International Journal of Agricultural Technology 2014 Vol. 10(6):1481-1491
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Participatory Varietal Selection of Submergence-Tolerant Rice Varieties

del Rosario, M. R.*

Laguna State Polytechnic University, Siniloan, Laguna, Philippines.

del Rosario, M. R. (2014). Participatory varietal selection of submergence-tolerant rice varieties. International Journal of Agricultural Technology 10(6):1481-1491.

Abstract An experiment consisting of 14 submergence-tolerant (SUB1) rice varieties/lines and one check variety in RCBD with 3 replicates was set up. Participatory varietal selection (PVS) followed by preference analysis and consumer sensory evaluation were implemented. ANOVA was used to determine differences among varietal yields. Pearson's correlation was used with preferential analysis while chi-square tested the independence of acceptability of cooked rice and variety. Ranking and probability of being accepted were used to describe the result of sensory evaluation. Although yields did not differ significantly, those of SUB1 varieties were generally higher than that of the check variety. Results from PVS produced 4 top choices: IR10F616, followed by IR 88344-8-1-2-B, and then IR10F198 and IRRI 119 with the same score. The criteria used for the choice were number of days to maturity, signs of pests and diseases, stem strength and vigor (lack of lodging), leaf color, tillering ability, and grain size. The Pearson's correlation revealed significant disagreement in the varietal preference between male and female farmers. The researchers were more in agreement with the male farmers than with the female farmers. Yield was not correlated with the preference of any of the respondents. Results from the consumer sensory test identified 3 acceptable varieties ranked as follows: IR10F198 > IR 88344-8-1-2-B > IR10F616. The probability of being accepted by consumers are 0.78, 0.86 and 0.73, respectively. The chi-square test revealed dependence of acceptability of cooked rice on varieties under study.

Keywords: flood-prone rice varieties, sensory evaluation, preference analysis

Introduction

New submergence-tolerant rice varieties were tested with farmers' participation in search for varieties that match farmers' needs.
Submergence tolerance is an important trait where flooding damages rice crops. Over 20 years of scientific research have identified the submergence-tolerant gene, the SUB1 that is able to avert stress to rice due to flooding (Septiningsih *et al.,* 2009). This gene has been transferred to varieties widely grown in large areas of Asia while retaining the original characteristics of the varieties under normal or favorable environments. Hence, the "SUB1 varieties" have grain

* **Corresponding author:** del Rosario, M. R.**; e-mail:** menchiedel27@yahoo.com.ph

yields equal to their parent varieties under non-submerged conditions and yield advantages of 1t/ha or more when affected by submergence (Mackill *et al.*, 2012).

When totally submerged, most rice cultivars elongate their shoots above water level. This helps to ensure adequate supplies of oxygen and carbon dioxide to support vigorous aerobic respiration and photosynthesis. However, it takes place at the expense of existing dry matter. This means that the energy required for elongation competes with maintenance processes. Moreover, long elongated shoots tend to lodge when water recedes. Consequently, survival or recovery after flooding is compromised. Hence, tolerance is greater in cultivars where elongation caused by submergence is minimal (Kawano *et al.*, 2009). In addition, survival after submergence is enhanced by reducing carbohydrate consumption. This allows the plants to recover upon de-submergence (Mackill *et al.*, 2010). A study found out that the cultivars that maintain a higher carbohydrate content at the end of submergence develop new leaves very quickly and accumulate greater biomass during re-emergence (Sarkar and Bhattacharjee, 2011).

SUB1 varieties show an inhibition of elongation and, upon submergence, they recover rapidly and continue growth (Mackill *et al.*, 2012). Varieties introgressed with SUB1 genes have been grown in flood-prone areas of eastern India, Bangladesh and Nepal, and found to enhance and stabilize rice productivity (Singh *et al.*, 2013). They are now spreading at an unprecedented rate. Participatory varietal selection (PVS) was employed to ensure farmers' adoption of the new varieties.

