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Research Article
Economic Analysis of Paw San Rice Adoption in Myanmar

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Abstract

Background and Objective: After the liberalization of domestic and international market in 2003 and completely liberalization rice exports in 2011, Myanmar became an emerging economy in Southeast Asia. To generate export revenue, Paw San rice is considered market-driven export products. Paw San rice is a premium quality rice of Myanmar. Awarded the world's best rice in 2011, the variety has a great potential to generate export revenue. However, despite its popularity, its production in Myanmar is very limited. The study aimed to reveal its economic benefits to farmers and identify factors contributing to the wider adoption of Paw San rice in Myanmar. **Methodology:** Farm survey data were collected for 561 rice farms from 370 rice farmers in Sagaing and Ayeyarwaddy regions in the monsoon season of 2013. Cost and return analysis of rice cultivation and a binomial logit model of Paw San rice adoption are used. **Results:** The results show that price and revenue from Paw San rice cultivation are significantly higher than from non-Paw San variety. Variable profit was also higher particularly in Ayeyarwaddy region where it is a traditional variety but not in Sagaing region where it was a recent introduction. The study also found that farmers in Ayeyarwaddy region who recognize the relative advantages of Paw San rice such as resistance to the rice stem borer and a higher market demand and price are more likely to adopt Paw San rice than those who do not. Its adoption in Sagaing region could be accelerated by promoting it to farmers with higher educational attainment, more experience and larger-scale farms. Farmers who avoid crop loss from rain damage by selecting varieties suitable to the area's climatic pattern and the typical planting time are more likely to be Paw San rice growers in both regions. **Conclusion:** Paw San rice significantly generates higher income for Myanmar farmers. To alleviate poverty and create export revenue, the results suggest that increasing the adoption and supply of Paw San rice may be driven through the development of high yielding Paw San rice variety with good cooking quality and government support to promote positive market signal such as high price.

Key words: Paw San rice, aromatic rice, fragrant rice, adoption, cost and return

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

During the 1930s, Myanmar was the world's largest rice exporter at about 3 million tons annually. Exports considerably reduced after the1930s and nearly vanished in the 1970s[1]. Market liberalization in the late 1980s led to the lifting of the ban on private exports in 1988; in 2004 export of rice was again privatized[2]. Rice exports started to expand after the liberalization of domestic and international markets in 2003[3] and by 2013/14 it had reached 1.6 million tons, the highest level in 40 years[4]. The government set target of rice exports of 2 million tons a year by 2015 and 4 million tons by 2020. However, the quality and price of the rice exported from Myanmar remain lower than the international market even as world demand for aromatic rice has increased as a result of the preference for high quality rice of high-income consumers[5]. At present, the price of aromatic rice is more than double the price of normal white rice[6] but the share of aromatic rice exporters in the world market remains small. In Southeast Asia, Thailand used to be the sole exporter of Jasmine rice. Recently, however, Vietnam and Cambodia have emerged as important exporters, Vietnam since 2007 and Cambodia beginning 2013.

Rice has been the focus in the history of Myanmar economic development. The IFAD[7] found that Myanmar is lack of market oriented production and one of the ways to alleviating poverty, development policies for promoting market-driven agriculture are recommended. After the abolishing of government procurement system that distorted the rice market, allowing private rice export in 2007 and completely liberalized rice export in 2011[8], Myanmar has the potential to capture the higher-value segments of the world aromatic rice market. Potential markets include the European Union and in the region Singapore, Hong Kong and most Southeast Asian countries for high quality aromatic rice[1,9] such as Paw San. Myanmar's Paw San rice is one of the world's most recognized high quality rice, it was awarded the world's best rice at the Rice Trader's World Rice Conference in 2011. Paw San rice has a similar aroma, grain quality and eating quality to the reputable aromatic rice varieties of the world, namely Basmati of India and Pakistan and Jasmine of Thailand. It has a strong aroma similar to Jasmine rice and the fluffiness and elongation-up to 3 times after cooking of Basmati rice. Despite these qualities, Paw San rice has not made it to the export market due to its low yield. As well, a high domestic demand leaves little to export. The low yield has been an important barrier to its wider adoption; only about 6% of the area under rice cultivation was planted to Paw San in 2013. In order to meet export target and increase export value, Myanmar would need to promote the wider adoption of Paw San rice. To support the campaign for adoption, the county also would need to develop the infrastructure and the technology to increase productivity[1,10,11].

