RESEARCH ARTICLE

SABRAO Journal
of Breeding and Genetics
47 (3) 299-314, 2015

PARTICIPATORY VARIETAL SELECTION (PVS): A "BOTTOM-UP" BREEDING APPROACH HELPS RICE FARMERS IN THE AYEYARWADY DELTA, MYANMAR

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SUMMARY

The participatory varietal selection approach is the first attempt in Myanmar through collaborative efforts from IRRI-LIFT. Sixteen and 12 varieties/lines were evaluated in the monsoon and dry season, respectively, through PVS in different villages in three townships of the Ayeyarwady Delta. Four varieties/lines (Saltol Sin Thwe Latt, Shwe Pyi Htay, Sin Thu Kha, and Shwe Ta Soke) in the wet season of 2012 and four varieties/lines (IR10T107, IR10T108, IR10T111, and CSR36) in the dry season of 2012-13 were selected by farmers through preference analysis, grain yield and sensory evaluation. After field evaluation, Saltol Sin Thwe Latt was released as a variety in Myanmar. Farmer-managed trials (baby trials) were carried out using the selected lines from the wet season. Based on baby trials in the 2013 wet season, Saltol Sin Thwe Latt (Saltol STL) and Sin Thu Kha (STK) were the first and second most adapted and stable high-yielding varieties for three townships in the Ayeyarwady Delta. PVS has the potential to become one of the best approaches in research for developing a variety based on farmers choice and enhancing their productivity and dissemination, especially in the Ayeyarwady Delta, Myanmar, to help resource-poor farmers in obtaining easy access to rice-based technology for improving their livelihood.

Keywords: Participatory varietal selection, bottom-up approach, mother and baby trials, rice, farmers, Ayeyarwady Delta

Key findings: Saltol Sin Thwe Latt (Saltol STL) is the most stable variety based on highest mean yield across environments thus may be the most appropriate rice variety for delta areas. The farmers' participatory approach helps in the rapid dissemination of new varieties and was found to be very effective in scaling-up seed transfer and adoption of the new varieties by farmers.

Manuscript received: May 18, 2015; Decision on manuscript: July 16, 2015; Manuscript accepted: August 16, 2015.

Communicating Editor: Bertrand Collard

INTRODUCTION

Agriculture is the backbone of the economy in Myanmar, where rice (*Oryza sativa* L.) is the most important crop in Myanmar agriculture. Rice is grown on about 8.0 million ha in

Myanmar and around 3.6 million ha are under rice cultivation in the Ayeyarwady Delta. This delta area is considered as the rice bowl or granary of Myanmar. The average yield of this area is 3.6 t ha^{-1}, lower than the country's national average (3.84 t ha^{-1}) mainly because of the cultivation of traditional varieties (MOAI, 2013). New high-yielding salt- and submergence-tolerant varieties can be introduced and farmers can help in selecting their need-based variety through participatory varietal selection. Participatory varietal selection (PVS) shows that breeders' selection criteria and their way of assessing cultivar performance – mainly quantitative and statistically based – often differ widely from the methods traditionally implemented by farmers (e.g. Sperling *et al.*, 1993; Ceccarelli *et al.*, 2000; Mekbib, 2006). Even among farmers and farmer groups themselves, these criteria can vary markedly depending on gender, environmental concerns, and economic status (Sperling *et al.*, 1993; Defoer *et al.*, 1997; Weltzien *et al.*, 1998). Bellon (2002), who analyzed the ways in which farmers in Mexico assess maize varieties, points out the importance of a selection program that takes into consideration "subjective" traits, that is, traits that are mainly a "function of human perception." To date, breeding objectives in countries where traditional cropping systems are dominating have not been appropriately oriented toward the perceptions of farmers, specifically their needs and preferences for the difficult growing conditions of their regions (Almekinders and Elings, 2001; Witcombe *et al.*, 2006; Mekbib, 2006). To overcome this problem, participatory varietal selection has been proposed to bring about a more bottom-up/decentralized breeding approach and the integration of farmers and their complex selection criteria into varietal improvement programs (Courtois *et al.*, 2001; Mulatu and Zelleke, 2002; Witcombe *et al.*, 2002; Ceccarelli *et al.*, 2003; Weltzien *et al.*, 2005; Ceccarelli and Grando, 2007; Weltzien *et al.*, 2008; Thapa *et al.*, 2009; vom Brocke *et al.*, 2010). Thapa *et al.* (2009), for instance, believe that farmers' criteria can be integrated using their overall preference scores while selecting for cultivars, as these overall scores take into consideration, and balance out, the effects of all pertinent traits. Other authors hope to achieve better adoption rates for improved varieties by quantifying farmers' selection criteria and adjusting breeders' criteria (Defoer *et al.*, 1997). Mekbib (2006), on the other hand, proposes combining farmers' selection with formal breeding in an integrated scheme specifically designed for the centers of crop origin and diversity. This paper focuses on PVS, which is the selection by farmers in their own fields of finished or near-finished products from plant breeding programs. These include released cultivars, varieties in advanced stages of testing, and well-characterized material such as advanced non-segregating lines in inbreeding crops or advanced populations in outbreeding crops. Previously, the conventional method involved considerable time and cost, thereby resulting in the selection of few adapted varieties (Joshi and Witcombe, 1996). The conventional system also restricts farmers' participation in technology development despite their wealth of knowledge and skills in selecting crops and varieties that can suit their needs, fit in local environments, and fulfill consumer satisfaction. An alternative approach is PVS, which employs an intensive system of farmer-managed participatory research (FAMPAR) (Joshi *et al.*, 2002). This system helps farmers to actively participate in selecting breeding lines (Joshi *et al.*, 2002) or the finished varieties. Their early participation helps farmers to select varieties according to their preferences, needs, and other expected characteristics. Such a system has been successfully tested in rice (Dorward *et al.*, 2007; Joshi *et al.*, 2002; Singh *et al.*, 2013; Singh *et al.*, 2014). Participatory varietal selection to identify preferred cultivars has three phases: identifying farmers' needs, searching for suitable material to test with farmers, and experimentation in farmers' fields. Once identified, the seed of farmer-preferred cultivars needs to be rapidly and cost-effectively supplied to farmers. The International Rice Research Institute (IRRI) has been carrying out a project for improving the livelihoods of rice-based rural households in the lower region of the Ayeyarwady Delta (Labutta, Bogale, and Mawlamyinegyun townships) in collaboration with partners, namely, Mercy Corps, Proximity Designs, Welthungerhillfe (WHH), and *Groupe* *de Recherche et d'Exchanges Technologiques* (GRET).

