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Progress of Rice Improvement through Recurrent Selection

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ABSTRACT

Improved rice varieties play an important role in increasing rice production, through raising and/or stabilizing rice productivity. Thus, it is urgent to develop improved rice varieties. Selection method is an important step in rice improvement. Implementation of recurrent selection in rice improvement was aimed to increase the efficiency and insurance in the success of improvement. Since 2004, Indonesian Institute for Rice Research has applied recurrent selection in breeding program. Promising lines of earliness and high yield potential were developed in relatively short time. A number of advanced lines has been produced and will be further evaluated, and a number of populations has been selected and used as base populations for recurrent selection in rice improvement program.

Key words: breeding, earliness, high yield rice, improvement

INTRODUCTION

To increase rice production, four important inputs are needed, e.g. water, fertilizer, pest control and improved variety (Poehlman, 1987). The first three: water, fertilizer and pest control relate with cultural practices that provide more suitable environment in which rice grows. The fourth, rice variety relates with inherent ability of the rice plant to produce within the environment provided. In other words, more productive plants and greater rice production can be achieved by improving the environment for rice growth and the heredity of the rice crop, but the use of improved varieties has the advantages because it is simple and minimize the environmental hazard.

Improved rice varieties play an important role in increasing rice production. Variety itself could contribute 5% of increasing of rice production, while irrigation and fertilizer contribute 16% and 4%, respectively. In combination of variety, irigation and fertilizer could contribute 75% of increasing of rice production (Fagi *et al*., 2003). World rice production increased from 257 million tons in 1966 to 560 million tons in 1990 due to the large scale adoption of high-yield semi-dwarf varieties such as IR8 and IR5 (Khush, 1995a) and rice production of Indonesia and Vietnam doubled (Khush, 1995b). The first self-sufficient of Indonesia in rice in 1984, was due to the wide spread of adoption of semi-dwarf high yielding rice varieties, such as IR8, IR5, Pelita I-1 and Cisadane (IBS, 1985). Increasing of rice production at about 5% in 2007-2008 was also the results of adoption of high yielding varieties, such as Ciherang, Cigeulis and Memberamo (Indonesian Ministry of Agriculture, 2009).

Methods of selection usually applied in rice breeding in Indonesia are pedigree, bulk and a modified bulk-pedigree. These methods depend on the natural accumulation of desired characters from the parents into a plant/line. Recurrent selection is systematic selection of desirable plants from a population followed by recombination of the selected plants to form a new better population (Fehr, 1987). This method provides opportunity to breeders to accumulate the desired characters into a plant or line through repeated crosses/hybridization among selected plants. Therefore, the method is more effective to develop rice with desired characters, such as high yielding varieties. This paper reported the progress of application of recurrent selection in rice improvement in Indonesia.

MATERIALS AND METHODS

Since 2004, a number of populations were selected to be used as base populations for recurrent selections. A thousand plants per populations were planted in distance space of 25 cm x 25 cm. Populations were observed for their performance in agronomic characters. Some populations that showing good segregations in plant type were selected to be used as base populations. Selected plants among the populations that having good agronomic characters were selected crossed to each other as shown in Figure 1. This procedure was

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repeatedly done until the populations having plants with desired characters to be selected. The selected plants then planted and evaluated at pedigree nurseries for performance agronomic characters, such as yield, earliness etc.

