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In-store losses of rice and ways of reducing such losses at farmers' level: An assessment in selected regions of Bangladesh

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Abstract

The study aimed at assessing the in-store losses of rice caused by biotic and abiotic factors in the storage structures/containers at farmers' level. The farmers' suggested ways of reducing in-store losses of rice are also discussed. A total of 96 villages covering 26 Upazilas under 14 civil districts across all the divisions of the country were selected for present investigation. The districts were put under five different regions to capture the dimensions of study. In all, 1360 samples of *Aus*, *Aman* and *Boro* rice farmers were selected randomly and purposively from the study areas and put into marginal, small, medium and large farm category based on their land ownerships. Data were collected through pre-tested questionnaires. Different traditional rice storage structures/containers like *Dole, Berh, Inside-house Gola, Outside-house Gola, Steel/Plastic drums, Motka, Gunny bag* and *Plastic/Polythene bags* were commonly used by farmers in the study areas. The storage time of rice varied from 3.05 to 7.24 months irrespective of rice, farm and region with the overall average being 5.5 months. Significant losses in stored rice occurred through the activities of both biotic and abiotic factors. The average in-store losses occurred for *Aus*, *Aman* and *Boro* rice were respectively 3.68, 3.80 and 4.12% with the aggregated average being 3.92%. The average in-store losses of rice in large, medium, small and marginal farmers were 4.48, 3.92, 4.0 and 3.59% respectively. The in-store losses occurred in regions 1, 2, 3, 4 and 5 were 3.31, 5.23, 3.62, 4.44 and 3.25% respectively. The farmers suggested a number of ways for reducing in-store losses of rice including training on capacity building and awareness for safe storage, credit for constructing durable storage structure, construction of common storage structures at village/union level, preventive measures against biotic and abiotic factors, supplying farmers with durable storage containers and keeping them well ahead informed about the natural calamities.

Keywords: In-store losses of rice, Farmers' level assessment, Ways of reducing in-store losses

Introduction

Rice is produced all over Bangladesh with high production intensity in some areas and plays a dominant role in providing food for the people. Rice is the staple food accounting for about 93 percent of the total food produced, about 70% of average calorie intake and 35% of household expenditure. Rice production is the largest contributor to farm income, while related trade and commerce are important sources of rural non-farm income (Ahmed, 2001). Bangladesh is the fourth largest rice producer in the world (FAO, 2010). In spite of this, the country is languishing with food deficit and each year the country has been importing over one million metric tons of rice at the expense of hard-earned foreign currency (BBS, 2009). A considerable amount of rice is lost in each stage of production especially in harvest, processing and storage. Previous studies showed that the losses of rice in post-harvest operations in Bangladesh were more than 13% (Calverley, 1994; Quasem and Siddiquee, 2009).

The farmers usually store rice using traditional storage structures/containers to meet their own consumption, facing emergency needs and seeds for the next sowing season. A portion of rice in the storage structures/containers at farmer's level is subjected to damages or rotten by the various biotic and abiotic factors. The biotic factors includes fungi, mites, mould, insect, pest, rodent, lizards, birds, etc and the abiotic factors includes temperature, moisture content, relative humidity, thermal properties of grain and storage structure, natural calamities like heavy rain and floods, etc. Out of the common biological agents, beetles and moths are the main rice storage pests found in the tropical countries responsible for the losses and deterioration of stored rice (Hall, 1970). The agents responsible for deterioration differ in their rate of development and ability to cause damage under different moisture and temperature conditions. Damage by rodents can be of serious problem, particularly at the farmer's level of storage. Storage fungi operate best at relative humidity of around 85% but the activity of fungi falls off below 75% effective humidity (Schroeder & Calderwood, 1972). Mold growth produces a number of deteriorative

effects on rice grain including health hazards to human. The optimum conditions for growth of most storage molds are a temperature within the range of 20-40^{0}C and relative humidity above 70%. Mould development can be virtually halted if grain is dried to a moisture content that results in an inter-granular relative humidity of less than 75%. Apart from direct spoilage due to mold growth, the presence of mold might encourage the development of some species of insects. If mould and insect infestation is not detected or their seriousness not realized at the earliest possible moment, losses will be much greater.

