RICE BREEDING AND MECHANIZATION FOR VALUE ADDITION IN LAOS

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ABSTRACT

In rainfed lowland rice ecosystem, farmers adapt to climate change by changing planting pattern from traditional hand transplanting to dry direct seeding in order to avoid early drought. Therefore, breeding for new aromatic photoperiod sensitive variety which is flowering in early October was developed for direct seeding purpose. In addition, labor shortage is common and it has increased the cost of employing labor. Thus traditional use of labor for planting and harvesting rice is not practical any more in some areas of central Laos. Increase of labor cost has increased the cost of rice production, resulting in lower labor productivity and reduced competitiveness of rice in the international markets. Mechanization may help minimize the labor shortage problem and improve the quality of rice in central Laos.

Transplanter, Seed drill and Broadcasting require less labor than hand transplanting, but produced crops with 8%, 10 and 9% lower mean yield compared to hand transplanted crops respectively. Combine harvesting requires less labor than hand harvesting, however, farmers need to dry combine harvested paddy rice either by sundry or artificial dryer. In addition, combined contracting service fee is quite expensive at 15-20% of total production. Optimum field size of 2,000 to 3,000 m^2 could be harvested by combine 4.5ha per day and reduces time for combine harvesting 1ha of rice field compared with original field size of less than 1,000 m^2. Mean yield loss from combined harvesting was 1.5% of the total yield, which should be well acceptable in the industry. Establishment methods did not appear to have effect on yield loss percentage.

Delay in harvesting was affected head rice returned, and when time of harvesting was delayed to 35 days after 75% flowering, head rice decreased greatly to 35% under flatbed dryer and 29% under sundry. Highest head rice returned was obtained when paddy was harvested at 25 days after 75% of flowering and this was 48% when dried in the flatbed dryer, and 32% under sun drying. Drying combined with harvested paddy rice using artificial dryer produced higher head rice return of 45% compared with sun drying with head rice returned of 38% and hence increases the market value.

Setting up mechanization production board should be considered by the government in order to direct mechanization business to the bank and other government institutes for encouraging mechanization activities. The board could organize to provide credit to farmers who wish to develop their rice field, and also set up community artificial dryer in their village. It could assist provision of long term credit to rice millers association for setting up commercial artificial dryer in the miller as well as credit to combine harvesting association to reduce cost of harvesting to promote farmer using service from the combination.

Keywords: Aromatic, Photoperiod sensitivity, mechanization, seed drill, transplanter, broadcasting, combine harvest, artificial dryer, sundry, delay harvesting, head rice

INTRODUCTION

Rice production is the main farming activity in Laos, accounting for over 80% of the total cultivated area. Lowland rice is grown under two main agro-ecosystems, namely rainfed lowlands covering 88% and irrigated lowlands covering 12% (DOA., 2016). Due to climate change rainfall pattern is affected, causing early drought occurring more frequency (Inthavong., et al, 2011 and Xangsayasane *et al*., 2014) and changing planting pattern from traditional hand transplanting to direct seeding in center part of the country. In addition, some years flood has occurred during end-August to September affecting production losses (Xangsayasane *et al*., 2012). Therefore, current breeding objective is focused on selection for photoperiod sensitivity, flowering in early to mid-October, and flood and drought tolerant with aromatic flavor.

In Central Laos, where rice production for commercialization is practiced, the labor shortage is common in these areas and has increased the cost of employing laborers. Thus traditional use of laborers for planting and harvesting of rice is not practical any more in some areas. Increase of labor cost has increased the cost of rice production, resulting in lower labor productivity and reduced competitiveness of rice in the international markets against neighboring countries.

Hand transplanting needs about 40 people to complete 1ha/day, including pulling the seedling and hand transplanting (Xangsayasane *et al*., 2016). The most common method practiced to save labor is broadcasting, however, this method may reduce the time of planting greatly, but often crop establishment is rather slow and not uniform and patchy. This may be related to uneven surface of paddies and also light cultivation after broadcasting causing seeds positioned at different soil depths. There are several methods practiced or tested in Laos such as drum seeders, seed spreaders, seed drills and transplanters to overcome the shortcomings of broadcasting. Transplanter has been commonly used and replaced hand transplanting in northern Asian countries. Its advantage over hand transplanting is reduced labor requirement and faster speed of operation compared to hand transplanting. It is sometimes used for high quality seed production of rice in Laos where hand transplanting is not feasible any more with increased labor cost. The other planting method is seed drill, which is gaining popularity in Savannakhet due to saving of labor cost compared to transplanting (unpublished). Compared to broadcasting, it can provide better establishment and also drill planted crops are easier for weed control. Performance of seed drill may be compared with broadcasting where direct seeding is already practiced and with hand transplanting where it is still practiced.