Participatory varietal selection (PVS) research began in the Ayeyarwady Delta of Myanmar in 2012 to involve farmers in selecting their preferred varieties according to their socioeconomic needs and disseminate those in new ways so that the farmers could harvest the benefit of new varieties without delay.

MATERIALS AND METHODS

Rice breeders from department of agricultural research (DAR) and IRRI jointly selected the most promising varieties from Myanmar and IRRI for the PVS trials under LIFT project PVS trials based on their past promising performance in the station trials. Researcher-managed (RM) or "mother trials" involving 16 varieties/lines in the wet season and 12 varieties/lines in the dry season were conducted on-farm using a randomized complete block design (RCBD) with three replications. PVS RM trials were established in each of the six villages in Bogale (Pyin Ma Kone, Mae Taw Su, and Ba Wa Thit), Mawlamyinegyun (Man Dat Chaung Village), and Labutta (Bo Kone and Kyu Taw) townships during the WS of 2012 (Figure 1; Figure 2a-2c). Preference analysis and sensory evaluation were also undertaken (Figure 3) following the procedures described by Paris *et al.* (2011).

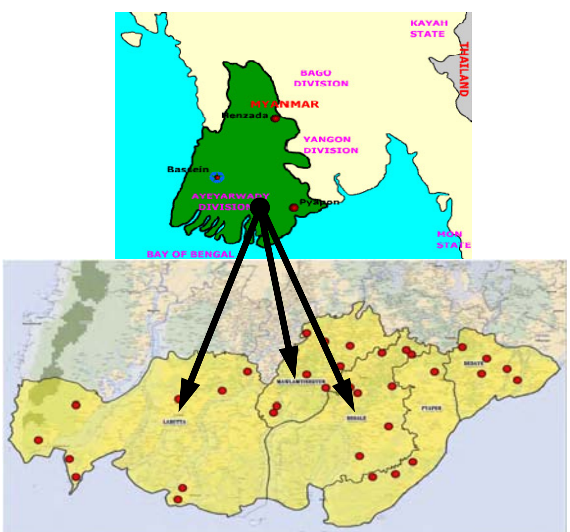
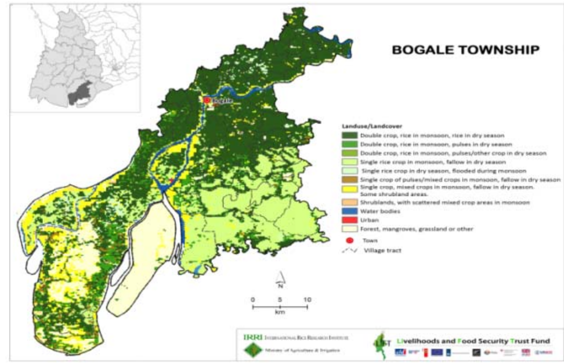


Figure 1. Geographic location of the experimental sites in the Ayeyarwady Delta, Myanmar.

(2a)



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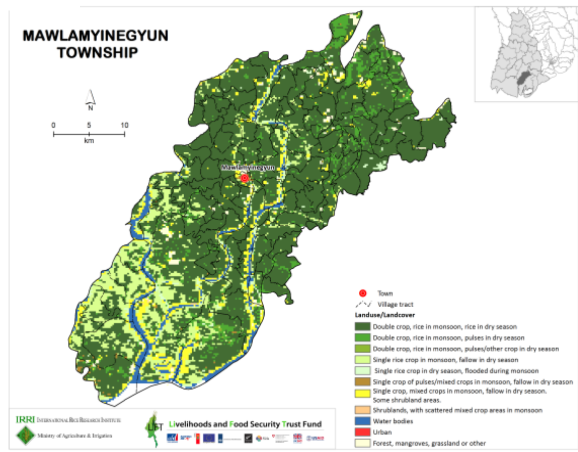

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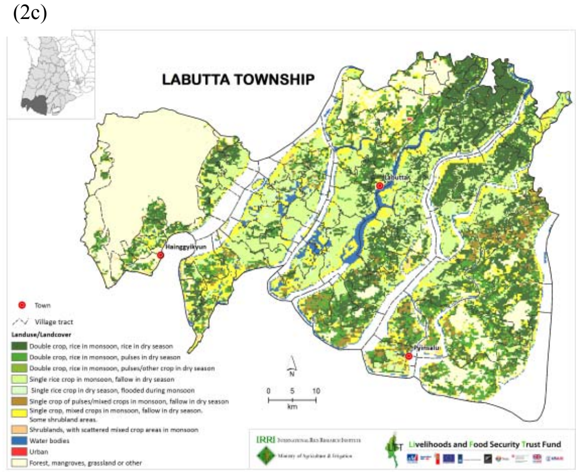

Figures 2a, 2b, and 2c. Project sites in Bogale, Mawlamyinegyun, and Labutta townships, respectively.

Sensory evaluation

The five most preferred high yielding salt-tolerant rice varieties during the preference analysis from the five sites were evaluated for their cooking and eating quality to conduct sensory evaluation (SE). A code was assigned to each sample for SE. A group of male and female participants was involved in an evaluation in which every participant was given a spoon and bottle of water. Drinking of water in between tasting was done to avoid any residual taste or rice sample left in the mouth before tasting the next sample. Each sample was evaluated based on individual acceptability and ranking. Acceptability was indicated by a yes or no response, where yes means acceptable and no means unacceptable. Ranking was done on 1-6 scale to determine farmers' preference where rank 1 and 6 mean the best and the least preferred variety, respectively.

Data analysis

A total of 319 baby trials were set up in the wet season of 2013 and data collected from a total of 117 baby trials in three townships of the Ayeyarwady Delta. Windostat version 3 was used to analyze the data for additive main effect and multiplicative interaction (AMMI) parameters and stability statistics as suggested by Eberhart and Russell (1966).

