

# Genetic resources management of local tidal rice in Riau province

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**Abstract.** There are at least 19 major groups of local tidal rice cultivars distributed in Pelalawan District which were not pure. This study aimed to report the progress of collaboration research among Riau AIAT, Pelalawan District Government and farmers has developed *in situ* and *ex situ* conservation of the local tidal rice cultivars from the year 2007 to 2018. Positive mass selection in Karya population has resulted in KN1-79 line with a yield potential of 6.74 t/ha dry milled grain (DMG), whereas in Cekau population has resulted in C1/KB line with a yield potential of 8.60 t/ha DMG. KN1-79 and C1/KB line have been released as Karya Pelalawan variety and Cekau Pelalawan variety, respectively. Both varieties have been registered by Center of Plant Variety Protection. The drawback of these local cultivars is late in maturity. Karya Pelalawan was crossed to Fatmawati and produced varieties Bono Pelalawan and Mendol Pelalawan which have early maturity character. Cekau 34 was crossed with Cisantana and produced Inpara Pelalawan with new characters such as early maturing, aromatic grain and tolerant to iron toxicity and salinity. Participatory plant breeding has promoted the released varieties to be widely and rapidly distributed as well as easily accepted by farmers. By promoting the ownership of local cultivars to the local government, local cultivars could be as a regional identity. Thus, it has been shown that Pelalawan District Government was actively involved in the development of released cultivars derived from local rice cultivars.

Keywords: genetic resources, genotype, local rice, tidal, participatory plant breeding.

## 1. Introduction

The decrease in land area for food crops due to land conversion to non agricultural purposes and the low productivity in Riau Province has become a strategic issue nowadays and in the future. Along with the conversion of land functions, local genetic resources of food crops from growing centers are also lost. The Government of Pelalawan District in Riau Province anticipates the decrease in rice production by prioritizing the increase in rice productivity and self-sufficient of rice seeds. Local government efforts to support food self-sufficiency include: (1) establishing rice development areas, (2) purifying and developing local cultivars with high yielding ability, (3) developing local-specific



early maturing lines to increase cropping indexes (CI), (4) developing seed production systems and foster breeders, and (5) establishing food crop management units to conserve genetic resources and produce quality seeds.

About 80,000 ha of tidal rice fields in Riau Province are planted with diverse tidal rice cultivars. Two popular cultivars, Cekau and Karya, which were found in Pelalawan District and released in 2011, are grown once a year. In general, the limitation of once-a-year crops in tidal land is caused by land and climate constraints.

Some of the local varieties have good taste and rice quality according to the local preferences. Local varieties are known to have several important traits for rice improvements such as tolerance to biotic stresses (pests and diseases) and abiotic stresses (flood, drought, Al- and Fe- toxicity, high temperatures and salinity). These traits are only a few positive traits presence in the local varieties. Therefore, the use of local varieties as gene donors in breeding program is highly recommended in order to get superior genes that are local specific and to expand the genetic background of the new developed varieties.

Early maturing and high yielding varieties can change the tidal rice farming system in Riau Province which is dominated by CI 100 to CI 200. One planting season for local cultivars takes 6–7 months, which is expected could be replaced by new early maturing varieties.

To improve the character of local tidal rice and conserve the genetic resources of rice, the Riau Assessment Institute of Agricultural Technology (AIAT) and the Pelalawan Regency Government have carried out the purification of local cultivars and a breeding program. This study aimed to report the progress of research collaboration between Riau AIAT with the local government in the management and development of rice local genetic resources from 2007–2018.

## **2. Materials and methods**

The research was carried out in 2007–2018 in Pelalawan District. A survey was first conducted to record the distribution of local cultivars. All types of rice grown by farmers were collected, observed and purified. Thirty local tidal rice cultivars obtained from the survey were selected and sown in the following experiments.

Seedlings at 21-day-old after sowing were transplanted at a distance of 20 cm × 20 cm with one seedling per planting hole. Basic fertilizers (200 kg/ha urea, 100 kg/ha TSP and 100 kg/ha KCl) were applied at 3 days after transplanting (DAT). The first supplementary fertilizer (50 kg/ha urea and 50 kg/ha KCl) was applied at 30 DAT and the second (50 kg/ha urea) was applied at 60 DAT. Pesticide and herbicide were applied as necessary using the recommended procedures.

