazan* lands; while during 2013-15

Table 1. Harvesting months of paddy by sample farmers

Sl.No.	Month of harvest	No. of farmers surveyed	
		2011-13	2013-15
1.	October	30 (60 %)	15 (18.3 %)
2.	November	20 (40 %)	32 (39.0 %)
3.	December	-	35 (42.7 %)

Table 2. Methods of harvest and post-harvestoperations followed by the farmers

Sl. No.	Unit operation	Method followed	Equipment used	Per cent of farmer surveyed, and per cent under Morod/Kher/Khazan season		Reason for losses as stated by farmers
				2011-13 50 (30/10/60)	2013-15 82 (55/18/27)	
1.	Harvesting Mechanized	Manual	Sickle	68.0 (30/0.0/38)	52.4 (50.0/0.0/2.4+3.7**)	- Over maturity, labour shortage, rains during harvest, waterlogging - No machinery access (**3.7 % in *Khazan* used both sickle and combine for harvesting as per accessibility of combine)
		Combine harvester/ self-propelled reaper	32.0(0.0/10.0/22.0)	42.7 (3.7/18.3/20.7)	- Crop over maturity due to delayed machine arrival (provided by Govt. on hire basis with subsidy) - 3.7 % in *Khazan* used both sickle and combine for harvesting as per accessibility of combine	
		Brush cutter with paddy harvesting attachment	-	1.2 (1.2/0.0/0.0)		
2.	Collection Collected and moved to yard or stored same day	Stacked on field	Manual	68.00	52.44	Rat, bird, cattle
			32.00	47.56		
3.	Threshing Treading by tractor/power tiller	Manual (Treading by feet/cattle) or beating with sticks	Men/women/Oxen	56.0 (20.0/0.0/36.0)	39.0(36.6/0.0/2.4+3.7**)	- Inaccessible field (**3.7 % farmers in *Khazan* used both manual and combine for threshing)
		Tractor	10.0(10.0/0.0/0.0)	14.6 (14.6/0.0/0.0)		
4,		Threshing machine	Multi-crop thresher	2.0(0.0/0.0/2.0)	2.4(2.4/0.0/0.0)	
		Combine harvester	32.0(0.0/10.0/22.0)	40.3(1.3/18.3/20.7**)	- Losses due to crop floating in waterlogged fields - Over matured crop harvesting due to late arrival of combine - Poor separation efficiency due to wet crop/ high weed infestation / low blower efficiency	

5.	Drying	Sun drying	Manual	100.00	10.00	- Losses due to vehicular traffic, birds and animals - Extended monsoon
6.	Packaging and storage	Woven plastic bag or gunny bag	-	88.00	100.00	-
	Kanagis with neem leaves Heaped in room					- Rat, insects as rice weevil, moth - No chemicals added except in rice storage with boric acid is added @ 50g/sack of 50 kg
			10.00	-		
		-	2.00			
7.	Transport	Manual/ mechanical	Manually on head/ Rickshaw/ tractor trailer	100.00	100.00	
8.	Parboiling	Batch	In brass pot using rice husk / coconut shell, etc. as fuel	90.00	100.00	- Overcooking at container bottom - Higher quantity of mmature rice which rices to top and is removed with ladle and disposed, mature rice too get trapped with these and are discarded.
9.	Milling	Mechanical	Huller-type rice mill	90.00	100.00	- Too many immature grains in rice - Incorrect roller clearance - Huller type mill(they contribute to qualitative loss due to breakage)

period it was 8.5 % in *morod* lands, 100 % in *Kher,* and 100 % in *Khazan* lands, showing that man power crisis and availability of machinery had a positive effect on mechanization. However, due to subsistence method of cultivation of paddy crop (72 % (2011-13) and 53.66 % (2013-15) of the sampled farmers had less than 0.4 ha of land), it was observed that the crop was sown by broadcast method (100 % in *khazan*, 50 % in *Morod* and *Kher* topography) with less spacing of 150 x 300 mm or less inall topographies. No intercultural operations were practiced under the water submerged *khazan* lands causing large number of weeds (Fig. 2). Irregular geometry of the fields made them unsuitable for use of machinery. The farmers used combine harvesters in such fields (Fig. 3) leading to more than 20 % harvesting losses (as reported by the farmers in the sample setduring enquiry,while field observations recorded up to 14 % harvesting loss during harvest on the farmer's field).

There is, thus, a need to sensitize the farmers on correct methods of crop management practices to make the farms suitable for use of mechanized weeding and harvesters and reduce losses, and also introduction of lighter machines for harvesting in the inaccessible farms.