However, there are no evidences on economic benefits of Paw San rice cultivation; this study sheds light on the comparison of the revenue and variable profit between Paw San rice and non-Paw San rice and identifies factors contributing to the adoption of Paw San rice. The purpose is to draw implications for policy needed to widely promote the adoption of Paw San rice production in Myanmar.

As in most Asian countries, rice is a staple crop in Myanmar. The decision to adopt a rice variety would thus be influenced not only by the income derived from its farming but also by the preferences of the household for its eating quality. Attitudes towards production and consumption play an important role in rice variety adoption[12,13]. Feder *et al.*[14] provided a comprehensive review of constraints to the diffusion of agricultural innovation. The evidences suggest that farm size (representing wealth and ability to take more risk), risk (such as vulnerability to weather and pest), human capital (i.e., education), availability of labor, credit constraint, input supply constraints (i.e., high-yielding seed and fertilizers) are key factors affecting the adoption of agricultural innovation in developing countries. In addition to the technical factors, Doss[15] highlighted the importance of well-designed enabling policies, capable institutions and the infrastructure that facilitates the supply of inputs, production and marketing. Access to financial capital (credit or cash), access to information (i.e., via extension services) and access to labor (household and hired) are important enablers to the adoption of agricultural technology. Infrastructure and irrigation significantly contribute to the adoption of improved rice varieties[16,17].

The relative advantage over existing technology, compatibility with needs and beliefs, complexity, triability and observability of the new technology are key attributes that influence the adoption of innovation[18]. The relative advantage of varietal traits such as drought and flood tolerance[13] and yield[16,19,20] was also found to significantly affect the adoption of rice varieties. Attributes of the technology such as labor requirement and input requirement[20] and suitability of climate, soil conditions and land type comprise a 3rd set of factors that influence the adoption of rice varieties[13,17,19,21,22]. This is consistent with compatibility attribute of the technology, according to Rogers[18]. Previous studies have shown that farm characteristics such as farm size[21,22], farmer characteristics such as age[19], education[12,21] and experience[12], as well as institutional factors[19,23] particularly extension services are key determinants in rice variety adoption.

There are 5 groups of rice in Myanmar: Emita, Let YweZin, NgaSein, Byat and Meedon[24]. Paw San rice is in the Meedon group and is the most popular and widely cultivated quality rice due to its superior quality and the strong demand for it, which enable it to command a high price in the local market. It has a strong aroma, extreme elongation after cooking and dry fluffy texture when cooked[25]. Although its grain is short, opaque and chalky, it expands to three times longer upon cooking. Local Paw San varieties are photoperiod sensitive although some improved Paw San varieties such as Paw San Yin are not. The yield of Paw San rice is significantly lower than that of modern rice varieties but has preferred eating qualities particularly aroma. Except for Paw San Ying, Paw San rice is more vulnerable than the modern varieties to pests such as rice stem borer, a major threat to rice crops in Myanmar and to diseases such as bacterial leaf blight.

The names of Paw San rice vary by location and official names may be different in the market. For instance, Paw San Gyi is called Shwebo Paw San and both Paw San Yin and Paw San Gyi are called Paw San Hmwe in the market. Paw San Yin is non-photoperiod sensitive and has a strong aroma which however fades after 5-6 months. In contrast, Paw San Gyi is photoperiod sensitive and retains its aroma for up to 2 years with proper post-harvest technology and good storage. Paw San Hmwe is the best aromatic variety. It was developed by pure line selection of the Paw San group in 1944. It is known as "Myanmar pearl rice" in the world market and was awarded the world's best rice in 2011.