Varietal purification was done in the first planting season by positive mass selection method. Panicles from selected rice clumps were advanced in the second planting season by planting one panicle per row. Negative mass selection was applied to these crops. Selected families from these plants were advanced to the next cropping season for seed multiplication.

Two local cultivars (Cekau and Karya), a new plant type variety Fatmawati and a national variety Cisantana were used in cross breeding. Single crosses between Karya × Fatmawati and Cekau × Cisantana were made. The offsprings of these crosses were selected using the pedigree method. One seed of each line was sown per planting hole at a distance of 20 cm × 20 cm. Plants were fertilized with 250 kg/ha urea, 100 kg/ha TSP and 100 kg/ha KCl. The variables observed were plant height, plant age, number of productive tillers, number of filled grains per panicle, number of empty grains per panicle, 1,000-grain weight, yield potential, percentage of broken rice husk composition, percentage of amylose content, resistance to pests and disease and tolerance to iron toxicity and salinity. Resistance to brown planthopper was evaluated based on the Standard Evaluation System (SES) of IRRI [1]. Plant responses to bacterial leaf blight disease were assessed based on the proportion of infected leaf area to the total leaf area according to the SES of IRRI [1]. Analysis of broken rice rendement was done according to SES of IRRI [1].

Evaluation of iron toxicity tolerance was carried out at Taman Bogo Experimental Station, East Lampung, Lampung, from June to September 2016. The land used for the trial was a rice field with

high Fe content (300–400 ppm). Mahsuri and IR64 were planted as tolerant variety and sensitive check, respectively. Seeds were sown until 21-day-old and then transplanted. One seedling of each line or variety was planted in 5-m rows at a planting distance of 20 cm × 20 cm. Fertilizers were applied twice: the first was at planting time with 75 kg/ha of urea, 100 kg/ha of TSP and 100 kg/ha of KCl; the second was at 4 weeks after planting with 75 kg/ha of urea. Iron toxicity tolerance was assessed using the SES of IRRRI [1].

Salinity tolerance was evaluated by using hydroponic media (Yoshida solution) containing 120 mM NaCl or Electrical Conductivity (EC) + 11 dS/m. The SES of IRRRI [1] was used for evaluation of salinity tolerance. While the process of purification, crossing and testing of lines was carried out in a participatory manner by involving farmers, local government, Riau AIAT and Institution for Seed Certification. Conservation of the genetic resources is carried out both *in situ* and *ex situ*.

### 3. Results and discussion

#### 3.1. Collection, characterization, and purification of local rice varieties

For decades, new national varieties have not been developed. To date, the dominant cultivars grown by farmers are local variety Cekau and Karya. There were 30 cultivars that have been characterized, of which ten are cultivars grown by farmers until 2018 (Table 1). The remaining 20 cultivars were not found during the survey but were still collected at the Indonesian Center for Rice Research (ICRR) and Riau AIAT. These 30 cultivars can be categorized into 19 main groups.

**Table 1.** Partial list of local cultivars recorded in rice planting areas in Pelalawan District during a survey in 2006 to 2012.

Name	Age (month)	1,000-grain weight (g)	Yield (t/ha)	Planting area (ha)									
				2006	2007	2008	2009	2010	2011	2012			
				S1	S1	S2	S1	S2	S1	S2	S1	S1	S1
Pulau Kijang	5	24.2	2.5	7	1	13	-	-	-	-	-	6	11
Sardani	4	23.3	3.3	2	1	-	-	-	-	-	-	50	60
Pulut Belanda	5	25.7	3.1	5	5	5	-	15	-	15	-	5	4
Pulut Hitam	6	24.5	2.8	13	17	20	-	20	-	20	-	20	30
Lembuk Sawah	4.5	22.0	3.1	30	10	20	-	34	-	26	-	21	14
Pasir	5	26.4	3.0	30	20	20	-	6	-	6	-	11	8
Cekau	5	24.5	3.8	3.5	3.5	3.7	-	4	-	4	-	4	4
Ketek Putih	6	23.3	3.5	20	50	50	-	27	-	33	-	29	25
Karya Rendah	5	20.7	2.7	200	200	200	-	200	-	200	-	100	100
Karya	4.5	23.1	2.8	4	4	4	-	4.5	-	4.5	-	1.5	1.5

S1 = planting season 1, S2 = planting season 2, - = data not available.