Most importantly, temperature and moisture content are the crucial factors limiting the distribution and abundance of insects, mites and storage fungi that contaminate and destroy stored rice (Ullah & Abedin, 1991). Seasonal variations in atmospheric temperature also change the temperature pattern throughout the stored rice bulk. During the summer months rice temperature in the storage is low and outside air temperatures are high. Conversely during winter months average temperature outside the rice storage is low and the rice temperature in the storage is high. The fluctuation of temperature causes accumulation of moisture due to condensation either at the top or at the bottom of rice bulk depending upon the direction of the natural convection of the air within the stored rice. Spoilage may occur if counter measures are not properly taken. Moisture migration due to natural convection can be prevented by eliminating or drastically decreasing the temperature differential across a rice storage wall. Before storing rice they must be dried to reduce moisture contents of about 13% (Samajpati & Sheikh, 1980). Pre-storage drying ensures long-term storage, maintenance of seed viability, and better quality of the products. A moisture content which is in equilibrium with 70% or less relative humidity is widely regarded as safe for stored rice (Christensen, 1974). When the rice is dried to moisture content of 16% only or even a higher moisture percentage, the period of safe storage is shortened to a few weeks (Michael, 1978).

The losses are higher in Bangladesh compared to other developing countries where better storage systems are available. According to study by the Brazilian Technical Commission for Agricultural Loss Reduction, the storage losses of rice in Brazil are 2.4% (FAO, 2004). The storage losses of rice in Asia ranged from 2 to 6% (De Padua, 1999). Hopf *et al* (1976) in his mail survey on stored grain losses at farm and village level reported that 5% rice was damaged or lost in woven bamboo bin storage structure in Bangladesh. Rice is lost at 3% in the similar type of storage structures in Laos and it was 2-5% in India. When the rice is stored in sacks the losses were 3.5-6% in India, 3-5% in Nepal, 2-3% in the Philippines, 5% in Thailand. These damages are caused mainly by rodents as reported in these countries. WeiFen *et al* (2003) in their studies in China found that grain storage loss was about 0.2% at national reserve level but 7-13% was in rural household storage level. Alam *et al* (2007) found in their studies that the farmers got lost of rice of about 2.33% in their storage structures/containers. The data on in-store losses conducted in different countries at different time intervals are so dispersed that there is no rigorous magnitude. A comprehensive research was, therefore, needed to achieve field level information on storage losses that would contribute to formulate policy guidelines in ensuring food availability from farmers' level storage of rice. The present study was undertaken to assess the rice, farm and region wise storage losses with the following specific objectives:

(a) To assess the in-store losses of rice at farmers' level caused by biotic and abiotic factors;
(b) To find the farmers' suggested ways of reducing in-store losses of rice.

Materials and Methods

Selection of the study area and sample size

A total of 96 villages covering 26 Upazilas under 14 civil districts across all the divisions of Bangladesh were selected for the present investigation. The details on sampling statistics are presented in Table 1. Selection of the areas was purposive based on the major and intensive production, accessibility, cropping patterns and surplus of rice as the areas under the districts contributed to about two-thirds of the country's rice production (BBS, 2009). The selection of regions, districts, Upazilas and villages were done purposively whereas the sample households were selected randomly using stratified random sampling technique with arbitrary allocation. The districts covered under the study were put under five different regions identified by 1, 2, 3, 4 and 5 to capture the dimensions of the study.

Table 1. Study areas covering number of Upazilas and villages with samples from each district

Region	Districts under the region	Number of Upazila under the district	Number of villages	Samples			Total number of sample
				Aus	*Aman*	*Boro*	
1	Dinajpur	2	8	20	40	40	100
	Rangpur	3	11	20	40	40	100
	Bogra	2	8	20	40	40	100
2	Rajshahi	1	4	10	30	30	70
	Natore	1	4	10	30	30	70
	Naogaon	1	4	2	22	32	56
3	Mymensingh	2	8	20	50	50	120
	Sherpur	2	8	12	45	37	94
	Kishoregonj	2	8	15	65	40	120
4	Sylhet	2	8	-	40	50	90
	Comilla	2	5	20	40	50	110
	Chittagong	2	6	20	40	40	100
5	Jessore	2	8	20	40	50	110
	Barisal	2	8	20	65	35	120
Total		26	96	209	587	564	1360

Three Upazilas were selected from Rangpur district and one each from Rajshahi, Natore and Naogaon districts. Two Upazilas from each of the rest districts were selected. No *Aus* farmer was included in the study from Sylhet district.

Rice type and farm category-wise sample distributions

Samples of farm households for the study were selected with stratified random sampling technique and thus requisite number of *Aus, Aman* and *Boro* rice growing households were selected. For this, lists of the farming households were collected from relevant Upazila Agricultural Offices. The farm households under rice cultivation were classified into four groups based on their land ownership and these were the marginal farmer having land less than 1.0 acre (<0.4 hectares), small farmer having land with 1.0-2.49 acres (0.4-0.99 hectares), medium farmer having land with 2.50-7.49 acres (1.0-3.0 hectares) and large farmer having land with more than 7.50 acres (>3.0 hectares).