The majority of Myanmar people prefer intermediate amylose rice (23-24%)[14] contributing to hardness quality. Amylose Content (AC) of Paw San rice is 21-24.9%, compared to 14.5% of Jasmine rice or Khao Dawk Mali 105 of Thailand. The low AC of Jasmine rice makes it soft and preferred by Thais, Chinese and many Europeans. Basmati and Paw San rice have medium AC, the hardness quality preferred by South Asians, British and Middle Eastern consumers[26]. In the domestic market, Paw San rice has more than double the price of some high yielding varieties. However, its suitability to a very specific climate and long maturation period has largely confined its cultivation to mainly Ayeyarwady and Sagain regions[9] and in small areas in Bago, Mon and Rakhine States. Pathein, Phyapon and Myaungmya delta are the major areas of Paw San rice production[25]. In 2012/13, about 391,000 ha of Paw San rice were planted to the variety, which was 6% of the county's total rice production area[1]. The production of Paw San rice slightly has increased in the last few years; however, the adoption of the variety remains very limited. Even though it was observed that a large number of farmers switch varieties in a single season depending on the outcome of the previous crop[1], it is hypothesized in this study that the adoption of Paw San rice also depends on other production constraints and farmer's perception of the characteristics of the variety including its productivity and market price.

Myanmar farmers typically make choices of variety based on the adaptation to growing environment, eating and cooking preferences, market preference and price and cost of seed[10]. More than 70% of the rice in Myanmar is planted during the monsoon season[1] and 70-80% of these are modern varieties. Almost the entire summer crop consists of modern varieties because of their early maturity and the absence of flooding risk. Local varieties, including Paw San rice are often preferred by farmers during the monsoon season especially in areas that are prone to flooding and drought because local varieties are generally less responsive to fertilizers. As such the farmers could avoid additional loss in case the crop is damaged by flood or drought. Most Myanmar farmers today plant seed from their own harvest or from neighboring farms, rather than buying new seed.

MATERIALS AND METHODS

This study was carried out in two major areas of Paw San rice production, namely Ayeyarwaddy and Sagaing regions. Sagaing is located in the Western banks of the Irrawaddy river, while Ayeyarwaddy also known as the rice bowl of the country is in the Southwestern part of the central plains. As Paw San riceis mostly cultivated during the monsoon season, the farm-level survey was carried out in the June-July, 2013 to December, 2013/January, 2014 cropping season. A three-stage stratified random sampling method without replacement was used for the farm survey. The first stage employed the intensity criterion, major zone (Paw San rice area is greater than 50% of rice sown area) and minor zone of Paw San rice cultivation. Intensity represents the suitability of the variety to area as well as the observability attribute of the technology. The existence of a seed farm in the district, corresponding to triability and access to inputs, was used as the criterion for the second stage. As a result, Shwe Bo, Monywa, Sagaing and Tamuu districts under Sagaing region and Pathein, Phyapon and Maubin districts under Ayeyarwaddy region were randomly selected. Finally, in the last stage, farm households were proportionally selected based on total farm households. Given the total households of 610,547 from selected districts and presuming $p = 0.5$, $d^2 = 5\%$, the sample size was 370 rice farmers. The respondents were randomly selected from 22 villages.

Farmers are assumed to make a decision based on maximization of expected utility (or profit) subject to

Table 1: Varietal characteristics of Paw San rice compared to modern varieties

	Paw San rice			Modern varieties	
Characteristics	Paw San Mhwe	Paw San Bay Kyar	Paw San Yin	Manawthukha	Sin Thwelatt
Maturity time/life-period (days)	Mid-January	Early to mid-January	145	130-135	140
Aroma	Aromatic	Aromatic	Aromatic	-	Slightly aromatic
Amylose content (%)	21	21	24.2	26.5	n/a
Photoperiod sensitivity	Yes	Yes	No	No	No
Eating quality	Excellent	Very Good	Very Good	Good	Good
Drought resistance	Moderate	Moderate	Good	Good	Good
Flood resistance	Good	Good	Moderate	Moderate	Good
Resistance pest	Moderate	Moderate	Resistance	Resistance	n/a
Resistance diseases	Moderate	Moderate	Resistance	Resistance	n/a
Year released	1944	1955	n/a	1978	1998
Potential yield (tons ha^{-1})	2.58	3.1	3.61	5.15	6.65