Fig. 3: Harvesting of broadcast sown paddy using combine harvester

Collection and Threshing

The crop was harvested, threshed, bagged and transported for drying on the same day in places where combine harvesters were used. In case of manual harvesting or harvesting by brush cutter/ self-propelled reapers, it was collected and stacked on the field and later threshed. Threshing was mostly done manually (Fig. 4) by treading with feet, beating with bamboo sticks, treading with tractor wheels, combine harvesters or crop threshers in the field.

Fig. 4: Paddy threshing by treading

It was observed that during the 2011-13 period, threshing was done by treading with feet/cattle/beating with sticks or on a hard surface (per cent of famers being 66.7 % in *morod*, 0.0 % in *Kher*, 60.0 % in *Khazan*), treading with power tiller/tractor (per cent of famers being 33.3 % in *morod*, 0.0 % in *Kher*, 0.0 % in *Khazan*),multi-crop thresher (per cent of famers being 0.0 % in *morod*, 0.0 % in *Kher*, 3.3 % in *Khazan*) or combines (per cent of famers being 0.0 % in *morod*, 100.0 % in *Kher*, 36.7 % in *Khazan*). During the 2013-15 period, it was done by treading with feet/cattle/ beating with sticks or on a hard surface (per cent of famers being 66.5 % in *morod*, 0.0 % in *Kher*, 22.7 % in *Khazan*), treading with power tiller/tractor (per cent of famers being 26.5 % in *morod*, 0.0 % in *Kher*, 0.0 % in *Khazan*) , multi-crop thresher (per cent of famers being 4.5 % in *morod*, 0.0 % in *Kher*, 0.0 % in *Khazan*), or combine (per cent of famers being 2.5 % in *morod*, 100.0 % in *Kher*, 90.9 % in *Khazan)*.

Manual harvesting was mostly done only in farms whose holding sizes were unsuitable for harvest machinery. In most farms in *morod* land, the crop was harvested and stacked in the field (Fig. 5). After only some auspicious rites, threshing by treading using oxen, tractor wheels or power tiller wheels was started. The major shift towards mechanisation occurred in the year 2013 in *khazan* area where subsidised custom hiring of combine harvesters was introduced by the State Agriculture Department.

Fig, 5: Harvested crop stacked on field

Drying

All farmers surveyed practiced sun-drying of paddy (Fig. 6) on the road sides or in the backyard of their homes.The procedure might have led to some losses due to birds and cattle, passing vehicles, and the likes. No separate drying or threshing yards existed in Goa. This type of loss was not quantified on farm during this study.

Fig.6: Losses during drying on field

Parboiling

Paddy is mostly consumed as parboiled rice in Goa (Manohara and Singh, 2013), and hence parboiling is an important unit operation in the State. Parboiling was done by the farmers using brass pot (Fig. 7) and rice husk/ coconut coir/ shell fired mud stoves. This method of parboiling was observed to lead to over-cooking of paddy at the bottom of pot causing breakage of grains during milling.

As farmers of Goa are not aware of the modern fuel-efficient methods of paddy parboiling developed elsewhere (NRRI design, 70 kg per batch capacity;

Fig. 7: Traditional parboiling

TNAU model, 125 kg per batch capacity; using steam parboiling for husk splitting to reduce over cooking) and suitable for home-scale parboiling by farmers in batches of 50-100 kg are good options (Gupta *et al*., 2012, Din *et al.,* 2013). Introduction of modern parboiling units with training is thus necessary as all farmers used parboiled rice for self-consumption. There is also good scope for parboiled organic red rice in the state, which presently sells for ₹ 50-200 per kg.

Storage

Storage of paddy/rice at villages was done in jute or plastic woven bag, bin, or heaped in room. Storage began as early as in the month of October in the form of paddy. After paddy was subsequently dried, it was stored by the farmers either without milling as paddy or parboiled, milled and stored as rice.

Altogether 38 % (period 2011-13) and 69 % (period 2013-15) of sampled farmers stored less than 1000 kg of paddy (Table 3) in their house for self-consumption. Paddy was mostly stored in jute bag or plastic woven sack, and stacked in shaded balcony of house or in a room. Farmers added *vitex negundo* (*Lingur*) leaves, neem leaves, etc., in the sacks to protect from pest infestation. Boric acid powder @ 50g per sack of 50 kg was usually added with rice to prevent pest infestation. Some traditional methods of paddy storage used were woven bamboo structures (Kanagis for paddy), earthen pots or woven straw (mudi for seeds), Fig. 8. Few metal bins were available with the farmers, but were not found to be in use. There was no awareness about the advantages of storage in metal bin. Hence, training of the farmers on safe storage methods using metal bins is