Hand harvesting has been a common practice in Laos, and this commonly requires about 35 labor/days to harvest 1ha of rice field and thresh grain. Combine contracting service has commenced recently in Khammouan, Vientiane capital and Vientiane provinces and it is expected that the adoption of combined technology will increase with time, particularly as labor availability becomes even more limited (Xangsayasane *et al*., 2016). However, limitations of combined adoption is associated with high combined fee charge, although the fees are expected to be reduced as combined contracting service becomes more common and combined harvester efficiency increases. The other limitation for the adoption of combined harvester is associated with availability of drying facilities, as combined harvested paddy is difficult to sundry in the farm.

The Lao government is promoting mechanization for improving quality of rice grains, especially in dry season rice production. In addition, utilization of mechanization is believed to reduce cost of rice production and overcome labor shortage issues in the agriculture sector. This mechanization includes crop establishment methods such as the use of transplanters and seed drills, combined harvesting and artificial dryers. However, it seems to be that the size of rice fields in Laos is rather too small for efficient use of machineries. This small paddy size is due to farmer's use of draft animals for land preparation with hand transplanting. In addition, most of the rice fields are located on sloped land, where small field size with levee is required for holding standing water in the wet season. Currently, mechanization is introduced to Laos as commercial operations in many provinces, and therefore, with the cost of fees incurring, farmers may need to increase their rice field size to gain maximum benefit from mechanization. The percentage of milled rice returns is one factor determining price of paddy by rice miller.

This research is aimed to study whole cycle of mechanization application for rice production in Central area of Lao PDR, to determine suitable crop establishment methods to reduce cost of rice production, factors affecting combined harvesting efficiency, particularly field size, and drying methods for optimum head rice recovering from combined harvesting.

MATERIALS AND METHODS

Development of new varieties for direct seeding

New glutinous aromatic with submergence tolerant and blast resistance population was developed by research collaboration between the Rice Research Center (RRC), National Agriculture and Forestry Research Institute (NAFRI), Ministry of Agriculture and Forestry (MAF) in Laos and BIOTEC center, National Science and Technology Development Agency (NSTDA) in Thailand. Hybridization was done in 2009 between TDK1*4/HNN//IR85620-34-141///RD6*3/JHN and using Marker Assisted Selection (MAS) to select traits of interest (Table1). TDK303-140-3-93 derived from BC3F2 (TDK1*4/HomNangnuan), developed by marker assisted backcrossing (MAB) at NAFRI through the Mekong breeding program, carries fragrance phenotype *(badh2)* from Hom Nangnuane. IR85620-34-141 carries *sub1* developed by MAB at IRRI. RGD07529-1-1-38M-1-0 derived from RD6*3/JaoHomnin, developed by MAB at Rice Gene Discovery Unit (BIOTEC) carries qBL1 and qBL11. Field selection was done based on morphology and plant types. Total of 20 fixed lines from RGD10033 population was tested on replicated yield trials at Rice Research Center in DS2014/15 and WS2015. On farm demonstration was done in WS2016 and WS2017 in Vientiane, Bolikhamxai, Khammouane and Savannakhet provinces.

Table1. Characteristic of parental lines

Breeding lines	Genetic backgrounds	Fragrance	Cooking quality	Submergence	Blast resistance
TDK303	TDK1	Badh2 ^{HN}	Glutinous	non	unknown
IR85264	TDK1	non	Glutinous	Tolerant (Sub1)	unknown
RGD07529	RD6	non	Glutinous	non	Broad spectrum resistance *(qBL1 and qBL11)*

Seed drill and transplanter

The study was done in 5 villages: Pakpung, Hatkhanhien, Tung, Paketue and Navangthong. Seed drills were provided by NAFRI to three villages (Pakpung, Hatkhamhien and Paketue). The seed drill was attached to hand tractor for planting rice. In the dry season, soil was prepared in December under dry condition and then rice was seeded by seed drill in the first study. Dry rice seed was put in the seed box attached with seed drill and seeded under dry soil condition. After seed germinated and seedlings were 5 to 10 cm, field was irrigated. Transplanters were owned by farmer group in Hatkhanhien, Tung, Paketue, while in Pakpung it was serviced by Takokkung center. Total of 2,000 seedlings trays was provided to farmers for growing seedlings before planting rice by transplanter. Broadcasting and hand transplanting were done by farmers. Land preparation was done by farmers as their usual practice. Fertilizer was applied at about 100-150 kg/ha of NPK. Rice was harvested by combine from NAFRI and grain yield was adjusted to 14% moisture content.