Source: Department of Agriculture[28]

constraints such as land availability and credit[14]. Random utility model is adopted in this study to estimate the probability of choices made by farmers. The choice made by a farmer is perceived to have a larger utility than alternatives[27]. The choices of rice varieties (Y) in this study are classified as Paw San rice adoption (Y_1) and non-Paw San rice adoption (Y_0). Paw San includes all Paw San rice varieties since they significantly fetch a higher price than other varieties and have distinctive quality characteristics (Table 1). As one farmer may have more than one rice plot, the adoption of Paw San rice is considered on a per plot basis. Given that x_{ij} is defined as factors influencing farmer i's utility of adopting rice variety j and μ the disturbance, $U_{ij} = V_{ij}+\varepsilon_{ij}$, j = 1, 0. The V_{ij} is a utility function that depends on x_{ij} and assumed to be linear. Thus, the probability of adopting Paw San rice is given as:

$$P_{i1} = P(U_{i1}>U_{i0}) = P(V_{i1}-V_{i0}>\varepsilon_{i0}-\varepsilon_{i1})$$

The ε is assumed to be iid and assuming the logistic distribution of disturbances, that is in Eq. 1:

$$\Pr = \left(Y_i = 1|x_i\right) = \frac{e^{xi^{\beta}}}{1+e^{xi^{\beta}}} \quad (1)$$

The binomial logit model of Paw San rice adoption is written as in Eq. 2:

$$In\frac{p_j}{1-p_j} = \propto +\sum_{k=1}^{m}\beta_k x_k \quad (2)$$

where, x_k are explanatory variables as listed in Table 2.

The change in probability of alternative j given a change in an observed variable x_k is calculated as in Eq. 3:

$$\frac{\partial \Pr(Y_i = j)}{\partial x_i} = \Pr(Y_i = j)\left[\beta_k - \sum_{j=0}^{1}\Pr(Y_i = j)\beta_k\right] \quad (3)$$

Table 2: List of variables used in logit model of Paw San rice adoptionin Myanmar

Variables	Unit/alternatives
Y	1 if Paw San rice adoption, 0 otherwise
EDU	0 if primary and middle school, 1 if high school and college
EXP	Years
FSIZE	Acre
RAIN	0 if no, 1 if yes
SEED	1 if saved seed, 0 otherwise
TASTEPREF	1 if worse than, 2 if same with, 3 if better than non-Paw San rice
YIELDATTD	1 if lower than, 2 if same with, 3 if higher than non-Paw San rice
MKTATTD	1 if lower than, 2 if same with, 3 if more than non-Paw San rice
BORERATTD	1 if lower than, 2 if same with, 3 if more than non-Paw San rice

Y: Farmer's choice on rice variety, EDU: Education of household decision maker, EXP: Farm experience of household decision maker, FSIZE: Total rice farming area, RAIN: Experience rain during harvest period, SEED: Source of seed, TASTEPREF: Taste preference of Paw San rice, YIELDATTD: Yield preference of Paw San rice, MKTATTD: Perception of market access of Paw San rice and BORERATTD: Perception of resistance to rice stem borer of Paw San rice

And the marginal effect of dummy variable x_k equals as given in Eq. 4:

$$\Pr\left(Y_i = 1|x, x_k = 1\right) - \Pr\left(Y_i = 1|x, x_k = 0\right) \quad (4)$$

RESULTS AND DISCUSSION

A total of 206 farmers from Sagaing region and 164 farmers from Ayeyarwaddy region were interviewed, 561 rice plots were considered. Table 3 summarizes farm attributes and farmer's characteristics of the samples. Farm household decision makers have an average age of around 50 and more than 20 years of rice farming experience. The average size of the household is five members in both regions. Most farmers have education less than high school and nearly all household decision makers work full-time on rice cultivation. The preferences for Paw San rice, compared to other varieties are predominantly positive in terms of better taste and better market access. However, the perception that the yield of Paw San rice is lower than that of non-Paw San

Table 3: Rice farm and farmers' characteristics in Myanmar, monsoon season 2013/2014

