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UPLAND RICE BREEDING LINES ADAPTED TO HIGH ELEVATION AREAS SELECTED THROUGH PARTICIPATORY APPROACHES

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SUMMARY

Upland rice in Indonesia is cultivated in about 1.15 million ha comprising diverse geographical areas of low to high altitude. To this day, in the high-altitude areas, farmers still cultivate traditional rice varieties mainly due to absence of improved varieties specifically released as suitable for these areas. Breeding to improve upland rice varieties adaptable to high elevation areas has resulted in a number of promising upland rice lines with high potential for farmers'adoption. A set of 12 upland rice lines were evaluated in replicated yield trials to assess their adaptability in two sites representing different altitudes. The first experiment was conducted in Cianjur District with an elevation of 1099 meters above sea level (masl). The second experiment was carried out in Wonosobo District with an elevation of 900 masl. Two check varieties used in both experiments included a traditional rice variety Sigambiri Putih and improved variety Jatiluhur. To assess farmers' acceptance of the breeding lines, a participatory varietal selection was conducted in Wonosobo District involving 10 female and 10 male farmers. These trials demonstrated differences in agronomic characteristics and yields among genotypes grown under two different altitudes. Most of the upland rice breeding lines performed well in 900 masl site only. In contrast, the traditional variety Sigambiri Putih consistently performed well in both altitudes. In 900 masl site, the line B11592F-MR-23-2-2 yielded 3.2 t/ha and was higher than check varieties Jatiluhur (2.75 t/ha) and Sigambiri Putih (3.09 t/ha). In 1099 masl site, the highest yielding genotype was Sigambiri Putih (4.45 t/ha), while among upland rice breeding lines B12161D-MR-1-1-5 showed the highest yield (2.25 t/ha). Participatory varietal selection in Wonosobo District revealed only 4 genotypes with positive preference scores including Jatiluhur, Sigambiri Putih, B13650E-TB-80-2 and B11592F-MR-23-2-2. The line B11592F-MR-23-2-2 which has high yield and obtained positive preference score has the potential for release as a new upland rice variety for high elevation areas of up to 900 masl.

Key words: Upland rice, high elevation, participatory varietal selection

Key findings: This study identified rice breeding lines most preferred by farmers and has potential for release as new upland rice varieties suitable for high altitude areas in Indonesia. The selected lines are important genetic materials for rice breeding program particularly for high altitude areas which remains limited.

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INTRODUCTION

Rice cultivation in upland areas worldwide accounts for about 15 million hectares and contributes about 4% of the total rice production in the world (GRiSP, 2013). In Indonesia, upland rice production covers about 1.15 million hectares and contributes about 5% of the national rice production (MOA, 2013). The national productivity of upland rice in the country remains low at 3.35 t/ha (MOA, 2013). Indonesian upland rice area is mainly cultivated in marginal areas, which comprise diverse geographical areas from low to high altitude.

Breeding to improve rice varieties for upland areas has been established in Indonesia since 1970s with the main target areas were upland rice in low altitude. In contrast, improvement of upland rice varieties for high altitude in the country was just initiated in 2011. It is estimated that 2.07 million ha of upland areas in high altitude has the potential for food crop production including rice (Abdurachman *et al*., 2008). However, in the high-altitude areas, farmers still cultivate traditional rice varieties mainly due to the absence of improved varieties specifically released for the areas.

Low temperature is considered as the main constraint for rice cultivation in high altitude areas (Andaya and Mackill, 2003a; Shrestha *et al*., 2012; Sipaseuth *et al*., 2007). Cold stress inhibits rice growth during the vegetative stages (Andaya and Mackill, 2003a) and induce sterility during the reproductive stages (Shimono *et al*., 2007; Ye *et al*., 2010). Many efforts have been attempted to elucidate cold tolerant mechanism in rice and to identify QTLs underlying cold tolerance in rice for breeding purposes (Andaya and Mackill, 2003a; Andaya and Mackill, 2003b; Ye *et al*., 2010; Zhang *et al*., 2014; Zhou *et al*., 2010). Through conventional breeding program several promising breeding lines adaptable under environmental stresses in high elevation areas of Indonesia have been developed. However, the adaptability of these lines needs to be further characterized and evaluated for their performance in different locations before formal release for farmers' adoption.