Combined harvesting efficiency- field size and yield loss

We harvested a total of 76 rice fields in dry season with combined areas of 15.3 hectares, of which 12.3 ha was harvested from enlarged field in three target villages, 5 hectares (26 fields) in Pakpung, Paksan district, Bolikhamxai province, 4.3 hectares (18 fields) in Hatkhamhien village, Xebangfai district, Khammouane province and 3 hectares (12 fields) in PakEtue village, Nongbok district, Khammouane province. About 3 hectares (20 fields) of original field size less than 1,000 m^2 in each village was also used for this study. Size of each enlarged field ranged from 1,023 to 8,560 m^2 depending on the slope and toposequence. In the sloped areas, top soil was removed from higher position to the lower position of the field. KUBOTA-DS700 was used for this study of combined harvesting efficiency in our target villages. The time required for the combination to complete harvesting was recorded for each field, and combined harvesting efficiency was calculated in each field after the field size was determined. Farmers in different villages had planted rice with different methods, including hand transplanting, transplanter, seed drill, drum seeder and broadcasting. Paddy rice harvested by combined was dried to reduce moisture content by sun drying and flatbed dryer to adjust to 14% moisture content. Yield loss from combined harvesting was collected in 8 sites and yield loss was determined by randomly collecting grain on the soil surface in one square meter soon after the combine harvested the area.

Effect of drying methods

The experiments were conducted on-farm with participation of farmers in 5 villaegs (Pakpung village, Paksan district, Bolikhamxai province; Tung and Hatkhamhien villages, Xebangfai district and Paketue and Navangthong villages, Nongbok district, Khammouane province). Paddy harvested by combine was dried either by the sun and flatbed dryer. Dried paddies were collected for milling quality evaluation. In DS2014-15, a total of 16 paddies samples were collected from different farmers who participated in the experiment in 5 villages. Of these samples 8 samples were collected after sun drying and 8 samples were collected from flatbed dryer. In WS2015, a total of 18 samples were collected from farmers in 4 villages. Of these samples, 8 samples were from flatbed dryer and 10 samples from sun drying. In DS2015-16, a total of 14 samples were collected from farmers in 2 villages. Of these samples, 6 samples were from flatbed dryer and 8 from sun dried. Flatbed dryer had 4-ton capacity and was used to dry paddy from combined harvester and rice paddies harvested in a similar manner were sundried by placing paddies on tarpaulin sheets. Paddy was dried for about 10 to 12 hours in flatbed dryer to reduce moisture content to 14 to 15%, while it took about 17-18 hours under sun drying (dried from 8 am to 5 pm, and paddy thickness was 5 cm). Under sun drying, paddy was turned out in every 2 to 4 hours and when paddy was dried to 14% moisture content, the samples were collected for milling quality evaluation.

Effects of rice harvesting time

The experiment was conducted in the Rice Research Centre, Vientiane, Laos. TDK8, a commercial rice variety was used for this study. Transplanting was done by transplanter when seedling age was 15 to 17 days. In DS2014-15 transplanting was done on January 10, 2015 and in DS2015-16, transplanting was done on January 15, 2016. Fertilizer was applied at the recommendation rate of 90:30:30 of N, P_2O_5 and K_2O. Randomized Complete Block Design was applied with three replications. Paddy rice was harvested by hand at 25, 35 and 45 days after 75% flowering. Each sample was dried under the sun and flatbed dryer until moisture content was reduced to 14%. A 125g of rough rice sample with moisture content of approximately 13% to 14% was used to determine milling recovery. Rough rice sample was dehulled by using a Satake laboratory sheller. Brown rice was recorded before milling in a McGill mill number 2 for one minute. The milled rice sample was collected in a jar and was allowed to cool before weighing; the weight of the total milled rice was recorded. Whole grains (head rice) were separated from the total rice with rice-sizing device and recorded. The percentage of milling recovery was calculated as follows:

$$\text{Brown rice } (\%) = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

$$\text{Total milled rice } (\%) = \frac{\text{Weight of Total milled rice}}{\text{Weight of rough rice}} \times 100$$

$$\text{Head rice } (\%) = \frac{\text{Weight of Head rice}}{\text{Weight of rough rice}} \times 100$$