	Sagaing		Ayeyarwaddy		Country	
Variables	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Age (year)	47.48	12.52	51.31	12.63	49.18	12.7
Experience (year)	23.88	13.29	26.38	13.46	24.99	13.41
Household size (member)	4.93	1.74	4.88	1.84	4.91	1.78
	No.	%	No.	%	No.	%
Education						
Primary school	90	43.69	76	46.34	166	44.86
Middle school	78	37.86	54	32.93	132	35.68
High school	24	11.65	27	16.46	51	13.78
College	14	6.80	7	4.27	21	5.68
Total (farmers)	206	100.00	164	100.00	370	100.00
Working time on rice						
Full-time	186	90.29	154	93.90	340	91.89
Part-time	20	9.71	10	6.10	30	8.11
Total (farmers)	206	100.00	164	100.00	370	100.00
Taste preference of Paw San rice						
Worse than non-Paw San rice	27	13.11	1	0.61	28	7.57
Same with non-Paw San rice	19	9.22	16	9.76	35	9.46
Better than non-Paw San rice	160	77.67	147	89.63	307	82.97
Total (farmers)	206	100.00	164	100.00	370	100.00
Yield preference of Paw San rice						
Lower than non-Paw San rice	49	23.79	113	68.90	162	43.78
Same with non-Paw San rice	61	29.61	46	28.05	107	28.92
Higher than non-Paw San rice	96	46.60	5	3.05	101	27.30
Total (farmers)	206	100.00	164	100.00	370	100.00
Perception of market access of Paw San rice						
Lower than non-Paw San rice	1	0.49	1	0.61	2	0.54
Same with non-Paw San rice	14	6.80	38	23.17	52	14.05
More than non-Paw San rice	191	92.72	125	76.22	316	85.41
Total (farmers)	206	100.00	164	100.00	370	100.00
Perception of resistance to rice stem borer of Paw San rice						
Lower than non-Paw San rice	34	16.50	49	29.88	83	22.43
Same with non-Paw San rice	123	59.71	92	56.10	215	58.11
More than non-Paw San rice	49	23.79	23	14.02	72	19.46
Total (farmers)	206	100.00	164	100.00	370	100.00
Source of seeds						
Own	146	62.93	293	89.06	439	78.25
Others	86	37.07	36	10.94	122	21.75
Total (plots)	232	100.00	329	100.00	561	100.00
Rain at harvest time						
Yes	2	0.86	48	14.59	50	8.91
No	230	99.14	281	85.41	511	91.09
Total (plots)	232	100.00	329	100.00	561	100.00
No. of farmers	206		164		370	
No. of plots	232		329		561	

1 ha: 2.471 acre

varieties is noticeable in Ayeyarwaddy region, while nearly half of the farmers in Sagaing region believe that Paw San rice has higher yield than non-Paw San varieties. As Paw San rice is somewhat susceptible to rice stem borer, about half of the farmers have perceptions that it has the same resistance to rice stem borer as non-Paw San rice; the rest have either more positive or more negative perceptions towards Paw San rice compared to other varieties.

Rice farmers still use their own seeds more than from other sources such as the agricultural extension division that produces certified rice seeds or seed shops. About 60% of rice plots in Sagaing and 90% in Ayeyarwaddy are planted to own seeds. Rainfall during the harvest time usually destroys the paddy. About 15% of sampled rice plots in Ayeyarwaddy were affected by rain during the harvest period while less than 1% of the rice plots experienced this problem in Sagaing region.

In terms of the total rice area per household, farmers in Ayeyarwaddy region have farms twice as large as farmers in Sagaing region (Table 4). And the average size of plots for Paw San rice is larger than for non-Paw San rice in both regions.