Rice type and farm category-wise population and samples are given in Table 2. The table shows that the *Aus* rice sample represented 13.61% of large farm households, 5.00% medium, 2.82% small and 1.61% marginal households. *Aman* rice sample represented 13.20% large farm households, 4.43% medium, 3.71% small and 1.61% marginal households. *Boro* rice sample represented 12.66% large farm households, 4.40% medium, 3.45% small and 1.57% marginal households. The samples were separately selected from *Aus*, *Aman* and *Boro* rice producing farm households from each area under the study. For the study 138 sample household were selected from the 1060 large farm households, 417 sample households were selected from the 9269 medium farm households, 437 sample households from the 12678 small farm households and 368 sample households from the 23106 marginal farm households. The proportion of selected large, medium, small and marginal sample farm households were 1: 3: 3.2: 2.7.

Data collection

The study was based on both primary and secondary data. The primary data were collected separately from *Aus, Aman* and *Boro* rice households. Separate questionnaires and PRA check lists were also used for collecting the primary data. The questionnaires were prepared based on the experience gathered in the pilot survey conducted in some 14 Upazilas and 55 villages under the selected study areas. The questionnaires were pre-tested amongst 110 farm households. The questionnaires were modified based

on the experience and feedback gathered through discussions with the farmers of different categories, districts and Upazila agriculture officers and in-house inception workshops. Data were collected by the research team and six trained enumerators for six months with the assistance of Upazila Agriculture Officers and Sub-Assistant Agriculture Officers in each Upazila. Data collection continued from March through August 2009, covering *Aman, Boro* and *Aus* rice in a cropping year. The PRA check lists were prepared and pre-tested and the final PRA check lists were used amongst 48 FGD groups, consisting of large, medium, small and marginal farmers of 24 Upazilas. The questionnaires were filled up by face-to-face interviews with the household respondent at their leisure times. The collected primary data were edited both at the field and at the laboratory. The secondary data were collected from publications of different research institutes including BRRI and Rice Foundation, BBS and websites. Simple statistical tools including Excel and SPSS were used for analysis.

Table 2. Rice type and farm category-wise total households and samples

Farm category	*Aus*		*Aman*		*Boro*		Total	
	Total farm household	Total sample household	Total farm household	Total sample household	Total farm household	Total sample household	Farm household	Sample household
Large	147	20 (13.61)	447	59 (13.20)	466	59 (12.66)	1060	138 (13.02)
Medium	1321	66 (5.00)	3996	177 (4.43)	3952	174 (4.40)	9269	417 (4.50)
Small	2235	63 (2.82)	5229	194 (3.71)	5214	180 (3.45)	12678	437 (3.45)
Marginal	3721	60 (1.61)	9738	157 (1.61)	9647	151 (1.57)	23106	368 (1.59)
Total	7424	209 (2.82)	19410	587 (3.02)	19279	564 (2.93)	46113	1360 (2.95)

Figures in the parentheses indicate percentage of total households

Results and Discussion

Storage structures/containers at farmers' level in the study areas

Due to lack of access to modern storage facilities farmers stored their rice in different traditional storage structures/containers like *Gola*, *Dole*, *Berh, Dhari,* etc and in earthen container, namely, *Motka*, *Jala*, etc and in gunny and plastic/polythene bags. They also stored their rice in *Chatai ghera mancha* and in *Attic* which is locally called *Chatal*. Mainly eight different traditional rice storage structures/containers were identified in the study areas and these were *Dole, Berh, Inside-house Gola, Outside-house Gola, Steel/Plastic drums, Motka, Gunny bag* and *Plastic/Polythene bags*. Among these, *Gunny bag* and *Plastic*/*Polythene bags* were the storage containers mostly used by the farmers for storing paddy for short duration and also for carrying rice from field to farmers' premises. On the other hand, *Dole, Berh, Gola, Motka, Steel/Plastic drums* were the containers used for long period of storage. The storage container *Motka* was not abundantly used by the farmers. The photographic views of some of the storage structures/containers commonly used by farmers' in the study areas are shown in Fig.1.