New high yielding varieties is favored by farmers in less than ten years after introduction because purified local varieties have gained popularity and shifted many local varieties. According to Oko et al. [2], new varieties should not replace local cultivars because most local cultivars have several advantages. Natural selection has formed local cultivars to have ecological adaptation and thus it may have more advantages than cultivars which are artificially selected by human. Therefore, farmers must be critical in accepting new varieties that may not be holistically comparable.

### 3.2. Purification of Karya and Cekau cultivars

Tidal rice farming in Riau Province is still dominated by late maturing local varieties which permit only once a year planting season. These local varieties have low to medium productivity and usually comprised of mixed lines. The survey carried out in 2007 had collected 30 types of rice in Pelalawan District. All of these local rice were not pure. The highest impurity was found in Karya and Cekau cultivars with an impurity rate of 78% and 57%, respectively. The level of line mixture in Karya and Cekau were characterized based on the yield and several criteria of phenotypic traits such as stem, flag leaves and tolerance to diseases. Karya cultivar was found to be more heterogenous than Cekau cultivar. It was consisted of 20 different lines, of which 50, 15.4 and 34.6% were worse than, almost equally the same as, and better than Karya in performance, respectively. An equal rate of lines with worse and better performance than Cekau was observed within this population.

**Table 2.** Agronomic performances of ten lines selected and purified from Karya cultivar.

Genotype	Plant height (cm)	Number of productive tillers	1,000-grain weight (g)	Number of filled grains/ panicles	Number of empty grains/ panicles	Yield (t/ha)
Karya (original population)	167	9	20.45	125	45	3.50
K5	140	11	17.62	255	45	6.18
K5K	148	13	20.42	264	41	7.86
K3A	160	9	22.61	185	15	4.72
KB	166	6	17.80	102	33	1.36
KG	160	9	23.97	201	77	5.42
KM	140	17	21.17	115	14	7.12
KN	170	14	19.46	168	30	5.73
KP	170	13	25.22	156	22	6.42
KR	162	5	19.53	78	33	0.95
KN1	160	13	24.51	169	45	6.74

Impure varieties that have been planted for decades can result in high genetic variability. Significant differences in several characters among cultivars generate high genetic variability [3]. Ten selected genotypes derived from 25 genotypes which are purified from Karya cultivar are presented in Table 2. Five genotypes, namely K5, K5K, KM, KP and KN1 had higher yield potential (>6 t/ha) than the original Karya (3.5 t/ha). Similarly, the selection from Cekau population resulted in three potentially high-yielding genotypes, namely C1/KB, C3/KB and NN1 with a yield potential of 8.60, 7.19 and 8.54 t/ha, respectively (Table 3).

According to Fujino et al. [4], repeated planting of local varieties in unique environmental conditions will produce information on their potential genetic and will be useful as genetic resources in local breeding programs. Selection in diverse local cultivars is based on high yield potential. According to Oladosu et al. [5], differences in the yield character play an important role in the development of rice varieties.

### 3.3. Crossing of local rice cultivars

One of the obstacles in the rice farming in tidal land is the difficulty in increasing CI due to the narrow planting season, which is largely affected by rainfall and pest infestation. Regular planting season takes place 7 months from August to February (7 months), and hence late maturing local varieties (6–7

months) are planted. One strategy to increase CI is to grow early maturing varieties so that the planting season can be carried out twice within 7 months.