Table 4: Revenue, variable cost and variable profit of rice cultivation in Myanmar, monsoon season 2013/2014

	Sagaing					Ayeyarwaddy					Country				
	Paw San rice		Non-Paw San rice			Paw San rice		Non-Paw San rice			Paw San rice		Non-Paw San rice		
Farm characteristics	Mean	Standard deviation	Mean	Standard deviation	t-statistic	Mean	Standard deviation	Mean	Standard deviation	t-statistic	Mean	Standard deviation	Mean	Standard deviation	t-statistic
Total rice farming area (acre)	7.99	5.60	5.93	3.46	2.93***	19.07	20.99	16.76	14.86	1.16	13.55	16.33	13.46	13.48	-0.07
Plot size (acre)	7.38	5.64	4.30	2.68	4.49***	10.36	12.98	5.26	5.69	4.69***	8.88	10.13	4.97	4.98	5.56***
Yield (kg per acre)	793.16	360.66	1,055.54	408.87	-4.96***	1,008.25	167.10	1,183.55	245.15	-7.52***	901.05	300.31	1,144.52	309.33	-9.40***
Price of paddy (kyat kg^{-1})	409.83	57.65	276.19	44.24	16.64***	316.22	49.80	243.30	64.50	10.95***	363.80	71.37	253.24	60.95	18.39***
Price of milled rice (kyat kg^{-1})	647.52	n/a[n]	474.77	116.18	1.39	543.96	94.24	409.25	112.60	3.32***	550.87	94.65	433.39	115.33	3.18***
Total revenue (kyat per acre)	329,509	154,592	293,306	116,072	1.80*	326,063	68,845	288,067	67,926	5.04***	327,780	119,357	289,664	85,303	4.24***
Total variable cost[†] (kyat per acre)	244,723	36,718	232,647	38,004	2.32**	155,341	24,972	163,976	24,298	-3.18***	199,890	54,637	184,912	43,004	3.53***
Variable profit (kyat per acre)	84,786	155,706	60,659	109,961	1.205	170,722	69,673	124,091	65,677	6.25***	127,891	127,766	104,752	86,610	2.44**
Number of plots (%)	157	(67.67%)	75	(32.33%)		158	(48.02%)	171	(51.98%)		315	(56.15%)	246	(43.85%)	

[†]Includes costs of labor, animal usage, seed, chemical fertilizer (urea, t-super, potash and compound), organic (cow and chicken) fertilizer, pesticides, insecticides, fungicides, herbicides, irrigation and machinery, [n]Not available due to one observation. Farmers can sell their products in either paddy or milled rice, up to 3 times of sales in one cropping season. The data on prices represent the average price of all sales, 1 ha: 2.471 acre, 1 USD: 975 Myanmar kyats, exchange rate based on the growing season and the most selling time by farmers (1st June, 2013 to 30th June, 2014), *, **, ***Significant level at 10, 5 and 1%, respectively

Table 5: Coefficient estimates and marginal effects of Paw San rice adoption model

	Sagaing region				Ayeyarwaddy				Country			
Variables	Coeff est	Standard error	Marginal effect	Standard error	Coeff est	Standard error	Marginal effect	Standard error	Coeff est	Standard error	Marginal effect	Standard error
EDU	1.0630**	0.5313	0.1947**	0.0958	0.5035	0.4334	0.1209	0.1040	0.8138**	0.3236	0.1799**	0.0711
EXP	0.0324**	0.0143	0.0059**	0.0026	0.0087	0.0129	0.0021	0.0031	0.0211**	0.0092	0.0047**	0.002
FSIZE	0.1457***	0.0473	0.0267***	0.0080	0.0071	0.0104	0.0017	0.0025	0.0051	0.0099	0.0011	0.0022
RAIN	-2.9646**	1.4680	-0.3857**	0.1853	-0.7759**	0.3396	-0.1936**	0.0847	-0.8173**	0.3304	-0.1996**	0.0808
SEED	0.3687	0.3828	0.048	0.0495	0.2019	0.3740	0.0504	0.0933	0.2599	0.2414	0.0635	0.0589
TASTEPREF	1.0037***	0.2563	0.1306***	0.0296	0.2949	0.3470	0.0736	0.0866	0.8682***	0.189	0.2120***	0.0462
YIELDATTD	1.7194***	0.2598	0.2237***	0.0205	0.0657	0.2260	0.0164	0.0564	0.9614***	0.1387	0.2347***	0.0335
MKTATTD	1.0695*	0.6418	0.1391*	0.0817	0.4557*	0.2603	0.1137*	0.0650	0.7076***	0.231	0.1728***	0.0564
BORERATTD	-0.8286***	0.3097	-0.1078***	0.0383	0.6144***	0.1832	0.1533***	0.0457	0.2315	0.1455	0.0565	0.0355