Rice type, farm category and region wise storage time

Rice type, farm category and region wise average storage time is shown in Tables 3 to 5. The storage time varied from 3.05 to 7.24 months with the overall average being 5.5 months. The storage time was the highest (6.59 months) for *Boro* rice in large farms and the lowest (3.52 months) for *Aus* rice in small farms. On an average, *Aus* rice was stored for about 4 months, *Aman* rice for about 5.5 months and *Boro* rice for about 6 months for all farms. The average storage times were more or less the same for all categories of farms. It was observed that the average storage time was the highest (6.84 months) in region 5 for large farm while it was the lowest (3.56 months) in region 2 for the same farm. It was also observed that the storage time was the highest (7.24 months) in region 5 for *Boro* rice while it was the lowest (3.05 months) in region 2 for *Aus* rice.

(a) Dole

(b) Berh

(c) Gola (bamboo made)

(d) Gola (wood & tin made)

(e) Outside house storage structure (bamboo, tin and wood made)

(f) Outside house storage structure (tin and wood made)

(g) Outside house storage structure (gable) made of bamboo, tin and wood

(h) Plastic drum

(i) Steel drum

(j) Motka

(k) Gunny & polythene bags

Fig.1 Traditional storage structures/containers commonly used by farmers in the study areas

Table 3. Rice type and farm category wise average storage time

Farm category	Average storage time (month)			
	Aus	*Aman*	*Boro*	Average
Large	3.97 (1.81)	5.57 (3.71)	6.59 (4.46)	5.79 (3.95)
Medium	4.02 (2.25)	5.84 (3.22)	6.22 (3.31)	5.75 (3.22)
Small	3.52 (1.43)	5.49 (2.85)	6.18 (3.04)	5.53 (2.91)
Marginal	3.61 (1.65)	5.08 (2.26)	6.09 (2.88)	5.26 (2.59)
Average	3.75 (1.82)	5.49 (2.93)	6.21 (3.25)	5.55 (3.05)

Figures in the parentheses indicate standard deviation

Table 4. Farm category and region wise average storage time

Region	Average storage time (month)				
	Large	Medium	Small	Marginal	Average
1	6.75 (4.77)	6.52 (4.14)	6.40 (3.36)	5.55 (2.74)	6.23 (3.62)
2	3.56 (1.54)	5.44 (2.91)	4.73 (2.03)	4.37 (1.79)	4.74 (2.30)
3	5.69 (4.13)	5.16 (2.87)	4.73 (2.60)	4.40 (2.13)	4.88 (2.80)
4	5.70 (3.52)	5.33 (1.61)	5.51 (2.20)	5.82 (2.40)	5.56 (2.27)
5	6.84 (3.89)	6.56 (3.99)	6.37 (3.75)	6.28 (3.31	6.45 (3.71)
Average	5.79 (3.95)	5.75 (3.22)	5.53 (2.91)	5.26 (2.59)	5.55 (3.05)

Figures in the parentheses indicate standard deviations

Table 5. Rice type and region wise average storage time

Region	Average storage time (month)			
	Aus	*Aman*	*Boro*	Average
1	3.63 (1.78)	6.58 (3.72)	7.06 (3.64)	6.23 (3.62)
2	3.05 (0.97)	4.94 (2.29)	4.94 (2.38)	4.74 (2.30)
3	3.38 (1.66)	4.68 (2.27)	5.7 (3.42)	4.88 (2.80
4	4.63 (2.22)	5.17 (1.84)	6.17 (2.47)	5.56 (2.27)
5	3.83 (1.56)	6.41 (3.75)	7.24 (3.78)	6.45 (3.71)
Average	3.75 (1.82)	5.49 (2.93)	6.21 (3.25)	5.55 (3.05)

Figures in the parentheses indicate standard deviations

Rice type and farm category-wise in-store losses

The average in-store losses of rice in different farms are shown in Fig. 2. The in-store losses occurred for *Aus*, *Aman* and *Boro* rice were respectively 3.68, 3.80 and 4.12% with the aggregated average being 3.92%. The in-store losses of rice in large, medium, small and marginal farmers were 4.48, 3.92, 4.0 and 3.59% respectively. The highest average in-store losses occurred in *Boro* rice with 4.70% in large, 4.06% in medium, 4.16% in small and 3.92% in marginal farms. Loss of *Aman* rice was the second highest in all the farms but the lowest for the *Aus* rice. In-store losses of all the types of rice were the lowest (3.59%) in marginal farms as they stored small volume of rice with a good care. Losses of all types of rice in large farmers were the highest (4.48%) as they stored larger volume of rice for longer time where biotic and abiotic factors influenced reasonably more than that stored by other category of farms.