In Participatory Varietal Selection (PVS), farmers are given the opportunity to express their opinions and preferences about the varieties being evaluated (Paris *et al.*, 2011). It offers farmers a choice of crop varieties to match to their needs. It was conceptualized from the realization of low farmer adoption of new varieties developed and tested on research stations because they do not work in the real world. Adoption of new varieties is relatively poor because the variety does not meet farmers' needs, or because farmers lack access to seed or information on new varieties (IRRI, 2006). In many cases, resource-poor farmers are not exposed to the most appropriate cultivar (Joshi and Witcombe, 2008). So farmers prefer to grow old, unproductive varieties prone to pests and diseases. This implies a need to improve communication between farmers and breeders so that farmers' concerns and preferences are incorporated in the research process. PVS bridges the communication gap between farmers and breeders. Success of the approach has been shown through increased farmers' access to preferred variety, enhanced adoption and increased genetic diversity resulting in a faster rate of diffusion through farmer-to-farmer seed exchange (Mulatu and Belete, 2001).

In the Philippines, around 70% to 80% of the rice areas are planted with only 10 different varieties in a given period; the weighted average age of rice variety being planted is 9 years; some farmers are still planting varieties released 20 years ago (Launio *et al.*, 2010). Farmers must be assured of greater yield or reduced production risks to ensure that the new submergence-tolerant rice varieties/lines would be adopted. Hence, a farmer-managed demonstration farm with 14 rice varieties/lines tolerant to submergence and one check variety was established. The study aimed to select the variety that matches local farmers' needs based on visual observations. Farmers were invited to evaluate and identify the cultivar of their choice, following the PVS approach. Selected cultivars were later on subjected to consumer sensory evaluation to determine the acceptability of selected varieties based on eating and cooking qualities.

Material and methods

A field experiment was established with 15 rice varieties/lines in Randomized Complete Block Design (RCBD) with 3 replicates. The varieties/lines were as follows:

IR10F109	PSBRc18-Sub1
IR10F198	Inpara-3
IR10F339	IR 88344-8-1-2-B
IR10F365	IR86376-47-3-1-B
IR10F548	IR86384-55-2-1-B
IR10F616	IR86384-93-3-1-B
IRRI 119	PSBRC 82 (IRRI 123) (check variety)
IRRI 154	

Seedlings were transplanted 30 DAS. At 14 DAT, the field was artificially flooded to 20 cm for about 1 week. Yield was determined from the 1-square meter harvest area. Yield advantage over the check variety was calculated from

$$yield\ advantage = \frac{yield\ of\ variety - yield\ of\ check\ variety}{yield\ of\ check\ variety}$$

Data Collection and Statistical Analysis

PVS was carried out according to the guidelines set by Paris *et al.* (2011). When most of the crops reached 80% maturity, farmers and researchers (officials and staff from the Department of Agriculture, and faculty members of the College of Agriculture, Laguna State Polytechnic University) were invited for varietal evaluation and selection. Respondents were asked to vote their most and least preferred varieties. Votes were tallied and the preference scores (PS) for each variety was then calculated from

$$PS = \frac{Number\ of\ positive\ votes - Number\ of\ negative\ votes}{Total\ number\ of\ votes\ cast}$$

Focus discussion was initiated to determine the criteria used by respondents in their selection.

Preference analysis was conducted based on computed PS. Four top ranking varieties/lines were identified. Samples of these varieties/lines were milled, cooked and subjected to consumer test (sensory evaluation) to determine their acceptability. A panel of respondents consisting of farmers and faculty members of the Laguna State Polytechnic University evaluated the cooked rice. Samples were coded using three-digit random numbers. Panelists were provided with a glass of water, and were instructed to rinse and swallow water between samples. They were given written instructions and asked whether they liked or disliked the cooked rice. Then they were asked to rank the samples from most to least liked. They were also asked to enumerate their criteria for their choice.