The relatively limited farmers' adoption of improved upland rice varieties poses a big challenge to formal rice breeding programs. Participatory varietal selection (PVS) has been developed to overcome these problems by involving farmers in selecting breeding materials based on their preferences (Almekinders and Elings, 2001; Paris *et al*., 2011; Witcombe *et al*., 1996). In this study, PVS approaches were used to complement the evaluation of advance upland rice breeding lines in high elevation areas. The objectives of this study include identifying the promising upland rice lines adaptable in high altitude areas and analysing farmer's preferences for the upland rice breeding materials.

MATERIALS AND METHODS

Rice genotypes

Twelve genotypes of upland rice breeding lines used in this study were selected from previous yield trials during the wet season (WS) 2013-2014 in high altitude upland rice areas in North Sumatra and Central Java (Table 1). An improved upland rice variety Jatiluhur and a traditional upland rice variety Sigambiri Putih were used as check varieties.

Yield trials

Upland rice lines and check varieties were evaluated in an advance yield trials in two sites representing different altitude during wet season (WS) 2014-2015. The first experiment was located in Cipanas of Cianjur District with an elevation of 1099 meters above sea level (masl) from October 2014 to March 2015. The second experiment was carried out in Kepil of Wonosobo District with an elevation of 900 masl from November 2014 to April 2015. Monthly data of precipitation and temperatures in each location are presented in Table 2. Rice blast is the common disease in high altitude upland areas in Indonesia; however, the rice blast incidence was low during the experiment. In each location, the experiment was performed in a randomized completed block design with four replications. The rice plants were planted using direct seeding method by planting 3 to 5 rice seeds in about 2 cm depth hole and covered

Table 1. Rice genotype selected for high altitude upland rice areas.

No.	Genotypes	Parentage	Source[1)]
1	B13650E-TB-80-2	IRAT13/Asahan//B11912G-TB-2	Selected from preliminary yield trial in
2	B13650E-TB-36	IRAT13/Asahan//B11912G-TB-2	Pakpak Bharat, North Sumatra (940 masl)
3	B13604E-TB-72	Limboto/B10580E-KN-28-1-1	WS 2013-2014
4	B12165D-MR-33-3-1	Batutegi/IRAT13	Selected from observational yield trial in Pulosaren, Wonosobo, Central Java (1100 masl), WS 2013-2014
5	B13626E-TB-9-1	Lagos/B11629C-MR-1	Selected from observational yield trial in
6	B13626E-TB-7	Lagos/B11629C-MR-1	Ropoh, Wonosobo, Central Java (900
7	B11604E-TB-2-4-1-1	IR60080-23//IRBL8/IRBL23	masl), WS 2013-2014
8	B11592F-MR-23-2-2	IR60080-23/BP303	
9	B12495C-MR-69-1-9	Rantai Emas/B11592F-MR-12-3-1	
10	B12161D-MR-1-1-5	Danau Gaung/IR60080-23	
11	B14086D-TB-88	TB409B-TB-14-3/B11178G-TB-29	
12	B14086D-TB-89	TB409B-TB-14-3/B11178G-TB-29	
13	Jatiluhur		Improved upland rice variety released in 1994
14	Sigambiri Putih		Traditional upland rice variety

[1)]Suwarno et al. (2014)

Table 2. Monthly data of precipitation, average temperature, minimum and maximum temperature in Cipanas of Cianjur District and Kepil of Wonosobo District.

Climate	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Cipanas, Cianjur[1)]												
Precipitation (mm)	294	268	330	271	208	115	88	110	124	233	331	297
Average temperature (ºC)	19.6	19.7	19.9	20.1	19.9	19.6	19.1	19.4	19.7	19.9	19.9	19.7
Minimum temperature (ºC)	15	14.9	15	15.3	14.9	14.2	13.4	13.2	13.7	14.3	14.6	14.9
Maximum temperature (ºC)	24.2	24.5	24.8	24.9	25	25.1	24.9	25.6	25.8	25.6	25.3	24.6
Kepil, Wonosobo[2)]												
Precipitation (mm)	431	392	439	318	227	121	90	72	103	226	355	436
Average temperature (ºC)	23.5	23.5	23.8	24	24.2	23.7	23	23.2	23.6	24.1	23.8	23.4
Minimum temperature (ºC)	19.5	19.4	19.7	19.8	19.9	18.9	17.9	17.9	18.6	19.3	19.6	19.3
Maximum temperature (ºC)	27.5	27.7	28	28.3	28.5	28.5	28.1	28.5	28.6	28.9	28	27.5