Table 3. Quantity of paddy stored

Sl. No.	Quantity of rice/ paddy stored, kg	Number of farmers	
		2011-13 (50)	2013-15 (82)
1.	<500	18 (36 %)	42 (51.22 %)
2.	500 - <1000	20 (40 %)	27 (32.93 %)
3.	1000 - <1500	6 (12 %)	10 (10 %)
4.	1500 - <2000	1 (2 %)	2 (2.44 %)
5.	2000 and more	5 (10 %)	1 (1.22 %)

Note: Figure in bracket represent per cent of farmers

Fig. 8: Storage practices for paddy in Goa

important to reduce storage losses in Goa. Since there is no supplier of metal bins in the state, development of a few entrepreneurs for manufacture of bins is also important.

Six of the Goa Cooperative Society owned go-downs storing paddy of rice were surveyed. The 14 go-downs owned by the Cooperative Society had stored total quantity of 1317.35 t of rice during the study period. Rice was stored in woven plastic sacks (50 kg capacity). Negligible paddy storage losses were noted in the go-downs as the paddy procured was sold to the farmers and vendors within a month of procurement.

Storage pests

Post-harvest losses in paddy in all channels of storage caused by unscientific storage methods, insects, rodents, microorganisms, is reported to account for about 0.31±0.08 % of total stored paddy in India, and 1.58±0.12 % in western coast plains and *ghats* of India (Jha *et al.*, 2015).

Periodic sampling of the stored paddy/rice samples were collected and examined under Stereo Zoom Leica Microscope, and occurrence of three storage insect pests of paddy *viz*., rice weevil *Sitophilus oryzae* (*Curculionidae: Coleoptera*), lesser grain borer *Rhyzoperthadominica (Bostrychidae: Coleoptera)* and rice moth *Corcyra cephalonica (Pyralidae: Lepidoptera)*were observed in the surveyed areas. The average damage was 3.80±1.91 % and 4.3±1.95 % during the period 2011-13 and 2013-15, respectively. The infestation increased with storage period.

Further detail studies considering parameters as initial storage moisture content, types of storage structures, preservation methods and period of storage on percentage losses and types of storage needs for parboiled / raw rice is required for the State.

Paddy milling

Paddy is milled in Goa mostly by traditional huller-type (without rubber roller or bran removal system) rice mills. Out of 18 mills surveyed, 15 were huller type and 3 were huller-cum-sheller type. Earlier, the farmers of the state of Goa were only cultivating the bold varieties of paddy, which they used to consume after parboiling and milling. Although high-yielding, less-bold varieties had been introduced, the rice mills had not been accordingly modernized. Thus, the farmers had the option either to mill their produce in these huller mills resulting in higher breakage, or to take the produce to neighbouring states for milling and consequently losing their profit margin. Most of the mills in the state have been either closed down or running at a loss as they operated for 1 – 10 hours per day during the peak season as reported by the mill owners as March-May, or April-May, or May only; or May and October. During off-season, these mills operated on monthly or weekly intervals on need basis for farmers who brought their stored grain for personal consumption. Some mills operated once or twice a week, and the farmers brought their paddy for milling only on those days.

The data reported by the mill owners and also verified by us indicated that that head rice recovery was 60-65 % for parboiled rice and 25-50 % for raw rice. Rehal

et al. (2017) in their review of various parameters affecting head rice recovery in mills had stated that parboiling results in head rice yield of 68-74 %, and is inversely correlated to temperature of parboiling. They have also stated that steaming of parboiled rice (as done in modern parboiling gadgets like NRRI unit (Din *et al*., 2013)) increases hardness of rice and the head rice yield. Bunna *et al*. (2019) had reported that head rice milling losses are due to fissured grains.Sinha *et al*. (2010) and IRRI (2013) had already reported that traditional stacking of harvested crop on field results in fissured grains.

The mill owners had also complained about the financial losses due to low volume of demand. Thus, the need for modernization of the rice mills in Goa is paramount to promoting and popularizing paddy cultivation. Product diversification options at the mills to convert them into agro-processing centres would make their operation more profitable. The Government of Goa has recently introduced a modern rice mill suitable for slender and bold varieties, and a few entrepreneurs have installed modern rice mills mostly for bold varieties.