One-way Analysis of variance was used to determine the significance of differences among varietal mean yields. Pearson' correlation established the agreement between the PS attributed by farmers and researchers to each variety/line. Chi-square was used to determine if the differences in the preferences based on ranking are different from each other. Statistical analyses were conducted with the aid of Minitab statistical software.

Results and discussion

Farmers' Selection Criteria

A farmers' field day was conducted on the demonstration farm to allow farmers to evaluate rice varieties. During the focus discussion the participants shared the criteria they commonly used in evaluating the acceptability of rice variety to grow based on visual observation. The criteria used were number of days to maturity, signs of pests and diseases, stem strength and vigor (lack of lodging), leaf color, tillering ability, and grain size. The number of days to maturity was the top criterion to reduce the risk of inclement weather and flooding. Farmers also preferred varieties with minimal signs of pests and diseases as they reduce the quantity and quality of yield. They considered grain size as an indicator of yield but placed it at the bottom of the list of criteria. They reasoned out that yield would ultimately be affected by losses due to flooding, pests and diseases and other factors.

Farmers in Vietnam also employed traits other than yield as basis of evaluating rice cultivars. Reported criteria were growth duration, pest and disease tolerance and panicle characteristics (Nguyen *et al.*, 2010), which are basically the same criteria espoused by the participants of this study. In India, the rice varieties were chosen for their early maturity, improved lodging resistance, higher fodder and grain yield, long-slender grains and excellent cooking quality (Virk *et al*., 2003). In Bhutan, PVS participants identified the following factors affecting their choice: small landholdings and scarcity of family labor, production stability, performance in different agro-climatic zones, and fit to household schedules (Tshewang and Ghimiray, 2010).

Preference Analysis

The yields of the different SUB1 varieties of this present study were generally higher than that of the check variety although differences were not significant. Only PSBRc 18-Sub1 yielded less than the check variety. Yields of test varieties/lines were compared with the check variety using comparative yield advantage (Table 1). Positive values indicating higher yield were exhibited by all varieties/lines, except PSBRc 18-Sub1. The three highest yielders were IR10F339, IRRI 154 and Inpara-3, in descending order.
A similar result was reported by Nguyen *et al*. (2010) on SUB1 varieties in Vietnam -- the yield of SUB1 varieties were found to be comparable with that of check variety.

Table 1 also presents the different varieties/lines arranged in descending order of PS. Leading choices based on preference analysis were the following: IR10F616 followed by IR 88344-8-1-2-B and then IR10F198 and IRRI 119 with the same PS. Note that 8 out of 15 varieties/lines were positively preferred – that is, they received more positive than negative votes. Least preferred was the check variety PSBRc 82. The local variety PSBRc 18-Sub 1 received a positive PS. This implies that even though yield was less than that of the check variety, it exhibited traits that passed the respondents' criteria for selection. This result also confirms that farmers' preference was not solely based on potential yield.

Table 1. Preference score of submergence-tolerant rice varieties/lines tested and yield advantage over check variety (PSBRC 82 (IRRI 123)

Varieties/Lines	Yield Advantage	Preference Score
IR10F616	0.35	0.139
IR 88344-8-1-2-B	1.69	0.069
IR10F198	0.80	0.056
IRRI 119	1.02	0.056
IR10F109	0.18	0.028
IR10F365	2.46	0.028
IR86376-47-3-1-B	0.65	0.028
PSBRc18-Sub1	-0.12	0.014
Inpara-3	1.72	-0.014
IR10F548	0.54	-0.028
IR86384-55-2-1-B	1.40	-0.028
IR86384-93-3-1-B	1.16	-0.042
IRRI 154	2.46	-0.056
IR10F339	3.56	-0.139
PSBRC 82 (IRRI 123)		-0.153

Respondents' Preferences and Gender Analysis in Rice Breeding

Table 2 provides a summary of the results of the correlation analysis between the preference scores of male and female farmers and the correlation between the PS of all farmers and researchers using Pearson's Correlation Coefficient (r). A weak but significant correlation ($r = 0.3934$, $\alpha < 0.05$) between the male and female PS was detected. This indicates that the preference of males may not necessarily be the preference of females. It implies further that women are not as knowledgeable as men in visual evaluation of rice characteristics.