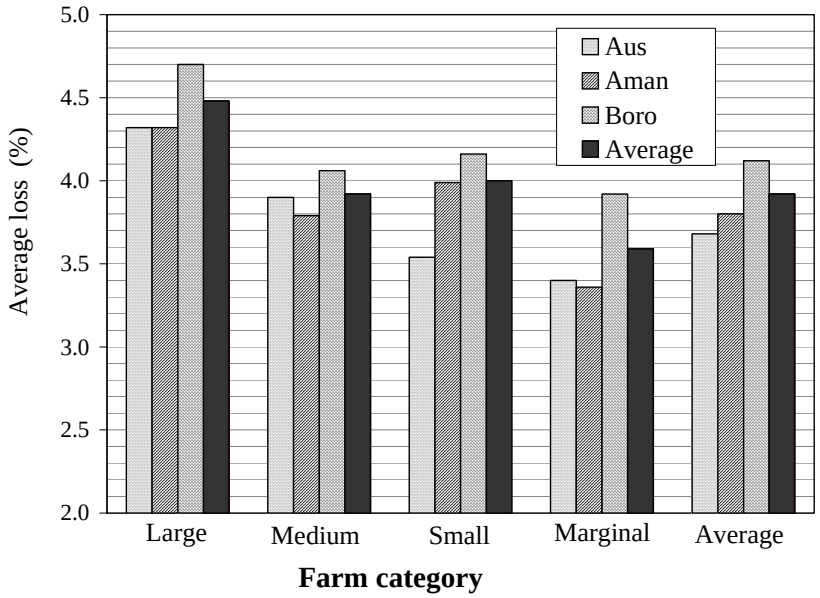

Fig.2 Rice type and farm category-wise average in-store losses of rice

Since freshly harvested rice has the moisture content of 20-24% or even more and, therefore, rice should be dried prior to storage. Rice can be stored safely for 2-3 months at 14% moisture content. For longer storage, the rice should be dried to moisture content of about 12% (Banglapedia, 2008).

Farm category and region-wise average in-store losses of rice

In-store loss of rice in different regions for all categories of farm is shown in Fig. 3. The average in-store losses occurred in regions 1, 2, 3, 4 and 5 were 3.31, 5.23, 3.62, 4.44 and 3.25% respectively with the aggregated average being 3.92%. The highest loss occurred in region 2 with 6.02% in large, 5.32% in medium, 5.02% in small and 5.09% in marginal farms. The second highest losses occurred in region 4. The reasons for such losses occurred in these two regions were due to severe attacks of rodents including mites and insects in the stored rice. Losses of stored rice were lower in regions 1, 3 and 5, although the rice kept in-stored in these regions ranged from 4.74 to 6.45 months for all categories of farm. The losses in small farms were the highest (5.02%) in region 2 but in region 1 the highest loss (3.56%) was incurred by the medium farms. The findings indicated that region and farm category wise losses were of similar occurrences except in region 3. The highest average loss occurred in the large farms (4.48%) and the lowest in marginal farms (3.59%). The weather parameters like temperature, humidity/rainfall, etc have a great effect on in-storage conditioning of rice in addition to type of storage structures/containers, duration of storage and initial moisture content of stored rice and may cause such discrepancies in magnitude of losses.

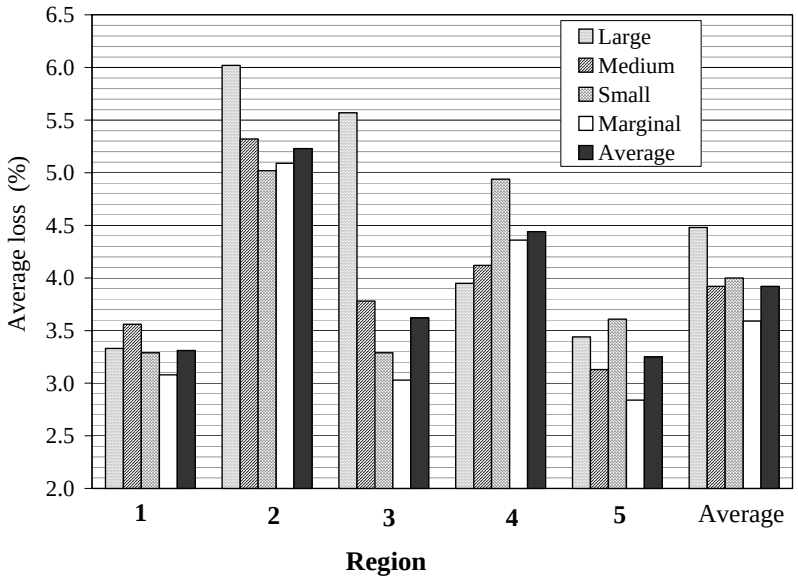

Fig. 3. Farm category and region-wise average in-store losses of rice

Rice type and region-wise average in-store losses

Rice type and region wise comparison of losses as shown in Fig. 4 revealed that the in-store losses of rice were again higher in regions 2 and 4 with averaging 5.23 and 4.44% respectively. The loss of *Aus* rice was the highest (5.92%) in region 2 but it was the lowest (2.62%) in region 5. The losses of *Aman* and *Boro* rice were more or less similar in regions 1, 2 and 4.