**Table 3.** Characters of eight lines selected and purified from Cekow cultivar.

Genotype	Height (cm)	Number of productive tillers	1,000-grain weight (g)	Number of filled grains/panicles	Number of empty grains (panicles)	Yield (t/ha)
Cekau (origin population)	167	10	23.24	198	26	4.20
C/KB	134	11	26.44	100	12	3.64
C1/KB	142	12	31.87	180	35	8.60
C3/KB	149	12	23.99	200	41	7.19
C5/KB	123	7	22.77	76	17	1.51
C6/KB	145	9	29.62	189	32	6.29
C7/KB	141	10	23.98	120	14	3.59
C8/KB	142	6	28.68	114	29	2.46
NN1	167	12	23.03	247	51	8.54

The purposes of the crosses of Pelalawan's local rice cultivars to national released varieties were to shorten the maturity of local rice, increase its productivity without changing too much the good characteristics and the rice taste already preferred by farmers and local consumers. Two crosses were made, i.e. Karya  $\times$  Fatmawati and Cekau  $\times$  Cisantana. Fatmawati is a new plant type (NPT) which has a big panicle and high 1,000-grain weight (30.6 g) [6]. According to Khush [7], NPT of rice have compact growth, 8 to 10 productive tillers, large panicles with 200 to 250 filled grains, medium height (semi-dwarf) and upright, have thick leaves with dark green color, deep roots, early maturing and resistant to pests/diseases. In addition, Peng et al. [8] stated that NPT must have few number of tillers but almost every of it are productive, plant height of 90–100 cm, age of 100–130 days, and also thick and strong stems. The cross of Karya  $\times$  Fatmawati produced Bono Pelalawan and Mendol Pelalawan varieties, whereas the cross of Cekau  $\times$  Cisantana produced Inpara Pelalawan. Bono Pelalawan variety inherits several characters of Fatmawati such as upright and broad leaves, large panicles, high number of productive tillers (10–12) and big grains (Table 4).

Bono Pelalawan, Inpara Pelalawan and Mendol Pelalawan have been released by the Ministry of Agriculture of Indonesia in 2017. The three varieties represent the majority of consumers' preferences in Indonesia. According to Custodio et al. [9], rice breeding programs must pay attention to farmers' preferences such as tenderness in Southeast Asia and slenderness in South Asia, when considering specific preferences. The results of the crosses showed a gain of advantage in the quality of rice and resistance to salinity stress. These results indicate that breeding practices have created new genetic structures for adaptability to specific environmental conditions and breeding goals [10].

**Table 4.** Description of three new varieties produced from local genetic resources.

Parameter	Mendol Pelalawan	Inpara Pelalawan	Bono Pelalawan
Origin of cross	Karya/Fatmawati	Cekau 34/Cisantana	Karya/Fatmawati
Plant age (day)	100	105	106
Plant height (cm)	129	116	139
Number of filled grains per panicle	264	280	275
Number of productive tillers	14	12	12
Flag	Somewhat erect	Erect	Erect
Yield potential (t/ha)	8.0	8.20	7.9
Yield average (t/ha)	7.30	7.45	7.3
1,000-grain weight (g)	25.4	27.4	27.6
Rice texture	Glutinous	Non-glutinous	Glutinous
Broken rice husk composition (%)	77.64	79.93	76.56
Amylose content (%)	19.25	25.25	19.22
Other information	Suitable for planting in tidal land types of overflow B and C	Tolerant to Fe (iron) poisoning and salinity	Rather tolerant to Fe (iron) poisoning and salinity

### 3.4. Participatory plant breeding with locality government and farmers

The low commitment of local government and the change in policies during the period of regional autonomy have constrained the development of food crops in Indonesia. Therefore, local governments must be persuaded to manage their genetic resources and their successful stories in this effort can be a good model for other local governments. Pelalawan Regional Government has given serious attention to the development of food crops and the conservation of plant genetic resources by financing various research activities. These activities included purification of local varieties, development of a new variety through crossing schemes, releasing varieties and conserving genetic resources.

The success of research activities depends on the willingness and readiness of the local government. While most local governments only make use varieties that are provided or produced by national commodity research centers, the Pelalawan District government took more initiatives by developing own varieties and conserving the genetic resources presence in the region. Several strategies were implemented to stimulate the interest of the local government in the use and conservation of their genetic resources, i.e. (1) introducing the superiority and the weakness of their local cultivars, (2) informing the benefits obtained through improving genetic character of local cultivars, (3) informing the opportunities and limiting factors in the rice farming system in the region, (4) informing the research activity progress on regular basis, and (5) increasing their awareness and enthusiasm in the research activities.