Similar to this report, Gridley *et al.* (2002) also reported gender differences in varietal selection. In contrast, significant correlation in preference scores given by male and female farmers was reported by Manzanilla *et al.*, (2013). The male preference was moderately correlated with the researchers' preference ($r = 0.5805$, $\alpha = 0.01$) but the female preference was weakly correlated with the researchers' preference ($r = 0.2801$, $\alpha < 0.05$). This means that the male farmers were more in agreement with the researchers' preference than the female farmers.

A highly significant moderate correlation ($r = 0.5826$, $\alpha < 0.01$) was found between the PS of farmers (male and female farmers combined) and researchers. This correlation is indicative of the degree of consensus between them. Thus, there is a moderate degree of consensus in the preference of the two groups. This further supports the importance of involving farmers in decision making for breeding rice varieties. It also provides an insight into the success of wide acceptability and adoption of new rice breeds. The same result was also reported in India (Paris *et al*., 2002) and some other Southeast Asian countries (Manzanilla *et al*., 2013).

The correlation between PS and yield was also analyzed. No significant correlation was found between yield and any group of respondents. This implies no agreement between the predicted yields and the resulting choices of the farmers based on their own set of criteria. This further reinforces that the respondents' preference was not based on yield alone as revealed during the focus discussion. Their top criterion was number of days to maturity. The same result was reported by Manzanilla *et al*, (2013).

Contrary to this findings, Atlin *et al*. (2002) reported that farmers' pre-harvest ratings in India, Laos, Indonesia and the Philippines were correlated with post-harvest ratings. They further stated that farmers' preference seems to be a strong criterion in varietal selection.

In these days that rice growing even in flood prone areas are becoming widespread, breeding rice genotypes with the best combination of desired traits possible and those that can survive excess water would be beneficial to help farmers avoid or reduce any potential decline in production. This can help alleviate the plight of marginalized farmers.

The target end-users of any breeding program are the farmers. Hence, their opinions to identify their most preferred cultivar, as well as their own criteria for the choice are important inputs. Farmer participation has been long recognized through the use of PVS. The approach highlighted the farmers' role to increase the chances of adoption of cultivars and breeding efficiency using their own criteria and site specific needs.

The results can also be used as bases for government policy and initiatives for rural development as well as and varietal dispersion programs.

Table 2. Correlation between the preference of farmers (male and female) and researchers

		Female	Farmer (male + female)	Researcher	Yield
Male	Pearson's Correlation	0.3934	0.9303	0.5805	0.2627
	Significance	0.0123*	0.0000**	0.0010**	0.3441^{ns}
	N	15	15	15	15
Female	Pearson's correlation		0.6467**	0.2801	0.0688
	significance		0.0003	0.0425*	0.8074^{ns}
	N		15	15	15
Male +	Pearson's correlation			0.5826	0.2089
Female	significance			0.0009**	0.8074^{ns}
	N			15	15
Researcher	Pearson's correlation				0.2520
	significance				0.3649 ^{ns}
	N				15

**- significant, ** - highly significant, ns – not significant*

Sensory Evaluation

Samples of cooked rice were given to farmers to determine the probability of a variety being accepted by farmers. Only the top four choices based on the preference analysis was considered. A probability >0.5 indicates that the variety has a good chance of being acceptable to farmers. The results are shown in Table 3.

As shown, IRRI 119 may not be grown by farmers at all while the rest have a good chance of being accepted. IR 88344-8-1-2-B received the highest acceptance probability of 0.86. This means that the highest number of "acceptable" votes was garnered by this variety. That is to say that the odds of success are 64 to 10. The next choice was IR 10F198, which got the second highest probability. The ratio of the probability of being accepted over being rejected was 3.62.