[1)] Data source for Cipanas, Cianjur District: http://en.climate-data.org/location/601231/
[2)] Data source for Kepil, Wonosobo District: http://en.climate-data.org/location/606094/

by soil. The plants were arranged in a spacing of 30 cm × 15 cm. Fertilizers were applied to the rice plants comprising 200 kg urea (90 kg N), 100 kg SP36 (36 kg P_2O_5) and 100 kg KCl (60 kg K_2O) (IAARD, 2008). Data were recorded for plant height, number of productive tiller, flowering time, maturity, number of grain per panicle, 1000 grain weight and grain yield. Data were analysed using ANOVA and mean comparisons between genotypes were performed using least significant different (LSD) test. Relationship between agronomic traits was determined by Pearson correlation. Data were analysed using SAS version 9.0.

Participatory varietal selection

A field day was conducted in Wonosobo District before harvest inviting farmers in the surrounding area to perform preference analysis. A total of 20 farmers including 10 females and 10 male farmers were invited to select the upland rice genotypes. Six rice breeders were also involved in the selection process to compare

Table 3. Mean square of location, genotype and interaction of genotype and location for agronomic traits of upland rice genotypes in the combined analysis of variance across two sites of yield trials in high elevation upland rice areas in WS 2014-2015.

Agronomic characters	Mean Square		
	Location	Genotype	Genotype × Location
PH	184.06 ns	1890.03**	90.65*
TN	52.39 ns	19.34**	3.91ns
FT	1856.57**	29.04 ns	18.53**
MT	3366.04**	22.84 ns	26.94**
FGN	148381.69**	2967.44 ns	2959.31**
EGN	28971.66*	6634.86**	994.55*
TGN	46222.72*	5277.72 ns	3126.18**
SS	34752.87**	1370.99**	295.75**
GW	119.07**	97.45**	3.86 ns
GY	38.53**	5.59*	2.08**

PH = Plant height, TN = Productive tiller number, FT = Flowering time, MT = Maturity, FGN = Filled grain number, EGN = Empty grain number, TGN = Total grain number, SS = Seed set, GW = 1000 grains weight, GY = Grain yield at moisture content of 14%, * = significant at $P < 0.01$ and $P < 0.05$, ns = not significant

their preferences to those of farmers'. Preference analysis was carried out based on the procedure described by Paris *et al*. (2011). Each farmer and breeder was given two ballots for varieties they prefer (indicated by symbol √) and two ballots for varieties they dislike (indicated by symbol ×). Ballots for male farmers, female farmers and breeders were distinguished by their colours. Farmers and breeders were allowed to observe all genotypes by walking through the trials before indicating their preferences through ballots placed in the box available in each plot of genotype. Preference score for each genotype was calculated as described by Paris *et al*. (2011):

$$\text{Preference score} = \frac{\text{Number of positive votes- negative votes}}{\text{Total number of positive and negative votes}}$$

RESULTS

Combined analysis of variance across sites

Combined analysis of variance across two sites of upland rice yield trials demonstrated significant effect of location for most agronomic traits except for plant height (PH) and tiller numbers (TN) (Table 3). The effects of genotype were significant for plant height, productive tiller number, empty grain number (EGN), seed set (SS), grain weight (GW) and grain yield (GY), while interaction of genotype and location were significant for almost all traits except for tiller number and grain weight (Table 3). The data from the two locations were then analysed separately, as described in the following sections.

Performance of upland rice breeding lines in high elevation upland area of 1099 masl

Variation in agronomic traits among upland rice genotypes were found in the yield trial conducted at 1099 masl (Table 4). In this area, both improved and traditional varieties flowered at the range of 111 to 119 days after sowing (DAS) and matured at the range of 150 to 160 DAS. Most of the upland rice breeding lines in this experiment showed very low seed set and grain yield. Among upland rice breeding lines, the line B12161D-MR-1-1-5 has the highest grain yield (2.25 t/ha). In contrast, the traditional rice variety Sigambiri Putih showed superior performance compared to improved varieties which were indicated by a high number of grains per panicle and a good seed set (Table 4). The grain yield of Sigambiri Putih (4.45 t/ha) was also significantly higher than all of the improved genotypes tested at this site.