RESULTS AND DISCUSSIONS

Development of new varieties for direct seeding

Table 2 shows results from yield trials of 20 promising lines in RRC. Of which 9 promising lines produced grain yield significantly higher than check varieties (Xebnagfai2 and Xebangfai3). All of 20 promising lines were test physical grain quality and panel evaluation at RRC and one promising line (RGD10033-77-MAS-438-46) was selected for on farm demonstration (Table 3). Grain yield in on-farm has showed promising compared with commercial varieties and have yield advantage than commercial varieties ranging from 20 to 32% (Table 4).

Table 2. Yield trial at RRC in DS2014/15 and WS2015

No	Name	Maturity date (days)	Plant height (cm)	Panicle #/hill	Grain yield (t/ha)	Remarks
1	RGD10033-77-MAS-43-B	118	97	10	4,090*	
2	RGD10033-77-MAS-149-14-B	118	90	8	3,659	
3	RGD10033-77-MAS-149-16-B	129	99	10	4,030*	
4	RGD10033-77-MAS-149-17-B	128	94	10	4,376*	
5	RGD10033-77-MAS-149-18-B	123	91	8	3,545	
6	RGD10033-77-MAS-291-20-B	121	93	9	3,601	
7	RGD10033-77-MAS-291-23-B	121	89	8	3,797	
8	RGD10033-77-MAS-291-24-B	126	91	9	3,810	
9	RGD10033-77-MAS-291-25-B	125	94	10	4,140*	
10	RGD10033-77-MAS-298-27-B	125	99	9	3,962*	
11	RGD10033-77-MAS-438-46-B	125	96	9	3,930*	
12	RGD10033-77-MAS-438-47-B	127	100	10	3,901	
13	RGD10033-77-MAS-524-76-B	129	97	8	3,386	
17	RGD10033-77-MAS-291-23-B	120	94	10	3,850	
18	RGD10033-77-MAS-327-43-B	123	91	9	3,645	
19	RGD10033-77-MAS-438-46	121	97	10	4,232*	Promising lines
20	RGD10033-77-MAS-438-50-B	124	97	10	4,078*	
21	RGD10033-77-MAS-327-42-B	126	100	9	4,020*	
22	RGD10033-77-MAS-291-21-B	125	101	9	3,824	
14	DS14-YT1-14	130	97	9	3,409	
15	Xebangfai 2	118	111	9	3,726	
16	Xebangfai3	125	114	9	3,705	
	Mean	124	97	9	3,851	
	CV (%)	2.9	7.8	2.1	451.8	
	LSD (5%)	1.4	5.0	14.1	7.0	

* significant difference compared with Check (Xebangfai2)

Table 3. Grain quality and panel evaluation

Name	1,000 grain Weight (g)	Paddy lengt (mm)	Brown rice length (mm)	Milled rice length (mm)	% Total milled rice	% Head rice	Panel evaluation
XBF4	28.2	10.1	7.0	6.9	64.1	50.6	Soft and aroma
TDK8	31.9	11.4	8.0	7.8	53.6	40.7	Soft and no aroma
RD6	24.6	8.9	6.8	6.5	60.0	43.7	Soft and aroma

Table 4. On farm demonstration of XBF4

Districts	Farmers	Areas (ha)	Variety	weight (kg)	Yield (kg/ha)	Yield advantage (%)
Paksan	Mr Bounhep	0.28	XBF4	1,200	4,286	100
Paksan	Mr Bounhep	0.32	RD6	1,200	3,750	88
Nongbok	Mr Fai	0.4	XBF4	1,400	3,500	100
Nongbok	Mr Fai	1.92	RD15	4,620	2,406	69
Xebangfai	Mr Sivone	0.45	XBF4	1,760	3,911	100
Xebangfai	Mr Sukhon	0.45	RD15	1,200	2,667	68
Phonhong	Mr IL	0.8	XBF4	2,500	3,125	100
Phonhong	Mr IL	0.96	RD6	2,400	2,500	80

Seed drill and transplanter

Mean grain yield of machine transplanted fields was about 20% lower than that of hand transplanted fields (Table 5). Quartile yields show its yield distribution across fields is uniformly lower than hand transplanting and broadcasting. Seed drilled crops produced similar yield to that of hand transplanting, but the number of fields established from seed drill was small in our experiments and also the farmer did gap filling when the initial establishment was not good. Grain yield of crops established from broadcasting was 7% lower than that of hand transplanting, but this was not significantly different from hand transplanting.