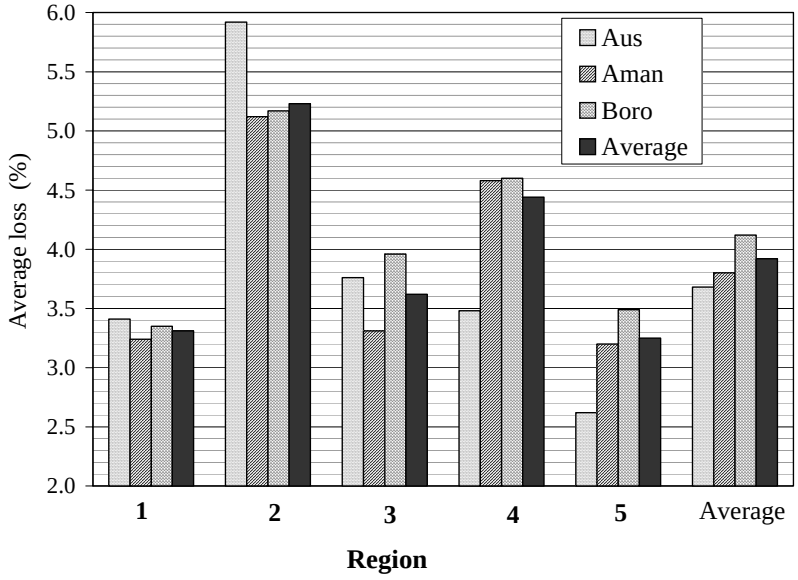

Fig. 4 Rice type and region-wise average in-store losses of rice

Suggested ways of reducing in-store losses of rice

Farmer suggested six major ways of reducing in-store losses of *Aus*, *Aman* and *Boro* rice occurred in different traditional storage structures/containers and these were imparting training on capacity building and awareness for safe storage, providing loan facility for constructing durable storage structure, constructing outdoor common storage structures at village/union level, taking on time preventive measures against biotic and abiotic factors, supplying the farmers with durable storage containers and keeping them informed about natural calamities well ahead of time. No significant differences were found among the farms and, therefore, the ways have been discussed on rice types and regions.

(a) Rice type-wise respondents on the suggested ways

Rice type-wise percent of respondents on the suggested ways of reducing in-store losses of rice are shown in Fig. 5. Referring to Fig. 5, imparting training on safe storage for creating awareness was suggested by about 37% of *Aus*, *Aman* and *Boro* rice farmers. This was opined by almost equal percentage of *Aman* and *Boro* rice farmers. Only 5% *Aus* farmers opined this as a measure for reducing in-store loss. Providing loan facilities for durable and functional storage structures was the second important suggestion towards reducing losses. Constructing durable storage structures of 20 years expected life like *Gola* having a storing capacity of 4500 kg of rice requires an expenditure of about Tk.40000.00 which is only possible to be used by large or medium farmers. If the small and marginal farmers want to use such type of durable storage structures, they would need to borrow money. Access to institutional credit would certainly offset the problems of using such storage structures. *Gola* is usually made of woven bamboo splits with thatched/tinned roof. However, constructing a brick-built pucca/permanent *Gola* for the same storage capacity one has to spend over taka one lakh which is, in most cases, impracticable even for large farmers.