Table 4. Agronomic traits of upland rice breeding lines and check varieties in the yield trial in high elevation upland area of 1099 masl in Cianjur District, WS 2014-2015.

Genotypes	PH (cm)	TN	FT (DAS)	MT (DAS)	FGN	EGN	TGN	SS (%)	GW (g)	GY (t/ha)
B13650E-TB-80-2	109.0	12.9	111	150	68.63	104.03	172.65	39.75	20.15	1.21
B13650E-TB-36	104.3	11.9	112	153	60.10	96.90	157.00	38.28	18.61	1.39
B13604E-TB-72	113.6	10.4	113	155	39.98	121.73	161.70	24.72	23.14	0.60
B12165D-MR-33-3-1	116.5	11.9	113	156	35.40	107.65	143.05	24.75	21.22	0.26
B13626E-TB-9-1	109.4	10.5	114	160	32.00	117.40	149.40	21.42	19.06	0.15
B13626E-TB-7	125.7	11.3	113	161	15.23	142.53	157.75	9.65	24.48	0.23
B11604E-TB-2-4-1-1	126.0	12.0	112	160	24.15	146.38	170.53	14.16	23.67	0.44
B11592F-MR-23-2-2	101.2	13.3	113	155	37.40	82.53	119.93	31.19	21.73	0.45
B12495C-MR-69-1-9	84.4	16.6	116	153	45.35	72.28	117.63	38.55	19.57	0.80
B12161D-MR-1-1-5	92.1	10.7	120	155	75.18	84.75	159.93	47.01	28.72	2.25
B14086D-TB-88	103.1	10.7	116	158	28.88	76.70	105.58	27.35	24.76	0.19
B14086D-TB-89	103.7	12.1	114	158	27.93	65.98	93.90	29.74	26.48	0.16
Jatiluhur	111.3	13.8	113	158	24.07	134.30	158.37	15.20	20.47	0.05
Sigambiri Putih	147.1	12.4	119	153	147.83	56.63	204.45	72.30	30.99	4.45
F-test (variety)	**	**	**	**	**	**	**	**	**	**
LSD (0.05)	11.9	2.6	1.8	3.5	27.30	34.28	43.99	14.11	2.98	0.91

PH = Plant height, TN = Productive tiller number, FT = Flowering time, MT = Maturity, DAS = Days after sowing, FGN = Filled grain number, EGN = Empty grain number, TGN = Total grain number, SS = Seed set, GW = 1000 grains weight, GY = Grain yield at moisture content of 14%, ** = significantly different at $P < 0.001$

Table 5. Agronomic traits of upland rice breeding lines and check varieties in the yield trial in high elevation upland area of 900 masl in Wonosobo District, WS 2014-2015.

Genotypes	PH (cm)	TN	FT (DAS)	MT (DAS)	FGN	EGN	TGN	SS (%)	GW (g)	GY (t/ha)
B13650E-TB-80-2	112.7	10.2	121	145	115.42	83.42	198.83	58.05	24.03	2.50
B13650E-TB-36	109.3	11.2	123	146	147.08	62.58	209.67	70.15	21.33	2.27
B13604E-TB-72	111.3	9.8	124	146	126.08	100.50	226.58	55.65	23.72	1.77
B12165D-MR-33-3-1	112.9	10.2	123	146	147.33	38.50	185.83	79.28	24.14	2.50
B13626E-TB-9-1	107.7	10.2	123	145	124.67	95.08	219.75	56.73	21.94	1.24
B13626E-TB-7	132.7	9.7	123	146	127.67	95.33	223.00	57.25	27.75	1.61
B11604E-TB-2-4-1-1	142.0	9.2	124	145	92.42	135.83	228.25	40.49	26.59	1.55
B11592F-MR-23-2-2	100.4	13.9	121	145	123.42	44.33	167.75	73.57	22.75	3.20
B12495C-MR-69-1-9	85.9	12.9	127	146	99.92	30.17	130.08	76.81	19.61	1.37
B12161D-MR-1-1-5	106.6	9.0	124	145	111.00	29.58	140.58	78.96	28.57	2.61
B14086D-TB-88	107.8	10.3	124	145	109.58	86.00	195.58	56.03	27.61	1.29
B14086D-TB-89	106.9	11.4	120	145	92.08	60.83	152.92	60.22	27.36	1.29
Jatiluhur	103.4	14.3	117	140	145.42	71.58	217.00	67.01	24.25	2.75
Sigambiri Putih	144.0	8.9	120	143	119.17	25.67	144.83	82.28	32.29	3.09
F-test (variety)	**	**	**	**	*	**	**	**	**	**
LSD (0.05)	6.3	2.6	2.4	1.5	34.02	25.06	45.25	9.39	1.61	0.79