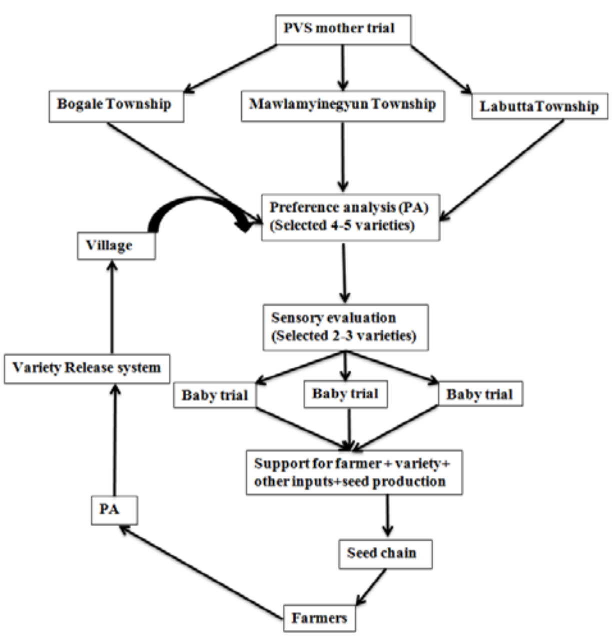

Figure 3. Illustration of a standard PVS mother-baby trial system, variety selection, seed network, and release system: a holistic method of farmers' participatory approach.

RESULTS

PVS mother trials – wet season

Two times during the growing season, farmer groups (a total of 181 farmers from 18 villages across the 6 PVS sites) conducted preference analysis (PA) of the 16 varieties on display in fields, preferably between late flowering and maturity stage. A subset of the farmers (n = 126; 74 were women) who participated in the preference analysis was also involved in SE for an assessment of the cooking quality and taste of the top-ranked varieties with local varieties for blind test. Across six villages in three townships, average grain yield ranged from 2.6 to 3.9 t ha^{-1}, with Paw San Yin having the lowest yield and Saltol Sin Thwe Latt the highest yield during the monsoon/wet season (WS) of 2012. The farmers' variety (Khun Ni), which is a very late duration variety, had an average yield of 3.2 t ha^{-1} (Table 1 and 2). The average yields of the other varieties were 3.4 t ha^{-1} (Sin Thu Ka), 3.8 t ha^{-1} (Shwe Ta Soke), and 3.1 t ha^{-1} (Shwe Pyi Htay). The advantage of Shwe Pyi Htay was its earlier maturity (125 days) than Saltol Sin Thwe Latt (142 days), Sin Thu Kha (140 days), and Shwe Ta Soke (172 days). The farmers' variety Khun Ni took 180 days to mature; hence, it was almost unsuitable for double cropping (Table 1). One of the objectives of the PVS is to demonstrate the importance of the shorter duration variety compared with the farmers' own varieties so that they can identify a suitable variety with high yield through PVS that can fit well into a cropping pattern with two rice crops per year and help to increase cropping intensity.

The farmers voted for Hnan Kar and Shwe Ta Soke as the best varieties during preference analysis (PA) followed by Sin Thu Kha and Saltol STL but the grain yield indicated the superiority of Saltol STL followed by Shwe Ta Soke, Hnan Kar, Sin Thu Kha and Shwe Pyi Htay. Ignoring the maturity duration, we continued the sensory evaluation (SE) of these five top varieties, the top performing and most acceptable variety was Saltol Sin Thwe Latt 2). Saltol Sin Thu Latt was developed using marker assisted backcrossing where Sin Thu Latt was used as recurrent parent

Table 1. Yield of varieties in a PVS mother trial (researcher-managed), wet season of 2012.

Variety name/ Locations	Yield (t ha^{-1})							Maturity (days)
	L1	L2	L3	L4	L5	L6	Mean	
Paw San Yin	2.8	2.9	2.4	3.0	1.8	2.7	2.6	149
Sin Thu Kha	2.7	4.6	3.0	4.6	2.3	3.3	3.4	140
Hnan Kar	3.7	4.8	2.7	3.7	1.8	4.1	3.4	173
Shwe Pyi Tan (PSB Rc68)	3.4	4.1	3.2	3.8	2.4	3.4	3.4	156
Yemyoke Khan Saba (Swarna-Sub1)	4.2	4.1	3.7	3.0	2.6	4.0	3.6	143
CR 1009-Sub1	3.6	4.2	3.8	3.8	2.1	3.2	3.5	145
Sin Thwe Latt	3.7	4.1	3.7	4.6	2.2	3.6	3.7	140
Saltol Sin Thwe Latt	4.5	5.3	3.6	4.9	1.9	3.4	3.9	142
Pokkali	3.7	3.4	3.8	3.0	3.5	3.1	3.4	157
IR71829-3R-10-3	3.7	4.9	3.6	4.2	2.5	2.9	3.6	137
IR71829-3R-73-1-2	3.0	4.5	3.5	3.8	2.4	2.5	3.3	138
IR84649-308-24-1-B	2.7	3.1	2.7	2.2	2.2	3.4	2.7	127
Shwe Ta Soke	4.1	6.2	3.4	3.8	2.1	3.2	3.8	172
Shwe War Tun	3.4	4.3	2.9	4.1	2.6	3.1	3.4	145
Shwe Pyi Htay	3.4	3.2	3.4	4.9	1.8	2.1	3.1	125
Khun Ni (FV)	3.3	3.4	2.6	3.8	2.2	3.8	3.2	180

Locations (L): L1 = Pyin Ma Kone, L2 = Mae Taw Su, L3 = Baw Wa Thit, L4 = Bo Kone, L5 = Kyu Taw, L6 = Man Dut Chaung.

Table2. Comparison of agronomic yield, preference score and sensory evaluation of 5 most preferred varieties in wet season 2012

Variety Name / Location	Average grain yield (t/ha)								Preference Score								Sensory Evaluation							
	L1	L2	L3	L4	L5	L6	Av	Rank	L1	L2	L3	L4	L5	L6	Av	Rank	L1	L2	L3	L4	L5	L6	Av	Rank
STK	2.72	4.57	3.00	2.32	4.59	3.25	3.4	4	-0.02	0.08	0.03	0.00	-0.07	0.15	0.03	3	6	5	5	5	2	2	4.2	3
Hnan Kar	3.55	4.79	2.73	1.75	3.74	4.05	3.44	3	0.00	0.03	0.02	0.09	0.08	0.09	0.05	1	5	2	2	6	6	4	4.2	3
Saltol STL	4.48	5.30	3.57	1.94	4.93	3.36	3.93	1	0.06	0.00	-0.02	-0.22	0.14	-0.03	-0.01	4	1	1	1	3	1	1	1.3	1
STS	4.09	6.23	3.44	2.10	3.81	3.19	3.81	2	0.13	0.00	0.13	0.01	-0.02	0.03	0.05	1	3	3	6	4	5	5	4.3	4
SPH	3.36	3.20	3.42	1.79	4.87	2.14	3.13	5	-0.01	-0.03	-0.12	-0.04	-0.02	-0.07	-0.05	5	2	4	3	1	3	6	3.2	2