Post –harvest Losses in Paddy Processing and Storage

By enquiry

The losses in various unit operations, as reported by farmers, are shown in Fig. 9. Highest grain loss was reported in harvesting operation (8.70±6.85 %) during the period 2011-13, and 3.30±3.71 % during 2013-15 period; followed by winnowing (4.97± 4.48) during 2011-13 as compared to 5.40 ± 6.28 % during 2013-15; collection-packaging-transportation (4.59±5.66 %) during 2011-13 and (1.41± 3.31) during 2013-15; parboiling (2.04 ± 2.38 %) during 2011-13 and (1.03 ± 1.28 %) during 2013-15; threshing (1.49±1.85 %) during 2011-13 and (0.64 ± 1.88 %) during 2013-15; storage (1.01±1.04 %) during 2011-13 (not recorded during 2013-15); and drying (0.26 ±0.35 %) during 2011-13 and (1.52 ± 5.03 %) during 2013-15. Thus, the total loss as reported by farmers was 19.26±14.63 % during the period 2011-13 (including storage losses), and 11.31±12.09 % during 2013-15 (excluding storage losses). The difference in reported values could be probably due to the fact that the participating farmers during 2011-13 had been sensitized about the losses, or due to the major shift towards combine harvesters during the period 2013-15.

By observation

The actual operation-wise data collected on the farmers' fields is summarized in Table 4. The losses were higher during the period 2013-15 as compared to 2011-13 for all operations, and an operation-wise comparison to losses reported by FAO (1997) and Jha *et al.*(2015) is presented below. Parboiling data was not collected in the year 2013-15.

The highest loss was observed during storage operation (3.80±1.91 %) during the period 2011-13 and 4.3±1.95 % during and the period 2013-15, followed by milling (0.82±1.33 % in 2011-13 & 0.26±0.23 % in 2013-15), parboiling (0.62±0.70 % in 2011-13), harvesting (0.44±0.40 % in 2011-13 & 2.04±3.56 % in 2013-15), winnowing (0.36±0.37 % in 2011-13 & 2.16±7.46 % in 2013-15), and threshing (0.11±0.10 % in 2011-13 & 2.88±5.16 % in 2013-15).

Harvest losses for south-east Asian countries was in the range of 1-3 % (FAO, 1997), and in West coast plains and *ghats* at 2.14±0.08 % (Jha *et al*., 2015), and

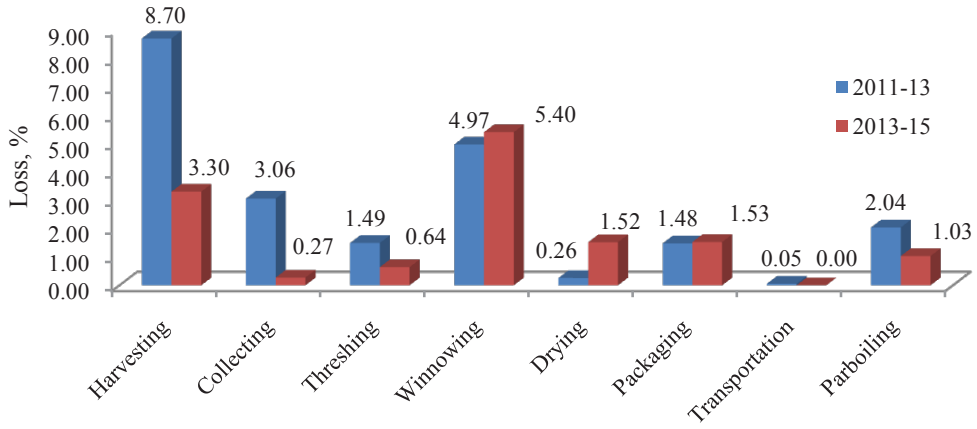

Fig. 9: Per cent post-harvest losses as estimated by farmers as collected by enquiry

Table 4. Operation-wise losses by observation (%)

Harvesting		Threshing		Winnowing		Parboiling		Storage		Milling	
2011-13	2013-15	2011-13	2013-15	2011-13	2013-15	2011-13	2013-15	2011-13	2013-15	2011-13	2013-15
0.44± 0.40*	2.04± 3.56	0.11± 0.10	2.88± 5.16	0.36± 0.37	2.16± 7.46	0.62± 0.20	Not recorded	3.80± 1.91	4.3± 1.95	0.82± 1.33	0.26± 0.23

* *Average ± S.D.*

similar (2.04±3.56 %) to that for Goa during 2013-15 as observed in this study. However, the loss recorded for the period 2011-13 was comparatively very low (0.44±0.4 %). Threshing losses in Goa during 2013-15 was 2.88±5.16 % as compared to 2-6 % in south-east Asia (FAO, 1997), and 1.18±0.13 % in West Coast and *Ghats* (Jha *et al*., 2015).Threshing loss during 2011-13 was comparatively low. Storage losses in Goas in both study periods were observed to be well within the range reported to be 2-6 % in south-east Asia (FAO, 1997), but higher than 0.2±0.0 % for on-farm storage (Jha *et al*., (2015). Losses in parboiling and milling were not reported in these studies.