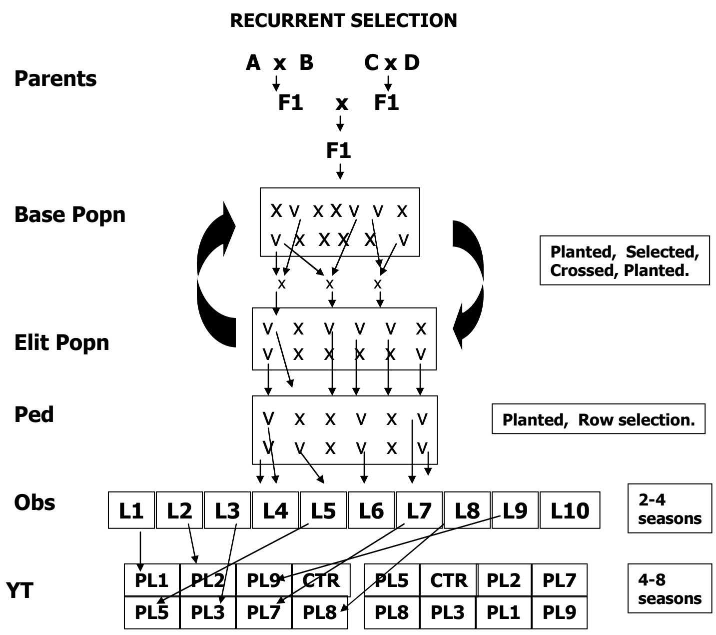

Figure 1. Recurrent Selection

RESULTS AND DISCUSSIONS

Earliness Promising Lines

Selection was practiced by our ancestors when they started domestication of such crops, thousand years BC. Selection is now one of the steps in crop improvement program. Therefore, it plays an important role in the success of crop improvement. In rice improvement, pedigree and bulk methods are usually practiced. Back cross method is practiced when breeders want to improved one character that is controlled by simple gene. Recurrent selection is a method of selection that is usually practiced to cross-pollinated crops, such as maize. This method is defined as the systematic selection of desirable individuals from a population followed by recombination of the selected individuals to form a new population (Fehr, 1987). By practicing recurrent selection, breeders are able to accumulate the desired characters from segregating plants. It is impossible pedigree or bulk methods. Therefore, recurrent selection is more useful to be practiced in crop improvement for high yield, or other characters that are controlled by polygenic genes.

Earliness is an important objective in rice improvement. Rice cultivars with early maturity are needed by farmers to be grown in rain-fed areas. A population of B11742, a backcross of BP360E-MR-79-PN-2 as recurrent parent and IR71218-39-3-2-MR-14, was selected as base population. BP360E-MR-79-PN-2 was an Indonesian new plant type (NPT) line and IR71218-39-3-2-MR-14, an IRRI NPT line, both matured at 125 -130 days. Plants having agronomic characters were selected and crossed to each others to produced improved population, in two cycles. Therefore, population produced from first cycle was coded as B11742-RS*^{1} and the second cycle as B11742-RS*^{2}. Selected plants from second cycle population were planted at pedigree nursery. A numbers of plants are identified at heading date, around 2 months after sowing, thus those plants are categorized as very early maturity. More than 50 plants/lines with good agronomic characters were selected and reevaluated in three successive seasons. Thirty two lines were selected and evaluated in observation trial for their homogenity and yield potential, and 7 very early maturity lines were selected. Those lines are now being evaluated in multi-location trials for their yield potential and adaptation. Seven very early maturity promising lines, matured at about 100 days after sowing (DAS) were developed in 5 generations after the second cycles of recurrent selection (Table 1). It meants that improvement for earliness through recurrent selection was completed within about 5 years. The lines that mature at about 100 DAS are relatively same with very early improved varieties (Dodokan and Silugonggo), but 25-30 days earlier than that of the parents. It is difficult to be accomplished through other methods, such as pedigree or bulk. Earliness is controlled by a recessive gene, therefore, by recombining the gene through recurrent selection give chance to get plants with homozygous genes for earliness. Sumarno and Fehr (1982) reported that there was no consistent change in maturity caused by recurrent selection for yield in soybean. The lines had more grain number per panicle than Dodokan and Silugonggo, while tiller number and grain weight is relatively same (Table 1). Therefore, the lines would have higher yield potential than that of the two varieties. The agronomic and grain characters of the seven very early maturity of rice are shown in Table 1.

Table 1. Very early lines bred through recurrent selection 2009

Line/Variety	Agronomic characters						Grain characters		
	Plant height	Maturity	Number of		1000 grain	Amil. Cont.	Length	Shape	Chalkiness
	(cm)	(d)	tiller	grain	(g)	(%)	*	**	***
B11742-RS*2-3-MR-34-1-1-3	80	100	18	156	26	26	L	Sl	Sm
B11742-RS*2-3-MR-34-1-1-4	80	100	18	131	26	24	L	Sl	Sm
B11742-RS*2-3-MR-34-1-1-5	80	100	20	136	25	24	L	Sl	Sm
B11742-RS*2-3-MR-34-1-2-1	80	100	20	149	26	24	L	Sl	Sm
B11742-RS*2-3-MR-34-1-2-3	80	100	18	150	25	25	L	Sl	Sm
B11742-RS*2-3-MR-34-1-4-1	80	100	22	138	26	24	L	Sl	Sm
B11742-RS*2-3-MR-34-1-4-3	80	100	20	143	25	24	L	Sl	Sm
Dodokan (Variety)	80	100	16	120	27	26	L	Sl	Sm
Silungonggo (Variety)	80	100	20	115	26	24	L	Sl	Sm

Notes: * L = long; ** S = slender; *** Sm = small

High Yield Promising Lines

Yield is the most important objective in crop improvement. There are three yield components in rice, e.g., number of tiller, number of fertile grain per tiller, weight of grain. This means that yield is composed of many characters and each character is controlled by many genes (polygenic). A population derived from a backcross of an Indonesian semi NPT variety, Gilirang as recurrent parent and a promising line, BP342F-MR-1-3 showed good segregating materials with good agronomic characteristics. Therefore, this population was selected as base population and coded as B11738. Plants having good agronomic characters were selected and crossed to each others to produce improved population in two cycles. Population produced from first cycle was coded as B11738-RS*^{1}. However, 3 populations produced from the second cycle were coded as B11953, B11954 and B11955 instead of B11738-R*^{2}.