Locations (L) 1: Pyin Ma Kone; 2: MaeTaw; 3: Ba Wa Thit; 4: Bo Kone; 5: Kyu Taw; 6: Man Dut Chaung
Varieties STK: Sin Thu Kha; Saltol STL : Saltol Sin Thew Latt; SPH : Shwe Pyi Htay

while Pokkali as donor for Saltol QTL responsible for salinity tolerance (Tin Tin Myint, DAR Myanmar, personal communication). While comparing to the maturity duration of all the selected varieties, Hnan Kar and Shwe Ta Soke were very late and took about 6 months to mature in WS, owing to their photosensitive nature while other three top varieties took 125 to 142 days and did not show photosensitivity. Finally we emphasized more on three varieties (Saltol Sin Thwe Latt, Shwe Pyi Htay, and Sin Thu Kha) based on PE, grain yield, SE and maturity duration and undertook seed multiplication during the 2013 dry season to conduct baby trials.

In the subsequent wet season of 2013, participating farmers were encouraged to select two of the three multiplied varieties and they were given 5 kg (of seed) of each variety to conduct trials with their own (farmer) management in a large plot. Among the lines, Saltol Sin Thwe Latt performed better.

Importantly, this line was released as a variety in 2013 in Myanmar based on PVS data and extensive field evaluation by DAR.

Sensory evaluation and baby trials

A group of farmers visited the PVS mother trials and voted for the most suitable varieties visually that were categorized on a quantitative scale to choose the best ones through preference analysis score. The group of farmers included farmers from neighboring villages in addition to the local farmers.

Through PA and SE, Saltol Sin Thwe Latt, Shwe Pyi Htay, Sin Thu Kha, Shwe Ta Soke, and Hnan Khar were identified as the most preferred varieties and were used for the farmer-managed/baby trials in the WS of 2013. Among the agronomic traits the farmers preferred were more spikelets per panicle, resistance to pests and diseases, uniform tillers, good panicle length, uniform plant height, and lodging resistance. Among the qualities for best cooked varieties mentioned by the farmers were good aroma and taste, white color, glossy finish, tenderness, and cohesiveness. However, Hnan Kar was not included in the baby trial because of its long maturity (173 days). In the WS of 2013, farmer partners were encouraged to select two to three varieties identified through PA and SE and consequently 5 kg of seed of each selected variety were given to 319 farmers to conduct their own baby trials.

Mother trial - dry season

The average grain yield across four freshwater sites in three townships ranged from 1.30 to 6.59 t ha^{-1} in the dry season (DS) 2012-13 trials. IR66946-3R-149-1-1 had the lowest yield in Ngwe Taung Village, while OM4900 had the highest yield in Kyee Chaung Village (Figure 4a). For the saline-prone environment (4-8 dSm^{-1}), average grain yield across six sites ranged from 0.72 to 4.23 t ha^{-1}. Theedat Yin (DAR) had the lowest yield in None Chaung Village while IR10T 109 had the highest yield in Gan Hnyin Tan Village (Figure 4b). It can be observed that grain yield under fresh water areas is twice of saline-prone areas. Earlier planting in November and December could help reduce the risk of salinity intrusion during the harvest time in April.

To find the suitability of the materials for the dry season for the promotion of double cropping, another set of participatory varietal selection researcher-managed (PVS RM) trials or mother trials was established during the dry season cropping (December 2012-January 2013 sowing) in 15 farmers' fields (six in Labutta, six in Bogale, and three in Mawlamyinegyun; Supplementary Fig. 1-3) and harvested in April 2013.

(a) Fresh areas

(b) Saline areas

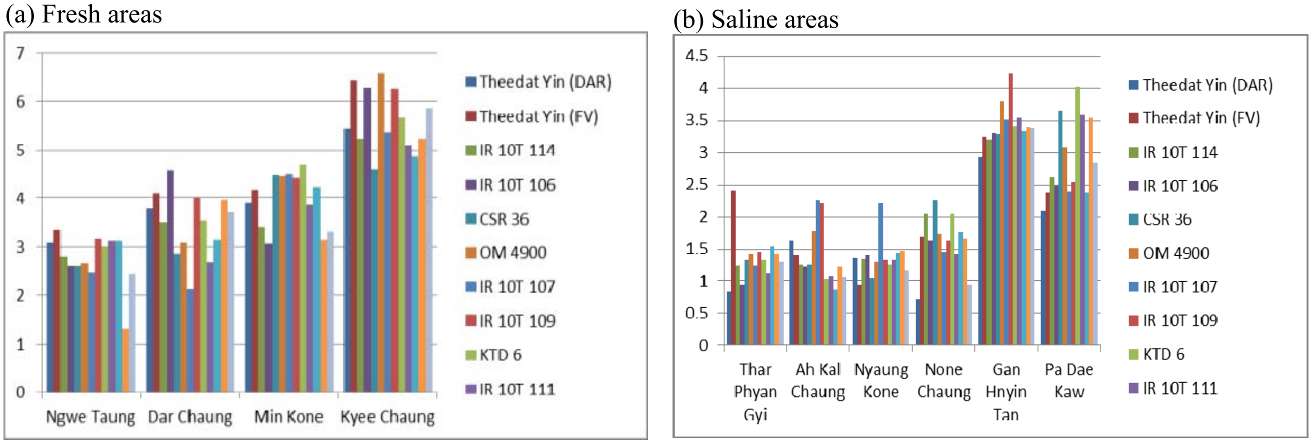

Figure 4. Yield of different genotypes evaluated in (a) freshwater areas and (b) salinity-prone areas, dry season, 2012-13.

Four villages represent the freshwater environment (two in Bogale and one each in Mawlamyinegyun and Labutta) and 11 villages are saline-prone environments. The trial consisted of 11 salinity-tolerant high yielding rice varieties with 115–119 days' maturity, and these were compared with the farmers' variety (Theedat Yin) with 119 days' maturity as a local check. Agronomic data were collected from 10 villages only since five villages (one village in Mawlamyinegyun and four villages in Labutta) were damaged by the intrusion of highly saline seawater. Salt-tolerant varieties could yield up to 50% of their potential yield under non-stress environments. Across sites, the grain yield obtained in the saline-prone areas is about 50% less than the grain yield obtained from freshwater areas (Table 3).