PH = Plant height, TN = Productive tiller number, FT = Flowering time, MT = Maturity, DAS = Days after sowing, FGN = Filled grain number, EGN = Empty grain number, TGN = Total grain number, SS = Seed set, GW = 1000 grains weight, GY = Grain yield at moisture content of 14%, ** = significant at $P < 0.001$

Performance of upland rice breeding lines in upland area of 900 masl

Result from the yield trial in Wonosobo District in 900 masl revealed significant differences among 14 rice genotypes for all traits (Table 5). The rice genotype flowered earlier in this site compared to the result from 1099 masl trial (Tables 4 and 5). In the 900 masl trial, numbers of filled grain of upland rice genotype were higher, while the number of empty grain was lower compared to the data from 1099 masl trial implying higher rate of the seed set in this location (Tables 4 and 5). Grain yield of upland rice genotypes grown in 900 masl ranged from 1.29 to 3.20 t/ha. The highest grain yield was achieved by the line B11592F-MR-23-2-2 (3.20 t/ha) and it was slightly higher than that of traditional variety Sigambiri Putih (3.09 t/ha).

Correlation between agronomic traits of upland rice genotypes in two high elevation areas

In the 1099 masl experiment, grain yield of upland rice genotypes showed significant and positive correlation with seed set (r = 0.51) and filled grain number (r = 0.32) (Table 6). The increase in days to flowering, days to maturity and empty grain number significantly reduced grain yield in this altitude with the correlation coefficient (r) of -0.34, -0.37, and -0.43, respectively (Table 6).

Rice grain yield significantly correlated with all agronomic traits except productive tiller number in the experiment at 900 masl (Table 6). Strong and positive correlations were shown between grain yield with filled grain number (r = 0.83) and seed set (r = 0.78). Similar result to the experiment at 1099 masl, days to maturity showed negative correlation with grain yield (r = -0.38) (Table 6).

Selected upland rice breeding lines based on farmers' preference analysis

Participatory varietal selection was conducted to analyse farmers' preferences on upland rice genotypes in Wonosobo District (900 masl). Variations were found in preference scores (PS) of male farmers, female farmers and breeders on 14 rice genotypes (Table 7). Most of genotype received positive votes from either male or female farmers except the lines B13650E-TB-36, B13626E-TB-9-1, B11604E-TB-2-4-1-1 and B14086D-TB-89, while from the breeders' perspective there were only six genotype received positive votes (Table 7).

Male farmers mostly preferred rice genotype B13650E-TB-80-2 (PS = 0.100), B11592F-MR-23-2-2 (PS = 0.025), Jatiluhur (PS = 0.125) and Sigambiri Putih (PS = 0.050). Female farmers mostly preferred rice genotypes B13650E-TB-80-2 (PS = 0.075), B12165D-MR-33-3-1 (PS = 0.025), Jatiluhur (PS = 0.150) and Sigambiri Putih (PS = 0.125) (Table 7). Combined male and female farmers' votes revealed four genotypes with positive preference scores including B13650E-TB-80-2 (PS = 0.088), B11592F-MR-23-2-2 (PS = 0.013), Jatiluhur (PS = 0.138) and Sigambiri Putih (PS = 0.088) (Table 7).

Relationship between farmers' preference scores and grain yield

Strong and positive correlations were found between preference scores of male, female and combined farmers (Table 8). While moderate and positive correlation was shown between breeders and male farmers preference score (r = 0.56), the correlation between breeders, female and combined farmers' preference score were not significant (Table 8).

Preference scores of male farmers significantly correlated with grain yield with the coefficient of correlation (r) being 0.66, while the correlation between grain yield and preference score of female farmers was not significant (Table 8). Positive and significant correlation were also observed between grain yield with combined farmers' and breeders' preference scores with the coefficient of correlation (r) of 0.61 and 0.55, respectively (Table 8)

DISCUSSION

Adaptation of upland rice breeding lines in high elevation areas

Table 6. Pearson correlation among agronomic characters of upland rice genotypes in the yield trial in high elevation area of 1099 masl in Cianjur District (above diagonal) and in high elevation upland area of 900 masl in Wonosobo District (below diagonal), WS 2014-2015.