Asked to rank the cooked samples based on overall acceptability, respondents chose IR 10F198 as the number one choice although it received the second highest number of "acceptable" votes. Ranked second by respondents was IR 88344-8-1-2-B which had the highest probability of being accepted.
Consistent as third and fourth choices were IR10F616 and IRRI 119, respectively.

Table 3. Sensory analysis

	IR10F616	IR 88344-8-1-2-B	IRRI 119	IR10F198
Probability of being accepted	0.73	0.86	0.32	0.78
Odds	2.70	6.40	0.48	3.62
Rank	3	2	4	1

The respondents also ranked their criteria for acceptability. The criteria were as follows: aroma, flavor or taste, color, gloss, tenderness and cohesiveness. This confirms that aroma is an important attribute that determines the market price (Nur Haqimzan and Anizan, 2013).

The null hypothesis that the acceptability of cooked rice is independent of varieties was tested using chi-square test of independence. The result was χ^2 = 1.889E-06. Hence, the null hypothesis was rejected. This means that there is enough evidence to conclude that the acceptability of cooked rice was associated with variety.

Conclusion and Recommendation

The study involved the participation of farmers and researchers in selecting submergence-tolerant rice varieties. Top choices ranked according to PS were (1) IR10F616, (2) IR 88344-8-1-2-B, (3.5) IR10F198, and (3.5) IRRI 119. The preference analysis showed a weak correlation in the preferences of male and female farmers. The preference of researchers was more in agreement with male preference than female preference. A moderate degree of consensus between farmers (total of male and female) and researchers was detected. However, there was no correlation between yield and preference of any of the respondents. This is explained by the use of traits other than yield in the respondents' choice of variety. The criteria used by the respondents were yield, number of days to maturity, signs of pests and diseases, stem strength and vigor (lack of lodging), leaf color, tillering ability, and grain size.

As for cooked rice, all of them except IRRI 119, were acceptable to farmers. The varieties were ranked as follows: (1) IR10F198, (2) IR 88344-8-1-2-B, (3) IR10F616, and (4) IRRI 119. The sensory evaluation showed high probability of being accepted by consumers.

Future research direction should focus on the performance of selected varieties on a wider scale and the extent of adoption of selected varieties.

References

Atlin, G. N., Paris, T. R., Linquist, B. and Suwarno (2002). Integrating conventional and participatory crop improvement in rainfed rice. Proceedings of a DFID plant science research programmes/IRRI conference, International Rice Research Institute, Los Banos, Laguna, Philippines.

Gridley, H. E., Jones, M. P. and Wopereis-Pura, M. (2002). Development of new rice for Africa (NERICA) and participatory varietal selection. Bpouake, Vote d'Ivoire: West Africa Rice Development Association (WARDA). Proceedings of a DFID plant science research programmes/IRRI conference, International Rice Research Institute, Los Banos, Laguna, Philippines.

IRRI. (2006). Factors affecting the adoption of improved varieties. Retrieved from http://www.knowledgebank.irri.org/ricebreedingcourse/Lesson_1_Factors_affecting_the_adoption_of_improved_varieties.htm

Joshi, A. and Witcombe, J. R. (2008). Farmer participatory crop improvement. II. Participatory varietal selection, a case study in India. Experimental Agriculture 32:461-477.

Kawano, N., Ito, O. and Sakagami, J. (2009). Morphological and physiological responses of rice seedlings to complete submergence (flash flooding). Annals of Botany 103:161–169.

Launio, C. C., Redondo, G. O. and Beltran, J. C. (2010). Recent Adoption and Spatial Diversity of Modern Rice Varieties in the Philippines. Kochi University Review of Social Science No. 97.

Mackill, D. J., Ismail, A. M., Pamplona, A. M., Sanchez, D. L., Carandang, J. J. and Septiningsih, E.M. (2010). Stress tolerant rice varieties for adaptation to a changing climate. Crop, Environment and Bioinformatics 7:250-259.