*, **, ***Significance at 10, 5 and 1% confident level, respectively, Coeff est: Coefficient estimates

The share of Paw San rice adoption in Sagaing region is about two-thirds of total sampled plots, larger than the 50% share in Ayeyarwaddy region. Farmers in Ayeyarwaddy region have several plots and normally grow several varieties; the survey found as many as seven varieties. In Sagaing, the number of varieties is three or less. The yield of Paw San rice is significantly lower than non-Paw San varieties. However, the prices for milled rice and paddy and total revenue from Paw San rice are significantly higher than those from non-Paw San varieties. The exception is the price of milled rice in Sagaing region. Farmers in Myanmar usually sell their product, either paddy or milled rice, multiple times from the same harvest, paddy is sold up to 3 times while milled rice is sold twice at the maximum. The variable cost of producing Paw San rice is significantly higher than non-Paw San varieties in Sagaing region and the country's average; that of Paw San rice in Ayeyarwaddy region is significantly lower than that of non-Paw San rice. As a result, the variable profit per area of Paw San rice is significantly higher than non-Paw San rice, especially in Ayeyarwaddy region. It is also higher than the country average. This implies that farmers who grow Paw San rice may obtain more income from Paw San rice cultivation by making higher profit and having larger farm size than farmers who grow alternative varieties.

From Eq. 2, Table 5 shows coefficient estimates of the choice model of Paw San rice adoption. In Sagaing region, farmers on average have a smaller total farming area than those in Ayeyarwaddy region. Farmers in Sagaing region who have larger farms can be assumed to be wealthier and to have better access to credit and thus are more likely to adopt Paw San rice. This result is in line with Wang *et al.*[29] who showed that larger farmers are more likely to adopt modern rice varieties in Cambodia. More educated farmers and those who are more experienced in rice cultivation are more likely to adopt Paw San rice in Sagaing region. A possible reason is they are more aware of the market situation and reputation of Paw San rice quality in the world market, that awareness influencing their choice of variety. Previous studies found that education[12,21] and experience[12] of farmers influence the adoption of rice varieties. Although education and experience do not influence the probability of adopting Paw San rice in Ayeyarwaddy region, they are found to be significant factors influencing the adoption of Paw San rice at the country level.

The adoption of Paw San rice in Sagaing region where it is cultivated more intensively is found to be responsive to farmer's preferences and perceptions including taste, yield and market and disease resistance. Farmers in Sagaing who prefer the taste of Paw San rice and believe that it has better market access than non-Paw San rice are more likely to adopt it. A similar result is reported by Jamal *et al.*[23] that the relative advantage of higher quality contributing to higher market price and better access to the market was found to generate positive perceived benefits, which influenced the adoption of aromatic rice. In contrast, the expectation of declining market price was found to negatively affect the adoption of premium rice such as Basmati[20]. The result of this study confirms that the expectation of price and market access of a high quality rice significantly influence its adoption. As Paw San rice was introduced in Sagaing region more recently than in Ayeyarwaddy region and has a taste that is distinct from other varieties, taste preference in Sagaing is significant and has a positive effect on the adoption of Paw San rice. This result is consistent with the findings of Napasintuwong and Pray[13] and Adesina and Zinnah[30] that farmer's preference for rice that has a superior taste increases the likelihood of its adoption. However, taste preference was found not to influence the adoption of Paw San rice in Ayeyarwaddy region where the varieties have been traditionally cultivated for a much longer time. Paw San rice has lower yield than non-Paw San rice; nonetheless, farmers in Sagaing who believe otherwise i.e., that Paw San rice has a higher yield than non-Paw San rice are more likely to adopt the variety. This is not the case in

Ayeyarwaddy where yield might not be seen as a prominent advantageous characteristic. The result in Sagaing as well as the national trend is consistent with the findings of Abdulai and Huffman[31], Hossain *et al.*[16], Li *et al.*[19] and Singh *et al.*[20] that the expected yield is one of the main factors that influence the choice of technology in rice cultivation.