	PH	TN	FT	MT	FGN	EGN	TGN	SS	GW	GY
PH		-0.42**	-0.15^{ns}	-0.15^{ns}	-0.02^{ns}	0.35**	0.27*	-0.28*	0.62**	0.14^{ns}
TN	-0.19^{ns}		-0.19^{ns}	-0.21^{ns}	0.08^{ns}	-0.16^{ns}	-0.08^{ns}	0.15^{ns}	-0.38**	0.06^{ns}
FT	-0.01^{ns}	-0.08^{ns}		0.65**	-0.14^{ns}	0.04^{ns}	-0.05^{ns}	-0.03^{ns}	-0.26*	-0.34**
MT	0.13^{ns}	-0.21^{ns}	-0.07^{ns}		-0.11^{ns}	0.05^{ns}	-0.03^{ns}	-0.09^{ns}	-0.26*	-0.37**
FGN	0.26*	0.14^{ns}	0.47**	-0.48**		-0.04^{ns}	0.59**	0.34**	-0.14^{ns}	0.32*
EGN	0.18^{ns}	-0.01^{ns}	-0.44**	0.25^{ns}	-0.29*		0.78**	-0.93**	-0.07^{ns}	-0.43**
TGN	0.37**	0.11^{ns}	0.03^{ns}	-0.20^{ns}	0.60**	0.60**		-0.54**	-0.14^{ns}	-0.15^{ns}
SS	0.03^{ns}	0.19^{ns}	0.55**	-0.51**	0.93**	-0.53**	0.34**		0.05^{ns}	0.51**
GW	0.33**	-0.15^{ns}	0.55**	0.09^{ns}	0.49**	-0.15^{ns}	0.28**	0.45**		0.15^{ns}
GY	0.31*	0.03^{ns}	0.56**	-0.38**	0.83**	-0.35**	0.40**	0.78**	0.48**	

** and * = significant at $P < 0.01$ and at $P < 0.05$; ns = not significant

Two advanced yield trials of upland rice genotype were conducted in two high elevation areas representing different altitudes, 1099 masl and 900 masl, evaluating the adaptability of the genotypes in such areas. The upland rice genotypes (Table 1) were selected from the previous yield trial based on their agronomic performance in different high-altitude areas (Suwarno *et al*., 2014). A significant interaction between rice genotype and altitudes revealed in this study (Table 3) indicated the importance to evaluate the agronomic performance of rice genotype in different altitudes. Differences in minimum and maximum temperatures in the two sites (Table 2) were suggested as the main factors determining the different responses of rice genotypes in the two altitudes. The effect of temperature on rice growth and yield has been intensively studied (Shrestha *et al*., 2012; Thakur *et al*., 2010; Welch *et al*., 2010; Ye *et al*., 2010). Spikelet fertility was the most important trait to be improved to increase the yield in high altitude areas as indicated by the high correlation between seed set and grain yield (Table 6). Several QTLs controlling cold tolerance of rice in booting stages have been identified and has potential to be used for further improvement (Andaya and Mackill, 2003b; Ye *et al*., 2010; Zhou *et al*., 2010).

Traditional upland rice variety Sigambiri Putih consistently performed well in two different altitudes (Tables 4 and 5). The variety currently is still grown by Indonesian farmers in high altitude areas of North Sumatera region due to the absence of improved variety for these areas. In other high elevation upland areas in Asia, traditional rice varieties were also still widely grown by farmers (Joshi and Bauer, 2007; Steele *et al*., 2009). Results from this study indicated that some of the promising breeding lines had comparable yield to Sigambiri Putih in the altitude of 900 masl (Table 5). The introduction of modern rice varieties adapted in high altitude areas is expected, and they can be grown simultaneously with existing traditional rice to maintain genetic diversity in the region. Further improvement of the upland rice is still needed targeting higher altitudes. Identification of genetic determinant of cold tolerance in traditional variety Sigambiri Putih is also important for the breeding program.

Farmers' preference on upland rice genotypes and potential deployment of new breeding lines

Participatory varietal selection has been intensively used to complement formal breeding programs particularly for unfavourable rice environment (Almekinders and Elings, 2001; Singh *et al*., 2014; Witcombe *et al*., 2001; Witcombe *et al*., 1996). In this study, male and

Table 7. Number of positive and negative votes and preference scores (PS) of male farmers, female farmers, combined male and female farmers, and breeders for upland rice genotypes based on the participatory varietal selection in high elevation area of 900 masl in Wonosobo District, WS 2014-2015.