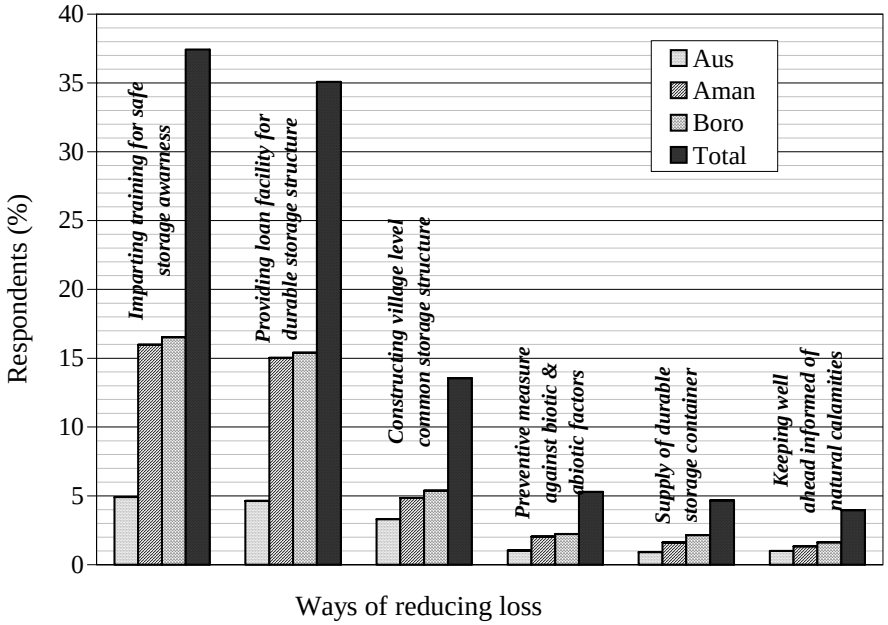

Fig. 5 Rice type-wise percent of respondents on suggested ways of reducing in-store loss

Constructing outdoor common storage structures at village/union level have been suggested by about 14% of the respondents in which most of them were small and marginal farmers. They expressed the need for village/union level storage structures for storing their rice under the arrangements of common management. Small and marginal farmers used to sell some of their rice immediately after harvest as *distress sale* towards meeting the dues for collecting production inputs and wage payments. They do not

supply their small quantity of rice to government procurement centres due to late payment and high transportation costs from the farmer's doors to procurement centres. In addition, the farmers are not sure whether their supply would be promptly taken by the procurement agents. Furthermore, the prices paid for the sale of their rice by the procurement agents like millers, are not fair. So, the establishment of common large storage facilities at village/union level has been suggested as a good alternative to reduce storage losses incurred by small and marginal farmers and thereby increase their stock availability of rice.

Supplying of durable storage containers by the government at subsidized rates were suggested again by small and marginal farmers. The small and marginal farmers usually stored rice in different types of open traditional storage containers like *Dole*, *Dally*, bags/sacks and on floor or on elevated place or on a small cot in their thatched house where the losses were huge caused by many biotic and abiotic factors. Supplying of durable structures/containers at subsidized rates need to fabricate/procure under the responsibility of the Upazila Agriculture Officers.

Farmers opined that they were not informed ahead of time to cope with the disasters or natural calamities which commonly occurs in our country and caused subsequent loss of stored rice. The natural calamities often caused havoc to the farmers especially for small and marginal farmers. Farmers requested for disaster related information to be made available to them in advance by the authorities so as to combat such eventualities.

(b) Region-wise respondents on the suggested ways

Region-wise percent of respondents on suggested ways of reducing in-store losses of rice are presented in Fig.6. The Fig.6 elucidates that imparting training for safe storage awareness was of the highest priority as suggested by rice farmers in all the regions of which region 3 (about 9%) led all the rest and nearing to it was the region 4. The farmers in these two regions were less aware about the losses occurred in the stored rice. In region 4, some rich farmers stored rice in pucca *Gola* at inside or outside their dwelling house causing relatively less in-store losses. In region 3, outside dwelling house pucca *Gola* was not used for storing rice. Farmers in these two regions stored rice in *Berh* and *Dole* of varying sizes and in bags/sacks of varying capacity. They were not fully aware of losses of rice occurred in the in-house stores rather more aware of losses during production and harvest operations.