Mackill, D. J., Ismail, A. M., Singh, U. S., Labios, R. V. and Paris, T. R. (2012). Development and rapid adoption of submergence-tolerant (sub1) rice varieties. Advances in Agronomy115, Burlington: Academic Press.

Manzanilla, D. O., Paris, T. R., Vergara, G. V., Ismail, A. M., Pandey, S. Labios, R. V., Tatlonghari, G. T., Acda, R. D., Chi, T. T. N., Duoangsila, K., Siliphouthone, I., Manikmas, M. O. A. and Mackill, D. J. (2011). Submergence risks and farmers' preferences: Implications for breeding Sub1 rice in Southeast Asia. Agricultural Systems 104:335–347.

Manzanilla, D. O., Paris, T. R., Tatlonghari, G. T., Tobias, A. M., Chi, T. T. N., Phuong, N. T., Siliphouthone, I., Chamarerk, V., Bhekasut, P. and Gandasoemita, R. (2013). Social and gender perspectives in rice breeding for submergence tolerance in Southeast Asia. Experimental Agriculture Cambridge University Press.

Mulatu, E. and Belete, K. (2001). Participatory varietal selection in lowland sorghum in eastern Ethiopia: impact on adoption and genetic diversity. Experimental Agriculture 37:211-229.

Nur Haqim, A. A. and Anizan, I. (2013). Physicochemical, Vitamin B and Sensory Properties of Rice Obtained by System of Rice Intensification (SRI) (Ciri Fizikokimia, Vitamin B dan Sensori Beras melalui Sistem Keamatan Padi (SRI). Sains Malaysiana 42:1641–1646.

Nguyen, T. L., Luy, T. T., Binh, T. , Thuan, T. D., Van Canh, V., Nguyen, V. B., Labios, R., Buu, B. C., Ismail, A. M. and Mackill, D. J. (2010). Evaluation methodology and utilization submergence gene in Southern Vietnam. Omonrice 17:41-53.

Paris, T. R., Singh, R. K., Atlin, G. N., Sarkarung, S. and Ram, S. (2002) Farmer participatory breeding and participatory varietal selection in eastern India: Lessons learned.

Proceedings of a DFID plant science research programmes/IRRI conference, International Rice Research Institute, Los Banos, Laguna, Philippines.

Paris, T. R., Manzanilla, D., Tatlonghari, G., Labios, R., Cueno, A. and Villanueva, D. (2011). Guide to participatory varietal selection for submergence-tolerant rice. Los Baños (Philippines): International Rice Research Institute.

Sarkar, R. K. and Bhattacharjee, B. (2011)**.** Rice genotypes with sub1 qtl differ in submergence tolerance, elongation ability during submergence and re-generation Growth at Re-emergence. Rice 5.

Septiningsih, E. M., Pamplona, A. M. Sanchez, D. L., Neeraja, C. N., Vergara, G. V., Heuer, S., Ismail, A. M. and Mackill, D. J. (2009). Development of submergence-tolerant rice cultivars: the sub1 locus and beyond. Annals of Botany 103:1151-160.

Singh, U. S., DAR, M. H., Singh, S., Zaidi, N. W., Bari, M. A., MacKill, D. L., Collard, B. C. J., Singh, V. N., Signh, J. P., Reddy, J. N., Signh, R. K., and Ismael, A. M. (2013). Field performance, dissemination, impact and tracking of submergence tolerant (sub1) rice varieties in South Asia. SABRAO Journal of Breeding and Genetics 45:112-131.

Tshewang, S. and Ghimiray, M. (2010). Participatory variety selection: increasing rice varietal diversity. Journal of Renewable Natural Resources 6:1-10.

Virk, D. S., Singh, D. N., Prasad, S. C., Gangwar, J. S. and Witcombe, J. R. (2003). Collaborative and consultative participatory plant breeding of rice for the rainfed uplands of eastern India. Euphytica 132:95–108.

(Received 25 August 2014; accepted 30 October 2014)