Genotypes	Male farmers			Female farmers			Combined farmers			Breeders			Ranking		
	(+)	(-)	PS	(+)	(-)	PS	(+)	(-)	PS	(+)	(-)	PS	Farmer's PS	Breeder's PS	Grain yield
B13650E-TB-80-2	4	0	0.100	3	0	0.075	7	0	0.088	3	0	0.125	2	2	5
B13650E-TB-36	0	0	0.000	0	5	-0.125	0	5	-0.063	0	0	0.000	13	9	7
B13604E-TB-72	1	2	-0.025	2	4	-0.050	3	6	-0.038	3	0	0.125	10	3	8
B12165D-MR-33-3-1	1	2	-0.025	2	1	0.025	3	3	0.000	0	1	-0.042	5	10	6
B13626E-TB-9-1	0	1	-0.025	0	1	-0.025	0	2	-0.025	0	4	-0.167	7	14	14
B13626E-TB-7	1	4	-0.075	1	1	0.000	2	5	-0.038	1	0	0.042	11	6	9
B11604E-TB-2-4-1-1	0	3	-0.075	0	3	-0.075	0	6	-0.075	0	2	-0.083	14	12	10
B11592F-MR-23-2-2	1	0	0.025	0	0	0.000	1	0	0.013	0	0	0.000	4	7	1
B12495C-MR-69-1-9	0	0	0.000	1	1	0.000	1	1	0.000	0	3	-0.125	6	13	11
B12161D-MR-1-1-5	1	1	0.000	0	2	-0.050	1	3	-0.025	1	0	0.042	8	5	4
B14086D-TB-88	1	2	-0.025	0	1	-0.025	1	3	-0.025	0	0	0.000	9	8	12
B14086D-TB-89	0	2	-0.050	0	1	-0.025	0	3	-0.038	0	2	-0.083	12	11	13
Jatiluhur	6	1	0.125	6	0	0.150	12	1	0.138	3	0	0.125	1	1	3
Sigambiri Putih	4	2	0.050	5	0	0.125	9	2	0.088	1	0	0.042	3	4	2

Table 8. Pearson correlation between preference scores of male farmers, female farmers, combined farmers, breeders and the grain yield of upland rice genotypes in participatory varietal selection in high elevation area of 900 masl in Wonosobo District, WS 2014-2015.

		Preference score			
		Male farmers	Female farmers	Combined farmers	Breeders
Preference score	Male farmers	1			
	Female farmers	0.72**	1		
	Combined farmers	0.91**	0.94**	1	
	Breeders	0.56*	0.41^{ns}	0.51^{ns}	1
Yield		0.66**	0.49^{ns}	0.61*	0.55*

** and * = significant at *P* < 0.01 and at *P* < 0.05; ns = not significant female farmers in Wonosobo District have been involved to select rice breeding lines adapted for high elevation areas. Four genotypes have been considered as the most preferred genotypes by farmers in Wonosobo including B13650E-TB-80-2, B11592F-MR-23-2-2, Jatiluhur and Sigambiri Putih (Table 7). The upland rice breeding line B11592F-MR-23-2-2 which had positive preference score and was high yielding (3.20 t/ha) has potential for released as new variety for high elevation areas in Indonesia particularly for 900 masl region. Further evaluation will be conducted in other high-altitude areas to determine the adaptability of the rice genotype in other locations.

Result from the present PVS trial indicated that farmers' choices were significantly correlated with grain yield (Table 8). However, it should be noted that other breeding lines with low yielding capacity also received positive votes from different farmers. Variation in preference scores for each genotype indicated the variability of farmers' preference on breeding lines (Singh *et al*., 2014; Witcombe *et al*., 2001). Variation in farmers' preferences needs to be considered in deploying new varieties as a strategy to maintain genetic diversity in the field (Witcombe *et al*., 2001). Furthermore, moderate correlation between farmers' and breeder's preference scores revealed in this study indicated an agreement in varietal assessment criteria between these two groups. This result strengthens the importance of farmer's knowledge to complement breeder's perspective in selecting rice varieties for a particular region (Manzanilla *et al*., 2011).

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