A positive attitude towards the resistance to rice stem borer of Paw San rice compared to non-Paw San varieties appears to negatively influence the probability of its adoption in Sagaing region. In Ayeyarwaddy, on the other hand, perception of stem borer resistance appears to positively influence the probability of farmers in the region adopting Paw San rice. A plausible explanation is that rice stem borer is not as significant a threat to rice farming in Sagaing as it is in Ayeyarwaddy region. At the country level, the perception on stem borer resistance of Paw San rice does not affect the probability of its adoption. Paw San rice has a longer maturity period than most modern varieties and its harvest time in the study areas is typically in December in the survey areas. The probability of farmers in both regions adopting Paw San rice is significantly reduced if the rains fall at harvest time. It implies that farmers who adopt Paw San varieties suitable to the climatic pattern of their area for instance the variety matures after the monsoon are more likely to avoid the heavy rains that make harvesting more difficult and spoil the ripening grains. This result is similar to the findings of Teklewold *et al.*[32] who found that rainfall satisfaction such as timeliness during the growing period and rain at harvest time affect the adoption of agricultural practice. The source of seed, however does not affect the adoption of Paw San rice. As most Myanmar rice farmers select and save seed from the current crop for subsequent crops and the standards of Paw San rice products do not require the purity of varieties, the source of certified seeds is not a significant factor in farmers' decision to adopt the Paw San rice. This result differs from Joshi and Bauer[11] who found that formal sources of seed affect the adoption of rice varieties.

As suggested by Custodio *et al.*[9] that aromatic rice is an important market in Asia and incorporating aromatic trait into varietal development programs will generate rice products that meet consumer's preferences in importing countries. The results from the Paw San rice adoption analysis suggest that farmers who prefer Paw San rice for higher yield, better taste and positive market signal will be ones who adopt it. Thus, breeding program to improve yield of Paw San rice will bring about a wider adoption and increase the supply of Paw San rice. As price policy is important in rice exporting countries, Myanmar's rice price has been much lower than the international price[8], creating export market that offers higher price will also accelerate the adoption of Paw San rice.

CONCLUSION

Paw San rice of Myanmar is premium quality rice that has a great potential in regional and international markets. This study reveals that although Paw San rice yields significantly lower than alternative varieties, the prices of and revenue from Paw San rice are significantly higher than non-Paw San varieties. The variable profit from Paw San rice is also significantly higher than from non-Paw San rice, particularly in Ayeyarwaddy region where it is a traditional variety; thus a positive attitude towards rice stem borer resistance increases the likelihood of its adoption. However, because the variable profit derived from of Paw San rice is not significantly different from non-Paw San varieties in Sagaing region where the variety has only been introduced recently, the advantage in its cultivation was not clear to the farmers. While Myanmar's previous development policies have been centered on rice, the results of cost and return analysis from this study imply that Paw San rice provides better income for farmers. Promoting the production of Paw San rice and strengthening supply chain towards high value export markets will help progressing Myanmar economic development.

The adoption of Paw San rice in this region could be accelerated by promoting it to farmers who have a higher educational level, more skills and experience in rice cultivation and cultivate larger farms. Also farmers who believe it has a high yield, commands a higher price and other market benefits and has the desirable cooking quality and taste would more likely adopt it. Overall, the recognition by Myanmar farmers that Paw San is a premium quality rice, fetches a high price and has a good market demand encourages them to choose the variety that is suitable to the climatic pattern in their area, the time of planting and soil type to avoid rain damage to the crop. Thus, the development of high yielding variety retaining the preferred grain characteristics, cooking quality, taste and aroma and government support to promote positive market signal such as high price and stable export demand would promote the wider adoption of Paw San rice in Myanmar.

SIGNIFICANT STATEMENT

Farmers who avoid crop loss from rain damage by selecting varieties suitable to the area's climatic pattern and the typical planting time are more likely to be Paw San rice growers in both regions. The findings suggest that the

development of high yielding Paw San rice variety with good cooking quality and government support to promote positive market signal such as high price in the export markets would promote the wider adoption and increase the supply of Paw San rice. Paw San rice generates more income for farmers and these results can be considered for promoting Paw San rice production in Myanmar.

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