The most preferred varieties for the dry season identified through PA (178 farmers; 52 were women) and SE (142 farmers; 65 were women) with about one-third female respondents, were IR10T107, IR10T108, IR10T111, and CSR36 (Figures 5 and 6). Seeds of these entries were multiplied at DAR from July to November 2013. As a component of the PVS farmer-managed or baby trials, 10 kg of seeds from each of these two to three varieties were distributed to 73 farmers in Bogale, 43 farmers in Mawlamyinegyun, and 114 farmers in Labutta Township in December 2013. Although IR10T109 was also preferred by farmers in PA, this variety was dropped as we found some non-uniformity in entry performance.

Preference analysis in dry season of 2013

Using the experimental fields of PVS mother trials, farmers' preferences for varieties and their selection criteria were elicited through preference analysis. Only five PVS RM or mother trials were used for the preference analysis. Farmers from other villages were invited to participate in the exercise.

Table 3. Grain yield (t ha^{-1}) of salinity-tolerant rice in Bogale, Mawlamyinegyun, and Labutta townships, dry season, 2012-13.

Variety	Freshwater				Saline-prone (4 - 8 dSm^{-1})			
	Bogale	Labutta	Mawlam yinegyun	Across 3 sites	Bogale	Labutta	Mawlam liyegyun	Across 3 sites
IR10T106	3.80	3.06	6.28	4.38	1.30	3.31	2.48	2.36
IR10T107	2.31	4.50	5.36	4.06	1.80	3.52	2.39	2.57
IR10T108	3.13	4.24	4.85	4.07	1.40	3.33	2.38	2.37
IR10T109	3.57	4.43	6.25	4.75	1.66	4.23	2.54	2.81
IR10T111	2.90	3.86	5.09	3.95	1.24	3.54	3.59	2.79
IR10T114	3.15	3.42	5.23	3.93	1.48	3.20	2.61	2.43
IR10T117	3.07	3.32	5.86	4.08	1.12	3.38	2.83	2.44
CSR36	2.74	4.48	4.60	3.94	1.48	3.29	3.64	2.80
OM4900	2.87	4.46	6.59	4.64	1.56	3.80	3.08	2.81
KTD6	3.28	4.69	5.67	4.55	1.42	3.40	4.02	2.95
IR66946-3R-149-1-1	2.63	3.13	5.23	3.64	1.44	3.39	3.54	2.79
Theedat Yin (FV)	3.72	4.19	6.43	4.78	1.61	3.24	2.38	2.41
LSD (5%)	1.33	0.48	0.74	0.88	0.55	0.898	1.63	0.67
CV	19.65	7.11	7.84	12.23	26.76	15.54	33.51	15.34

Pedigree of IR10T lines: IR10T106: IR 66946-3R-178-1-1/2*IR64680-81-2-2-1-3; IR10T107: IRRI 126/IR71606-1-1-4-2-3-1-2; IR10T108: IR68144-2B-2-2-3-1/IR66946-3R-78-1-1//IR77080-B-4-2-2; IR10T109: NSICRc106/AS996; IR10T111: IRRI147/IR 66946-3R-178-1-1; IR10T114: NSIC Rc106/IR 7080-B-34-3; IR10T117: IRRI147/IR66946-3R-178-1-1

Figure 5. Preference analysis conducted in Kyee Chaung Village, Bogale, 10 April 2013.

Figure 6. Preference analysis was done in Thar Phyan Gyi Village, Bogale, 8 April 2013.

The results revealed no correlation between farmers' (both male and female) preference for the varieties and yield at the sites under study except for Dar Chaung, Bogale, with r = 0.566, at the 5% level of significance (Table 4). This indicates two things: that either farmers were not able to predict the high-yielding varieties, based on yield or performance potential, simply by visual observation, or that the females, who do most of the purchasing and cooking, have different perspectives when selecting varieties. Further, these results indicate that yield is not the only criterion for selecting rice varieties. These findings shed light on the importance of testing varieties under farmers' field conditions to identify location-specific varieties with better adaptation and traits that meet local needs.

Table 4. Association between farmers' scores and rice yield, Myanmar, dry season, 2012-13.

Sites (municipality, province)	Participants (no.)		Varieties (no.)	Correlation between male and female farmers [a] (r)
	Males	Females		
Labutta				
Min Kone	23	8	12	0.136 (ns)
Gone Hnyin Tan	20	5	12	0.475 (ns)
Bogale				
Dar Chaung	19	6	12	0.566*
Thar Phyan Gyi	15	10	12	−0.148 (ns)
Mawlamyinegyun				
Kyee Chaung	25	8	12	0.512 (ns)

a* = Significant at the 0.05 level (2-tailed), ns = not significant.

Sensory analysis - dry season

The lines IR10T107 and IR10T108 were consistently chosen as the most preferred varieties because of the following characteristics: good taste, white color, gloss, tenderness, and cohesiveness (Figure 7). IR10T111 and CSR36 were also constantly preferred by farmers because of grain shape, taste, and aroma. The farmers' variety and IR10T106, on the other hand, were least preferred because of their fair taste, hardness, fair cohesiveness, and lack of aroma. Varieties IR10T107, IR10T108, and CSR36 were recommended for seed multiplication for the baby trials in the 2013-14 dry season crop based on preference and sensory analysis.

Baby trials - wet season

There were different combinations of four rice varieties, Shwe Pyi Htay (SPH), Saltol Sin Thwe Latt (Saltol STL), Sin Thu Kha (STK), and Shwe Ta Soke (STS), and the farmers' variety (FV) evaluated under a baby trial. We report here only the varietal combination of four varieties, Variety 1. SPH; Variety 2. Saltol STL; Variety 3. STK; and Variety 4. FV, because this combination was tested at 50 farmers' locations. We analyzed the varieties for stability using the Eberhart and Russell model (1966) based on mean (μ), regression (β_i), and deviation from regression (S^2_{di}) that inferred significant differences among the varieties (G) as well as environments (E). The G x E interaction was also found significant (Table 5). Saltol STL (4.67 t ha^{-1}) attained the highest average yield, followed by STK (4.39 t ha^{-1}) and SPH (4.07 t ha^{-1}). FV yielded 4.20 t ha^{-1}. Since the farmers' variety changed from one location to another, the average is not an indication of the yield of the same variety. But still, the farmers' variety is like a check to compare the performance, so the higher yield above that of the check infers the superiority of the test varieties.