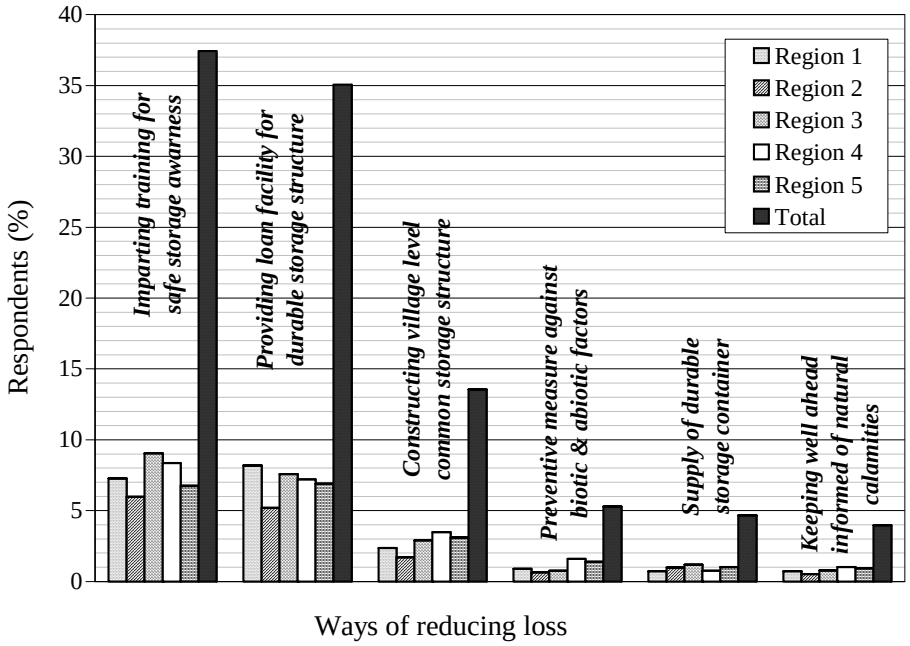

Fig. 6. Region-wise percent of respondents on suggested ways of reducing in-store loss

Access to loan for constructing durable storage structures were suggested by almost equal percent of farmers (7-8%) in all the regions except region 2. The numbers of marginal, small and medium farmers in region 2 were more than those in all other regions and the number of large farmers were a very few. They used to live in the houses with tinned/thatched roof and mud-walls and stored rice in bags/sacks of different capacity and sizes only for several months and, therefore, less aware of getting institutional loans. According to their perceptions, the efforts to be paid for collecting loan were of so torturous that they felt discomfort for searching any loan sources.

Some marginal, small and medium farmers stressed the need for constructing village/union level common storage structures though it was suggested by a less number (4%) of farmers in the regions. These people opined that village/union level common storage structures would be effective for reducing in-store losses through a common maintenance so that the rice could be made available for season-wide consumption as well as meeting costs for production and seed need. Preventive measures against biotic factors through chemicals were suggested by only less than 2% farmers in all the regions. Preservation of rice by chemicals was harmful to health though it was very much effective. Preservation of rice using IPM method in which use of *neem* leaves and garlic were the most effective.

Supplying of durable storage containers, usually plastic containers, by the government at subsidized rates were suggested in most of the regions largely by small and marginal farmers, especially, in region 2 and 4 where the attack by insects and rats were very high. They were unable to erect pucca *Gola* due to shortage of capital required for initial investment. The supply of durable plastic drums would also helpful in storing rice seeds in a good condition. Being well informed about the natural hazards, especially in region 4 and 5, was noted to be of utmost important. In these two regions, sudden occurrence of flood, cyclone and other natural calamities were frequent than those in others. Farmers in these regions would be able to keep their rice at safe place if they were well informed about the natural calamities.

Conclusion

The farmers in the study areas are not fully aware of losses of rice occurred in their in-house storage structures/containers rather more aware of losses incurred during production and harvest operations. Significant losses in stored rice occurred due to influence of both biotic and abiotic factors. In-store loss of rice was about 4% at aggregate level with the highest being for *Boro* and the lowest for *Aus* rice. *Gunny* and *Plastic*/*Polythene bags* were the storage containers mostly used by the farmers for storing rice for short duration. On the other hand, *Dole, Berh, Gola, Motka, Steel/Plastic drums* were used for long period of storage of which *Dole*, *Berh* and Plastic drum were the least loss storage structures/containers. The small and marginal farmers were resource poor and they could not build good storage structures. In-store losses of rice at aggregate level were the lowest for marginal farms. The large farmers incurred the highest in-store losses as they stored larger volume of rice for a longer time where both biotic and abiotic factors influenced reasonably more than that stored by other category of farms. Village/union level storage structures can be constructed for common use, especially for small and marginal farmers, not only to reduce storage losses but also to enhance their capacity of storing and getting fair price of produce. The farmers can be given institutional credit and training to enhance their capacity and awareness for safe storage. The farmers should also be kept informed well ahead about natural calamities so that they could take on time measures to safeguard their stored rice. Bangladesh can thus offset the storage loss of rice over half a million metric tons per year by developing her storage systems and building capacity for safe storage at farmers' level.

Recommendations

(a) Farmers' awareness programme and training on capacity building for safe storage of rice could be implemented. The BAU and DAE could be initiated to take the lead involving the private sector development partners.
(b) Appropriate storage structures/containers for different farm category could be developed. Public extension organisations should be sensitized to be engaged in playing a pro-active role in assisting farmers for effective use of these storage structures.

(c) Establishment of common/co-operative storage structures at village/union level should be initiated especially for small and marginal farmers towards enhancing their capacity of storing and thereby ensuring fair price of food grains.
(d) The unused LSD godowns at different growth centers across the country could be renovated and brought under co-operative storage system through proper management planning.

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