Four promising lines with good yield component characters have been developed (Table 2). The lines were achieved in 3 generations after second cycle of recurrent selection. It means that accumulation of many desired characters related with rice yield improvement through recurrent selection could be achieved in a short time. Tiller number of the developed lines was higher than Fatmawati (NPT variety) but the same as Ciherang (improved popular variety), while number of grain per panicle was relatively same as Fatmawati, but doubled of Ciherang. Plant height and maturity of the developed lines were relatively same as Fatmawati and Ciherang. Significant increase in yield of each cycle of recurrent selection in soybean improvement has reported by Sumarno and Fehr (1982).

Segregating plants with agronomic characters were selected and planted at pedigree nursery. A hundred lines were evaluated and selected for their homogeneity and yield potential at observation yield trial. Four promising lines showed better yield than the control varieties (Fatmawati and Ciherang) at the Primary Yield Trials (PYTs) and selected to be evaluated for their yield and adaptation at Advanced Yield Trials (AYTs) in 2009. The agronomic and grain characters of the four lines are shown in Table 2.

Table 2. High yield lines bred through recurrent selection 2009

Line/Variety	Agronomic characters					Grain characters			
	Plant height	Maturity	Number of		1000 grain	Amil. Cont.	Length	Shape	Chalkiness
	(cm)	(d)	tiller	grain	(g)	(%)	*	**	***
B11953-MR-23-1-4	106	108	11	249	26	24	L	M	M
B11954-MR-21-1-1	112	106	10	225	24	19	L	S	S
B11955-MR-84-1-4	99	110	13	260	26	20	L	M	S
B11955-MR-66-2-5	98	105	12	225	24	21	L	M	M
Fatmawati	106	105	9	250	28	23	L	M	M
Ciherang	97	109	13	132	24	24	L	L	S

Notes: * L = long; ** S = slender; *** Sm = small

The development of very early maturity and high yield line in relatively shorter time through recurrent selection proved that this method was more efficient and promising in rice improvement. A number of advanced lines have been developed for further evaluation. A number of populations had also been selected as base populations of recurrent selection. Recurrent selection alternating with haploid steps was reported as a rapid breeding procedure for combining agronomic traits in barley (Foroughi-Wehr and Wenzel, 1990). Combination of recurrent selection with anther culture was reported to increase the speed of development of NPT line of rice (Abdullah *et al.,* 2008).

Forty four advanced lines from three crosses, e.g., B11738, B11742 and B11957 with high yield potentials characters were also selected from the observation yield trials and now being evaluated at PYT in 2009 (Table 3). A number of 65 homogeneous lines with good characters for yield were selected from pedigree nursery and then to be evaluated for their homogeneity and yield potential at observation yield trial in 2009 (Table 4). Those lines consisted of 8 lines produced from recurrent selection RS cycle 1 (RS^{*1}), 18 lines from RS^{*2}, and 39 lines from RS^{*3}, and were derived from 5 crosses, e.g., B11738, B11742, B11998, B12010 and B12238.

More than twenty cross combinations are now being used as base population in rice improvement through recurrent selection program. The base populations consisted of multiple crosses with more than 4 parents of each cross and many objectives, examples are shown at Table 5.

Table 3. Selected homogeneous lines of recurrent selection program from observation trial to be evaluated at preliminary yield trials 2009

Cross no.	Cross combination	Number		
		RS*1	RS*2	RS*3
B11738	Gilirang/BP342F//Gilirang	0	0	19
B11742	BP360E-MR-79-PN-2/IR71218-39-3-2-MR-14//BP360E-MR-79-PN-2	0	6	0
B11957	Cimelati*2/IR71218-39-3-2-MR-14 Gilirang*2/BP342F	7	12	0
Total		7	18	19

Notes: RS*1, RS*2, and RS*3 = Recurrent selection cycle 1, 2, and 3

Table 4. Selected homogeneous lines of recurrent selection program from Pedigree Nursery to be further evaluated at observation yield trial 2009