Table 5. Analysis of variance for stability of genotypes under baby trials across environments during 2013 WS

SV	df	MSS	F-Value
Rep within Env	100	0.078	0.145^{ns}
Varieties	3	3.328	6.172**
Env +(Var x Env)	196	2.374	4.403**
Environments	49	7.347	13.623**
Var x Env	147	0.717	1.329*
Environments (L)	1	360.015	667.53**
Var x Env (L.)	3	0.616	1.143ns
Pooled deviation	192	0.539	7.572**
Pooled	300	0.071	

*,** : significant at P=0.05 and 0.01 respectively

Figure 7. Sensory analysis was done in Min Kone Village, Labutta, 24 April 2013.

Table 6. Stability parameters for genotypes under baby trials across environments during 2013 WS

Variety	Mean (μ) (t/ha)	Regression value (B_i)	Deviation from regression (S^2_{di})
Shwe Pyi Htay (SPH)	4.07	0.939	0.414**
Saltol Sin Thwe Latt (Saltol STL)	4.67	1.072	0.631**
Sin Thu Kha (STK)	4.40	1.070	0.389**
Farmers variety (FV)	4.20	0.918*	0.431**
LSD (P=0.05)	0.105		

*,** : significant at P=0.05 and 0.01 respectively

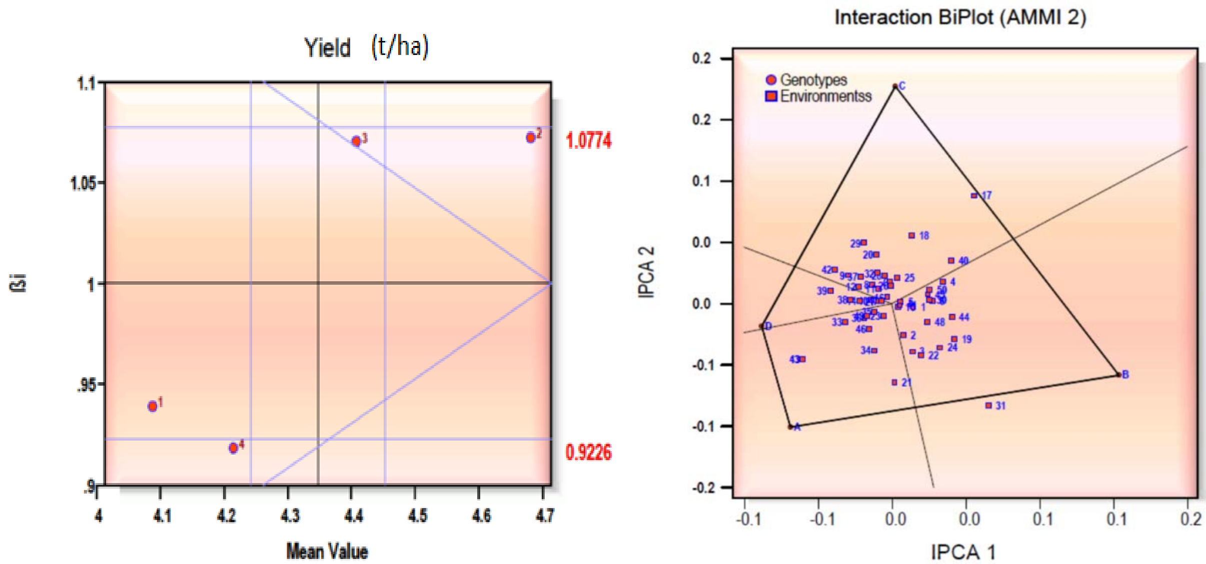

Figure 8a. Mean grain yield (μ) and β_i, values indicating high and low stable genotypes; **8b**. Plot of the principal components of standard values of stability of yield, estimated by using yield data from four rice genotypes grown in 50 environments. (here, 1, 2, 3, and 4 and A, B, C and D refer to Shwe Pyi Htay (SPH), Saltol Sin Thwe Latt (Saltol STL), Sin Thu Kha (STK), and farmers variety (FV) , respectively, for both graphs.

SPH (1), Saltol STL (2) and STK (3) were found to be more stable varieties than FV (4) because of significant regression (β_i) different from unity. Although the deviation from the regression (S^2_{di}) value different from 0 for all the genotypes but the values are not much higher and invariably show significance for the abiotic stress experiments (Table 6, Figures 8a,b).

DISCUSSION

Four varieties (Saltol Sin Thwe Latt, Shwe Pyi Htay, Sin Thu Kha, and Shwe Ta Soke) were preferred in the wet season and IR10T107, IR10T108, and CSR36 during the dry season through preference analysis. Male and female farmers showed their distinct interests and willingness to adopt the varieties they preferred. This methodology contributed significantly to facilitating varietal selection based on farmers' preference, and is useful for considering the potential to consolidate selection indicators used by breeders, agronomists, agricultural extension workers, and farmers.

Varietal development is the foundation for improving the ability of rice farmers to feed growing populations in some of the world's poorest nations and making a difference in livelihood. In Myanmar, a research institute needs approximately 15 years to develop a new rice variety (Figure 9). Constraints to varietal development and accessibility to improved germplasm in Myanmar are (1) the lack of varieties adaptable to different agro-ecological conditions; (2) the lengthy varietal evaluation procedures commonly used in Myanmar that limit the release of superior varieties; (3) limited resources for varietal development research; (4) fewer personnel trained in plant breeding, including modern breeding tools; and (5) weakness in properly maintaining varieties after they are released because of the lack of skilled personnel in maintenance breeding programs. To overcome the constraints and reduce time and resources in current varietal development and adoption efforts, the farmers' participatory approach may help in the evaluation and rapid dissemination of new germplasm corresponding to the needs and preferences of farmers, consumers, and traders in Myanmar through work done by IRRI and its research partners.