Table 5. Comparison of yield obtained from 4 establishment methods of 76 fields examined in the dry season

Methods	Number of fields harvested	Total harvested area (ha)	Mean field size (m^2)	Mean yield (kg/ha)	Relative yield (% of hand transplanting)
Hand transplanting	21	3.8	1,532	3,638	100
Transplanter	25	4.7	1,393	3,362 ns	92
Broadcasting	19	4.2	3,000	3,090 *	85
Seed drill	11	2.6	1,924	2,894 *	80
Total/mean	76	15.3	1,962	$3,246 \pm 324$	

ns = not significantly different from the hand transplanted yield, * = significantly different from the hand transplanted yield.

Combined harvesting efficiency- field size and yield loss

Combined efficiency was estimated in relation to the size of paddies by measuring the time required to complete harvesting a paddy and relate this to the size of measured paddies. The results of combine harvesting of about 15.3 ha from 76 fields of various sizes have shown that combine speed was low when harvesting smaller paddies particularly less than 1,000 m^2. Combine harvesting efficiency increased with the increase in field size (Table 6). In the fields that we enlarged in size to about 2,000-3000 m^2 the efficiency was about 0.64 ha/hour and no further efficiency gain is expected over 3,000 m^2 fields. The combine efficiency gain in the enlarged field size of 2,000-3,000 m^2 over the small traditional fields of less than 1,000 m^2 would be about 52% (daily harvesting area ratio of 5.1ha/3.35ha). It appears about 3-5 paddies/ha may be optimum size for rainfed lowland rice in Central Laos.

Table 6. Yield and combine harvesting efficiency in the fields for different field sizes

Field size (m^2)	Mean size (m^2)	Fields harvested	Yield (kg/ha)	Speed (ha/hour)	Efficiency (ha/day)
$<$499	322	11	3,313	0.364	2.9
500-999	766	8	3,521	0.472	3.8
1,000-1,499	1,146	19	3,280	0.541	4.3
1,500-1,999	1,680	16	3,542	0.544	4.4
2,000-2,999	2,280	12	2,984	0.637	5.1
$>$3,000	4,808	10	3,825	0.630	5.0

Mean yield loss from combine harvesting in two dry season experiments varied from 0.8 to 2.2% of the total yield (Table 7). Crop establishment methods did not appear to have effect on yield loss percentage. The mean yield loss was about 1.5% which should be well acceptable in the industry. The loss depends on several factors, but higher combine speed would increase grain loss. As combine harvesting does not involve separate threshing and handlings of grains as in manual harvesting, the loss found here should be considered to be less than the expected loss from hand harvested crops.

Table 7. Yield loss from combine harvesting at 29 farms

Date	Farm	Village	Combine loss		Yield
			kg/ha	%	kg/ha
DS2014-15	8	5	78	2.2	3,676
DS2015-16	21	2	27	0.8	3,728
Total/Mean	29	7	52	1.5	3,702

Effect of drying methods and milling quality

The mean head rice return under flatbed dryer was 44.5% which was higher than mean head rice under sun drying of 37.9% (Table 8). In most cases, about 9 to 10 hours of drying was required to bring the moisture content from 28% after combine harvesting to 14-16%. Participating farmers made comments that sun drying required much more work, while flatbed dryer did not require constant attention. It should be pointed out that the sun drying was conducted throughout the day, and the higher head rice percentage may be obtained if sun drying was done in the morning only from 8 am to 1 pm, but it would take three days for drying to reduce moisture content to 14%. Improvement in techniques in both drying methods could reduce broken rice percentage.

Table 8. Drying methods and milling quality

Number of sites	Type of drying	% brown rice	% milled rice	% rice hull	% rice bran	% broken rice	% head rice
8	Flatbed dry	77.3	64.2	22.7	13.1	19.7	44.5
8	Sun dry	76.8	62.4	23.2	14.3	24.5	37.9

Effects of rice harvesting time

When time of harvesting was delayed to 45 days after flowering 75%, broken rice increased greatly up to 42% in DS2014-15 and 47% in 2015-16, while head rice decreased sharply up to 13% and 8% respective, even drying by flatbed dryer (Table 9). Highest head rice returned of 48% was found when paddy was harvested at 25 days after flowering 75% and dried in flatbed dryer, and when paddy was dried under sun drying head rice returned reduced to 32%. When paddy harvested at 35 days after flowering 75% and dried in flatbed dryer, head rice return reduced to 35%, and 29% under sun drying.