Cross no.	Cross combination	Number		
		RS*1	RS*2	RS*3
B11738	Gilirang/BP342F//Gilirang		17	19
B11742	BP360E-MR-79-PN-2/IR71218-39-3-2-MR-14//BP360E-MR-79-PN-2		1	20
B11998	Fatmawati*2/Klemas/BP140F///BP140F/Pucuk//BP140F////BP140/// BP140F/T. Unda//BP140F	5	0	0
B12010	BP140F///BP140F/ Pucuk// BP140F////BP140F/T.Unda// BP140F/////B11445E-PN-2	1	0	0
B12238	Ciapus/B10384// Ciapus/// BP140F/Angke//IR71218/// B10386/T.Petanu// Ciapus////// BP140F///BP140F/Pucuk// BP140F//// BP140F/T.Unda//BP140F	2	0	0
	Total	8	18	39

Notes: RS*1, RS*2, and RS*3 = Recurrent selection cycle 1, 2, and 3

Table 5. Cross combinations used in recurrent selection program, 2009

Cross no.	Cross combination	Objectives
B12238	Ciapus/B10384//Ciapus/// BP140F/Angke//IR71218///B10386/T.Petanu// Ciapus/////BP140F///BP140F/Pucuk// BP140F////BP140F/T.Unda//BP140F	Yield., grain quality, RTV, BLB
B12509	B11742-RS*3-4-1 /4/Klemas / IR71190 // Lampung Pulen / Bio12-26 /3/ Cisantana / B10590 // NH124-24 / HSPR	Yieldd, arliness., Bl, BPH, grain quality, aroamtic
B12689	BISH I-MR-160-4-LR-B39-6 /8/ B11742-RS*3-4-1 /7/ IR71190 /4/ BP360E / CODE // BP360E /3/ IR68552 / BP360E // IR68552 / 5/ BP360E-MR-79-2-PN-3 /3/ UPL-RI-17 // HAMOLICAD / TAJUM / 6/ LAMPUNG PUTIH / IR71190 // LAMPUNG PULEN / IR36	Yield, BPH, grain quality RTV, BLB, BL, earliness
B12509	B11742--RS*3-4-1/Klemas/IR71190//Lampung Pulen/Bio12-26/3/Cisantana/B10590 // NH124-24/HSPR	Earliness, grain quality, Bl, BPH
B12990	Ciherang // IR72968-65-3-1/Rojolele I /// Logawa /4/ Cimelati // IR72986-65-3-1/Rojolele I /// IR71218/IR64 // IR64	Yield, grain quality, aromatic, BPH, BLB, BL
B12995	Ciherang // IR71963-111-6-2-2-2/Rojolele I /// Pepe /4/ Code // IR71693-111-6-2-2-2/Rojolele I /// IR71033-14-17-2-PN-3-2	Yield, grain quality, aromatic, BPH, BLB, BL
B12998	BISH1-MR-160-4-LR-B-39-6 /// B11742-RS*3-2-2 // Selegreng / Batang Gadis /4/ Cimelati // IR71693-111-6-2-2-2/Rojolele I /// IR71033-14-17-2-PN-1-3	Yield, grain quality, aromatic, BPH, SB, BLB, BL
B13017	MILKY RICE / B11578E-MR-8-17 // CODE / HIBRIDA CINA /9/ BISH I-MR-160-4-LR-B39-6 /8/ B11742-RS*3-4-1 /7/ IR71190 /4/ BP360E / CODE // BP360E /3/ IR68552 / BP360E // IR68552 / 5/ BP360E-MR-79-2-PN-3 /3/ UPL-RI-17 // HAMOLICAD / TAJUM / 6/ LAMPUNG PUTIH / IR71190 // LAMPUNG PULEN / IR36	Yield, grain quality, aromatic, BPH, BLB, RTV, BL
B13022	BISH I-MR-160-4-LR-B39-6 /5/ B11742-RS*3-4-1 /4/ KLEMAS / IR71190 // LAMPUNG PULEN / BIO 12-26 /3/ CISANTANA / B10590 // NH12-92 / SINTANUR /6/ IR65482-7-216-1-2-MR-4-2-1	Yield, grain quality, aromatic, BPH, BLB, RTV, BL

Notes: BPH = brown planthopper; SB = stem borrer; BLB = bacterial leaf blight; BL = blast; RTV= rice tungro virus

CONCLUSIONS

Recurrent selection has been implemented in rice improvement in Indonesia since 2004. Promising lines of earliness and high yield potential have been developed in relatively short time. A number of advanced lines and elite populations have been developed, and populations have been identified and used as base population for recurrent selection in rice improvement program.

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