All sampled farmers had reported that they reused the storage sacks after washing and sun-drying for subsequent year. Storage losses in Goa thus mainly occurred either due to pest infestations due to reuses of same storage bags in subsequent years without adequate sanitization practices or fumigation, or due to paddy being stored at higher moisture without being dried to safe moisture content due to frequent showers during sun-drying period, using traditional storage structures as *kanagis* (open woven bamboo bins, plastered with cowdung and/ or gypsum), without being hermetically stored leading to high storage pest infestation. Farmers were also observed not to use advanced storage structures as modified *kothars* or bins (Gowda and Shakuntala, 2018) to reduce pest infestations and moisture migration.

As mentioned earlier, threshing was mostly done manually by treading with feet or beating with sticks, by tractor or power tiller; while few farmers used combine and mechanical thresher. Losses were more in manual threshing (4.48±6.41 %) as compared to 1.35±1.56 % by mechanical threshing. Threshed produce was generally stacked in field due to which losses were higher, and this also led to lesser head rice yield during milling as also reported by various researchers (Sinha *et al*., 2010; IRRI, 2013; Bunna *et al.*, 2019). Farmers had also reported that lack of manpower led to delay in threshing, which in turn increased shattering loss on the field. Ali *et al*. (2019) had reported 0.7 % shattering loss in paddy fields. It was observed that in case of use of combine, machine settings were sometimes not correctly set, leading to more paddy present in the stalk after threshing. Combine harvesting loss was found to be 1.19 %, which was mainly due to shatter and paddy remaining in the hay after threshing. Improper crop geometry or closer spacing due to broadcast method of sowing, high weed infestation due to lack of intercultural operations might be some of the causes for such high loss with use of combine harvester. Researchers have reported on higher crop cutting height by combine (240 mm) as compared to 67 mm by reapers and 40 mm by manual cutting (Leonce and Saraswat, 2015).They had also compared various methods of harvesting and threshing with respect to the cost of operations and grain losses, and found that combine harvesting was more advantageous when compared to manual, followed by manual or other methods of mechanical threshing. Bunna *et al*. (2019) have reported higher grain loss in combines when harvest dates were delayed.

Winnowing was generally manually done using natural wind (Fig. 10), leading to lesser separation efficiency and causing higher (0.36±0.37 % during 2011-13 and 2.16±7.46 % during 2013-15) losses. Parboiling operation also witnessed additional losses due to use of traditional brass pot using fire wood, causing

Fig. 10: Manual winnowing (still in use)

higher per cent of (average broken rice during milling 38.55±17.99 %, reaching as high as 67.65 %) broken rice during milling. Total losses by observation method on the farms was 5.92±2.62 % (2011-13) and 9.04±9.74 % (2013-15).

There was a wide variation (harvest loss: 94.94 %, threshing loss: 92.62 %, winnowing loss: 92.76 %, parboiling loss: 69 %, storage loss: 27.6 %) between the losses observed by enquiry method and actual observations in farms during the period 2011-13. But during the subsequent study period (2013-15), some of these variations (harvesting loss: 38.18 %, threshing loss: 35.0 %, winnowing loss: 60.0 %) were reduced. This could be due to the fact that the awareness towards losses increased among the farmers, and they actually estimated the data based on their observations during 2013-15, whereas in 2011-13 they were over-estimating the losses due to lack of awareness about the losses.

CONCLUSIONS

An assessment of the harvest and post-harvest losses in paddy cultivation in Goan farms was conducted during the years 2011-13 and 2013-15. Total post-harvest losses of 5.92±2.62 % (including parboiling losses) during 2011-13,and 9.04±9.74 % (excluding parboiling losses) at farm level were observed. Introduction of combine harvester for small and fragmented land holdings, lowland and undulating upland was considered to be important to ensure timely operations and reduce losses in paddy. Introduction of modern rice mill is suggested to reduce milling losses and proper milling of hybrid paddy varieties. Improved storage practices using metal bin of 50-200 kg capacity, *Pusa* bin, *Kothars* can reduce on-farm storage losses. Sensitization of farmers has to go hand in hand with improved rural road infrastructure for transporting harvested paddy, threshing and drying yards and storage structures to ensure better management of paddy in Goa.

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