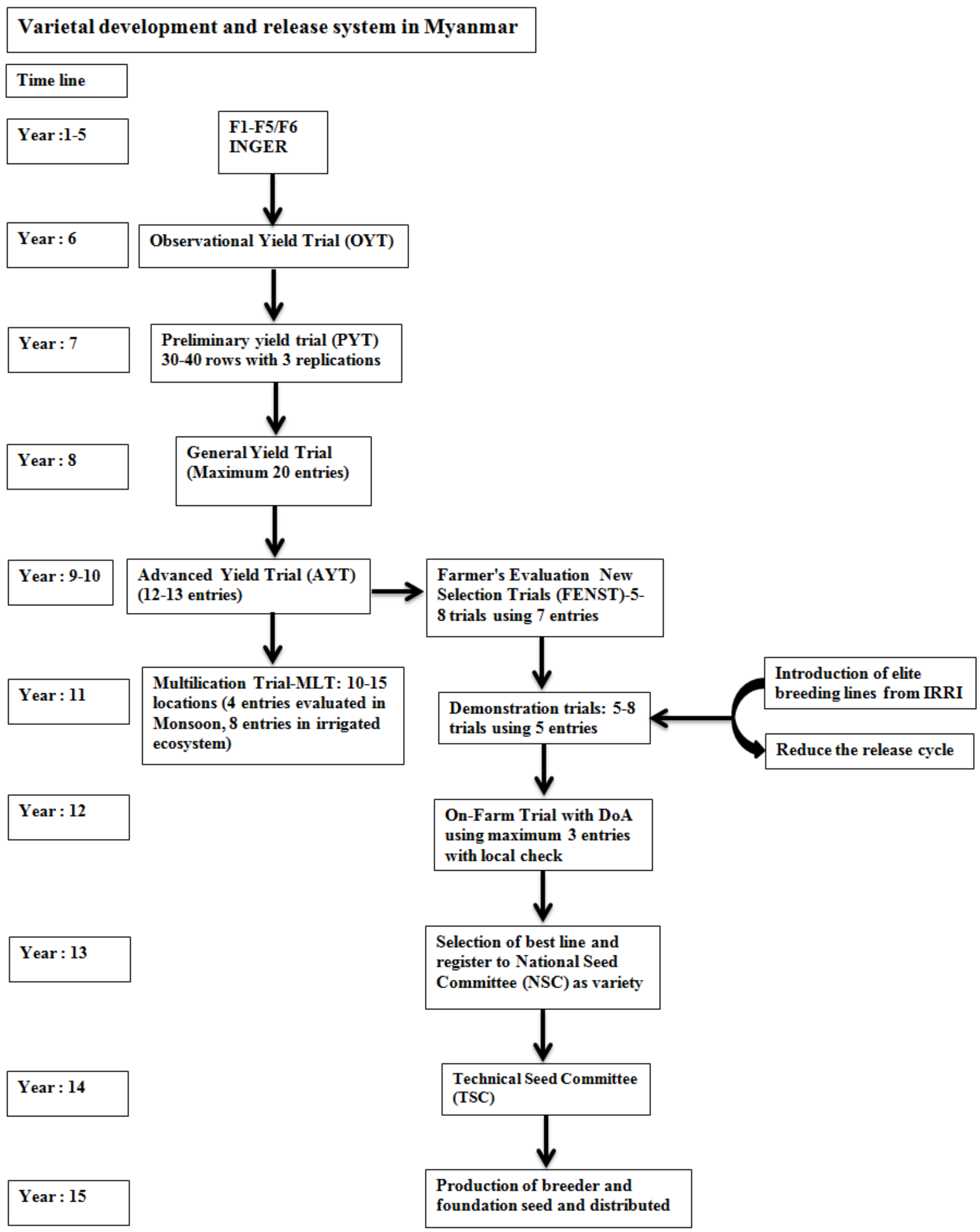

Figure 9. The varietal development and release process in Myanmar.

Farmers' participation a key to varietal selection process

Selection is the key activity in any breeding program and it occurs at all stages of the breeding process: choosing the composition of base material, selecting parents for crossing, selecting among progenies, selecting among experimental varieties, and maintaining breeder seed stocks. Selection is often conducted for several traits simultaneously, and thus requires consideration of their relative economic importance (what trade-offs are to be made) and their heritabilities (how much opportunity for progress). Each of these selection stages is normally conducted at experiment stations where uniform conditions and facilities for handling large numbers of test materials exist.

Farmers' visits to experiment stations are usually limited to viewing demonstration plots of a few highly selected advanced varieties. Feedback from farmers on these displayed options is usually not sought, and opportunities for their input into the selection process are thus extremely limited, which should not be the case, if breeders want quick adoption and dissemination of varieties among farmers (Singh *et al*., 2013; 2014). However, the possibilities for farmers' participation in selection are as diverse as the nature of selection itself, for example, selection among single plants, progeny rows, experimental varieties, selection on-station, or selection on-farm.

We have experimented with farmers' participation in selection among new varieties grown in on-farm conditions in order to supplement our conventional on-station varietal evaluations with farmers' opinions and observations. This activity was also intended to improve our understanding of farmers' preferences for different varietal traits. It presented a wider range of genotypes to farmers who selected prospective ones through PVS under on-farm conditions.

Farmer participation in the breeding of crop varieties for low-resource farmers is regarded by some as necessary to ensure acceptance and eventual adoption (Franzel *et al*., 1995; Gyawali *et al*., 2007; Maurya *et al*., 1988; Mekbib, 2006; Nkongolo *et al*., 2008; Prain *et al*., 1992; Sperling *et al*., 1993). Despite the importance of rice as a staple food, little research has been carried out in this stress-prone area of the Ayeyarwady Delta of Myanmar.

Participatory varietal selection can be used effectively to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Joshi and Witcombe, 1996; Witcombe *et al*., 1996; Witcombe *et al*., 2006). Moreover, participatory research increases the research thought and efficiency of the scientists (Bellon, 2001) and farmers' knowledge that enables it to be retained effectively from year to year (Grisley and Shamambo, 1993). Research costs can be decreased and adoption rates increased if farmers are allowed to participate in varietal testing and selection (Joshi *et al*., 1995). In addition, production increases when farmers adopt new varieties identified in participatory research (Witcombe, 1999).