Table 9. Time of harvesting and mean milling quality in DS2014-15 and DS2015-16 for paddy dried in flatbed dryer and the sun

Flatbed dry				
	% brown rice	% milled rice	% head rice	% broken rice
25 DAF	76	60	48	12
35 DAF	76	60	35	25
45 DAF	74	54	13	42
Sun dry				
	% brown rice	% milled rice	% head rice	% broken rice
25 DAF	76	59	32	26
35 DAF	77	60	29	31
45 DAF	75	55	8	47

CONCLUSION

Development of new varieties for direct seeding

Variety suitable for direct seeding in the wet season should possess photoperiod sensitivity, flowering in early October to avoid rainfall at harvest time, as direct seeding needs to plant in May before rain comes. In addition, variety should be tolerant of flood, resistant to blast disease, and have good milling quality, good eating quality and also aroma flavor to meet market requirement. Therefore, promotion of XBF4 (RGD10033-77-MAS-438-46) should be done to ensure farmer will have an access to this variety for future production.

Drill and Transplanter

One potential factor that’s affecting grain yield is rather wide rows used for transplanter and this may be a disadvantage for transplanter planted crops particularly during the dry season (DS), when hand transplanted crop has rather narrow row spacing. The use of transplanter needs to be assessed carefully particularly as farmers use young seedlings. They are prone to submergence damage, and hence the transplanter should be avoided in low lying areas where flood is likely to be a problem and also avoid areas where golden apple snail is a problem. Seed tray is an important component of transplanter technology, about 200-220 trays would be required per hectare for establishing a crop with sufficient plant density.

Seed drill appears promising as long as the planting condition is favorable for the drill planting. This was achieved by innovative farmers positively engaging in the use of seed drill, and they often have become contractors and they extended the use of technologies to other smallholders in the nearby villages. The areas drills are spreading have more sandy soils and early planting of rice using drill is an advantage, especially in flood prone plain. However, this planting technique requires of using photoperiod sensitive varieties that flower in early October, as the crop with photoperiod insensitivity such as TDK8, a commercial variety may mature too early in early October, and this could possibly cause a problem particularly if harvested by combine and rain falls at the time of harvesting.

Paddy size and other factors affecting combined harvesting efficiency

Optimum paddy field size for maximum combined efficiency appears to be around 2,000-3,000 m^2 and paddies could be amalgamated to this size for improved combined harvesting efficiency. The advantage of larger field size may also apply to other field operations such as land preparation and mechanized planting and this advantage for different operations may be examined in the future. In addition, farmers in our villages believe water is saved with enlarged fields, perhaps also as a result of land leveling. Water management time may be reduced with the reduction in the number of levees. Combined adoption depends on the decision by at least three different groups (farmers, millers and combined contractor). A mechanism is required to ensure that all bodies involved in combined harvesting will work together for the common goal of development of mechanized rice production so that all bodies will get benefit in a longer term. The combined contracting business appears profitable, and further development of the business is encouraged. The current combined contracting fees in Laos are expensive partly because of short term credit the contractor has signed on and increasing credit term will assist lowering fees, hence further promoting adoption of combined harvesting. There is strong link between the farmer adoption of combined harvesting and availability of facilities to dry paddies, and for the adoption of combine harvester we need to ensure the paddies harvested can be dried properly.

Effects of drying and grain quality evaluation

Highest mean head rice returned was 44.5%, if paddy was dry under flatbed dryer which was higher than mean head rice under sun drying of 37.9%. This indicates that paddy needs to be dried under artificial dryer to achieve higher head rice return and hence net profit. However the higher head rice percentage may be obtained if sun drying was done in the morning only from 8 am to 1 pm, but it would take three days for drying to reduce moisture content to 14%. Improvement in techniques in both drying methods could reduce broken rice percentage.

Effects of rice harvesting time

Time of harvesting is a main factor affecting head rice return, and when harvesting was delayed to 45 days after 75% flowering, broken rice increased greatly and head rice decreased sharply. The optimum time for harvesting is 25 and 35 days after 75% flowering to achieve maximum head rice return. In addition, flatbed dryer has increased head rice return after milling compared with Sun drying. Therefore, optimum time of harvesting with proper drying techniques could increase head rice return and can meet the requirement of white rice market in local and international market.

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