Participatory plant breeding can increase the enthusiasm of farmers and local government in breeding process although it can take several years. Through participatory plant breeding, the sense of belonging and sense of responsibility to conserve and developing the lines and varieties they create can be expected. Farmers and Agriculture Service Staff in Pelalawan were actively involved in the selection process of the lines.

Plant breeding programs need to involve a variety of stakeholders in capturing the variety with desired characters in the process of the development of varieties. In participatory plant breeding,

adoption begins during the selection process before the release of varieties. Another difference between participatory breeding programs and conventional breeding is the increase in agrobiodiversity. Biodiversity is higher in the former program because of the rapid changes in the varietal testing locations and the seed accessibility of the new varieties to farmers, which in turn can contribute significantly to food security [11].

Varieties tested in experimental field without involving farmers as partners in evaluating varieties may lead to low adoption rate of varieties. Farmers are the end-users of various varieties produced so that the decisions by farmers when assessing varieties must be considered. By doing so, the selection process is more effective and adoption soon expands [12].

### 3.5. Fostering seed breeders and development of breeder seeds

The use of high-quality seeds is the initial stage of successful farming. In 2008–2011, one farmer group has been fostered as a seed breeder. Since 2013, the farmer group has developed and distributed candidates of varieties among the members. The breeder seed development program was a collaboration project among breeders, local government and institution for Seed Certification (Table 5). In 2017–2018, there were two active farmer groups that breed local varieties and their essential derivatives with the support from the local government.

**Table 5.** Breeder seed development programs.

Executor	Activity	Responsibility
Breeder Seed Technical Implementation Unit (UPBS) and seed breeder	Producing nucleus seeds (NS) and breeder seeds (BS); planting BS, foundation seed (FS), stock seed (SS), and extension seed (ES)	Collaborating with the Seed Certification Center and Riau AIAT
Farmers	Planting ES to produce rice	Dealing with rice traders

To support the program of developing high-yielding variety seeds and conserving genetic resources, the Government of Pelalawan District established a Seed Technical Implementation Unit in Mendol Island. Thus, the need for seeds for agriculture on remote islands can be met.

In 2017, the breeder seeds (BS) produced through crossing varieties were planted in 2-ha rice field and in 2018 foundation seeds (FS) were planted in 40 ha rice field. In addition to being reproduced and conserved in their origin (*in situ*), local varieties and new developed varieties were also planted in farmers' rice field in Siak and Meranti Islands District (*ex situ*). *Ex situ* conservation usually involves breeders and cooperative farmers or research partners. Some breeders provide some of their rice fields to be used for growing local rice genetic resources.

*Ex situ* conservation have been proved to stimulate the adoption of varieties by local farmers. Farmers who are interested in varieties at *ex situ* conservation sites have selected several varieties and developed them independently. The most widely adopted varieties are Inpara Pelalawan, Karya Pelalawan, Cekau Pelalawan and Bono Pelalawan. Zhu et al. [13] stated that *in situ* conservation is an important complement to the *ex situ* conservation of local varieties. Management of mixed cropping (intercropping) of traditional and hybrid rice varieties in China has dramatically increased the cultivation of traditional rice varieties [13].

## 4. Conclusions

Selection and purification of two local rice varieties Cekau Pelalawan and Karya Pelalawan has resulted in new variety Bono Pelalawan, Mendol Pelalawan and Inpara Pelalawan. Pelalawan District Government has been actively involved in the development of those released cultivars and also collaborated with Riau AIAT in the *in situ* and *ex situ* conservations of local rice genetic resources. Participatory plant breeding program involving local government and farmers has stimulated rapid distribution and adoption of released varieties by farmers. Among the strategies implemented to raise

the interest of local government in funding the research activities were suggesting the local government to obtain the ownership rights of local cultivars and make them as the regional identity, informing the progress of research activities periodically and highlighting the advantages of the research results.

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