Probably, this was the first time to introduce PVS in the Ayeyarwady Delta when a large number of selected varieties/elite lines were evaluated in different villages and selection made by the farmers themselves. This has increased the genetic diversity of cultivated rice and eventually reduced the risk of a disease epidemic. Increased biodiversity is very useful since pathogens and pests are exposed to particular genotypes for less time and have less chance to overcome host-plant resistance (Witcombe *et al*., 1996; Olaoye *et al*., 2009). For varietal diversity, it is also advisable to address varied physical environments, socioeconomic conditions, and the needs of farmers. The widespread adoption of participatory methods at the national level will almost certainly increase the replacement rate of old cultivars, so that the weighted average age (number of years since release) of cultivars grown by farmers will decrease and biodiversity over time will increase (Witcombe *et al*., 1996).

Selection criteria of the farmers to choose the variety was not much different than the breeders but still it is better to involve them in selection and variety release process. Both male and female farmers used selection criteria for submergence- and salinity-tolerant rice varieties included uniform plant growth, good spikelet formation, few unfilled grains, long grain shape, tolerance of submergence and saline water intrusion, resistance to pests and diseases, medium plant height, and fewer days to maturity, with high grain yield. Female farmers were more focused on cooking quality traits as they are dealing with quality related traits every day. Aromatic varieties were preferred over non-aromatic rice varieties. Our research experience showed that farmers are eager to participate in selecting new varieties that can be further tested in their own fields as a baby trial under circumstances that represent their conditions. Hence, it is important to include farmers in varietal selection.

The inferences from wet season baby trials can be summarized in the present study as follows:

a. Since all three varieties, Shwe Pyi Htay (SPH), Saltol Sin Thew Latt (Saltol STL) and Sin Thu Kha (STK), fall within a β_i value that is non-significantly different from 1, the best ones are chosen based on the highest mean yield.

b. Although farmers used different rice varieties (mostly local) at different places as farmers variety (FV), but still it was found to be unstable due to significant regression value ($\beta_i \neq 1$).

c. Saltol STL, which is also a stable variety based on its non-significant β_i value from unity, has the highest mean yield (4.67 t/ha) and is the most suitable variety for delta areas, including high-performance in favorable environments. STK is another best bet variety which is stable along with better yield than farmers varieties. It is also suitable for the favorable environments as well.

d. SPH is also stable varieties but relatively low yielder hence cannot be recommended over Saltol STL. However, SPH is better adapted to low-performing environments (placed on lower side of β_i confidence limit in fig 8a) with reasonable yield of 4.1 t/ha and hence could be recommended for the poor environments.

e. Overall, based on mean across 101 farmers' locations (including 50 locations analysed for stability using Eberhart and Russell model) and stability parameters, Saltol STL is the best variety, followed by STK and SPH for the across-delta region.

f. Based on the AMMI model, 50 common environments are clustered into four groups depending upon their interaction with genotype for expression of a trait (yield/ha). The locations where variety Saltol STL performs best, is represented by the cluster of locations with Saltol STL on vertex (variety B in figure 8b) in positive direction. Similarly next best variety at most of locations is STK (variety C on vertex in figure 8b) that performed better at many locations in positive direction. There were number of locations where SPH (variety A on vertex in figure 8b) was top yielder and in negative direction for the components. It further strengthen the evidence that SPH is better under higher stress environments. We can go back to the sites (farmer locations) and probably correlate with the stress level. The number of environments relates to the farmers' location on the data sheet. This might be the most important part for segregating varietal preference based on stress level and location (Fig. 8).

Since Saltol STL is adjudged as the best variety under baby trials with an average grain yield of 4.57 t ha^{-1} tested over 101 locations and found to be very consistent, hence this huge data set gives us confidence in this variety. Besides the average performance over locations, this variety was found to be a very stable variety. Importantly, stress-tolerant rice varieties are low yielders but Saltol STL is a high-yielding stress-tolerant rice variety that performs better under non-stress environments. We did much detailed analysis for 2012WS selections followed by their baby trials in 2013WS comparing to DS selections but complete analysis and inferences for both the seasons over years would be processed after the project completion.

The lack of information about improved varieties and accessibility to good-quality seeds are two major reasons for the poor adoption of improved varieties. Information dissemination could be made possible through the combined efforts of breeders, agronomists, social scientists, agricultural extension workers, and local government officials in reaching farmers. The advantage from PVS could be attained when seeds of farmers' preferred varieties and associated technical knowledge are made easily available to them (Singh *et al*., 2013; 2014). The non-availability of quality seeds of farmers' preferred varieties at the right time, in the desired quantity, and at a reasonable price is identified as the major constraints in marginal rainfed and coastal areas.

The farmers' role is a primary interest in this study as they are the targeted end-users of the technologies being developed for unfavorable rice environments. Since they are sources of local knowledge, there is greater likelihood of farmers adopting a technology if they become involved early in project implementation. Hence, farmers' preferences should be considered in technological development and dissemination strategies if research investments are to be environment-friendly, cost-effective, and impact-oriented.

CONCLUSIONS

This is the first time when farmers participatory approach was extensively used in Myanmar to identify the suitable variety for the target environments that suits the need of farmer as well as consumers (sensory evaluation). A separate set of rice varieties for WS and DS were selected by the farmers based on preference score, grain yield and sensory evaluation. Four rice varieties were shortlisted in both the seasons and tested extensively as baby trials.

Shwe Pyi Htay (SPH), Sin Thu Kha (STK), and Shwe Ta Soke (STS) were found to be more stable varieties for WS based on large scale baby trial analysis. Since Saltol STL is adjudged as the best variety under baby trials with an average grain yield of 4.57 t ha^{-1} tested over 101 locations and found to be very consistent, hence this variety is proposed as most suitable in Ayeyerwady region based on huge data set. Besides the average performance over locations, this variety was found to be a very stable variety. Importantly, stress-tolerant rice varieties are low yielders but Saltol STL is a high-yielding stress-tolerant rice variety that performs better even under non-stress environments.

The farmers' participatory approach helped us in the rapid dissemination of these new varieties; otherwise, a long period, typically 5–6 years, is required in the conventional system to commence appreciable adoption after official release. Farmers' selected varieties are extending very rapidly and increasing varietal diversity. Farmer-to-farmer seed transfer was found to be very effective in scaling-up seed transfer and increasing varietal diversity.

ACKNOWLEDGEMENTS

We thank the United Nations Office for Project Services-Livelihoods and Food Security Trust Funds (UNOPS-LIFT) for financial support and institutional partners (Mercy Corps, GRET, Welthungerhillfe-WHH, and Proximity Designs) in the Ayeyarwady Delta, Myanmar, for their assistance in conducting this research work.

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