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About the cover: The life cycle of the rice plant starts with a seed. The seed takes up water to begin the process of growing the first leaf and root. When taken care of, young rice plants interact well with the soil and aerial environment, and undergo the different phases of growth until they mature to produce more seeds for food and propagation. Seeds of rice varieties differ in color that can be associated with health-promoting properties, while size, shape, and texture are considered in postharvest handling and processing. Seed size, shape, texture, color, and aroma have commercial value.

Photographed by Ms. Janica M. Gan at Agronomy Experimental Field, PhilRice, Nueva Ecija.

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Effects of Seed Priming and Coating on Germination and Seedling Establishment of Hybrid Rice Mestiso 19 Direct-Seeded under Submerged Soil Condition

Danica Riza D. Macaisa, Susan R. Brena*, Clint Henry D. Pablo, and Jennifer M. Manangkil

Seed Technology Division, Philippine Rice Research Institute (PhilRice), Central Experiment Station, Science City of Muñoz, 3119, Nueva Ecija, Philippines
*Corresponding author: sr.brena@philrice.gov.ph

Abstract Poor seed germination and seedling establishment are some of the problems in direct-seeded rice culture. We assessed the effects of seed priming/soaking with $CaCl_2$, seed coating with fungicide (0.4% captan, 4% chitosan, and no coat), and seed coating for seedling establishment [1000 mg/L gibberellic acid (GA_3), iron powder, and no coat] on germination and seedling establishment of hybrid rice Mestiso 19 direct-seeded under submerged soil condition. Results showed that in contrast to the various seed coating treatments, seed priming with $CaCl_2$ had significant positive effect on germination percentage (GP), seedling mean emergence time (MET), final emergence (FE), and emergence index (EI). Fungicide coating, establishment coating, combinations of priming and fungicide coating, and fungicide coating and establishment coating had significant effects on MET, FE, and EI. Shoot length (SL), root length (RL), and seedling dry weight (SDW) were improved in captan- and GA_3-coated non-primed seeds. Iron-coated non-primed seeds improved FE and vigor index (VI), while chitosan-coated primed seeds improved MET and SL. While priming with $CaCl_2$ may be used indpendently to improve GP, MET, FE, EI, SL, RL, VI, and SDW, seed coating with a natural biopolymer such as chitosan may be tested for other rice genotypes to assess seedling growth or its inhibitory effect on seed-borne pathogens.

Keywords: Direct Seeding, Germination, Hybrid Rice, Priming, Seed Coating, Seedling Establishment.

Introduction

Direct-seeded rice has received much attention because of its low-input demand than transplanting (Farooq et al., 2011). Direct seeding involves sowing pre-germinated seed onto a puddled soil surface (wet seeding), standing water (water seeding) or dry seeding into a prepared seedbed (dry seeding). In the Philippines, Malaysia, and Thailand, direct seeding has slowly replaced transplanting (Pandey and Velasco, 2002) as it results in cheaper crop establishment with the advantage of faster and easier planting, and earlier crop maturity of 7-10 days (Balasubramanian and Hill, 2002). Direct seeding can also be used to establish hybrid rice as preferred by farmers in Isabela, Philippines owing to its higher profitability than the transplanted hybrid rice (Gado, 2005). However, some farmers are still reluctant to adopt the method due to some constraints of direct seeding such as poor seed germination, high fungal infection, lower yield in farmer's field condition, uneven stand establishment and high weed infestation that translate to high cost of chemical weed control (Du and Tuong, 2002; Pandey and Velasco, 2002; Singh et al., 2005; Rao et al., 2007). Hybrid rice is more expensive than inbred rice and using a higher seed rate would be too costly for the farmers. Thus, technologies to overcome the constraints imposed by direct seeding are necessary.

Shallow flooding immediately after sowing could help control weeds but will result in poor crop establishment (Ella et al., 2011). Seed treatment such as seed priming and seed coating were reported to be effective, convenient and affordable way to help optimize conditions to improve germination and seedling growth, control seedborne pathogens, help protect seeds from biotic and abiotic stress during critical phase of seedling establishment, and increase yield (Farooq et al., 2006; Basra et al., 2005; Zeng and Shi, 2008; Tiwari et al., 2011; Afzal et al., 2012). Seed coating acts as a delivery system for nutritional elements, plant growth regulators, fertilizers and other nutrients to increase seed germination and performance. In Japan, direct seeding under submerged paddy field condition using iron (Fe)-coated rice seeds as an alternative method to transplanting has generated considerable attention (Mori et al., 2012). Iron-coated rice offers an advantage as it reduces the number of floated rice seeds and seedlings, controls seed-borne diseases of rice seedlings, and requires less labor and time (Yamauchi, 2004; Inoue et al., 2009). Treatment of seeds with the plant growth hormone gibberellic acid (GA_3) has been reported to improve seed germination, number of fertile grains, grain yield, and total plant biomass when applied as film coating (Gevrek et al., 2012). Fungicides and pesticides are commonly incorporated to avoid pathogen attack and decrease disease susceptibility during germination in the soil (Zeng et al., 2010). However, the use of fungicides and pesticides pose phytotoxic effects on the seed that can subsequently affect seed germination and vigor and can lead to environmental problems. Seed treatment with captan for instance, has been reported to reduce maize seed storability and affected the flowering behavior in the field (Von Pine et al., 1995).

The use of natural and biodegradable products as alternative biological control of fungi in rice to enhance seedling performance has been explored (Thobunluepop, 2009; Thobunluepop et al., 2008). Chitosan is a natural biopolymer derived from chitin, which is a component of the exoskeleton of shrimps and crabs. It has been widely studied as natural seed treatment and plant growth regulator, and found to increase yields of rice, maize, and strawberry (Boonlertnirun et al., 2012; Lizarraga-Paulin et al., 2011; Abdel-Mawgoud et al., 2010). It was found that chitosan-lignosulphonate polymer inhibited the activity of seed-borne fungi for 6 months (Thobunluepop, 2009). Chitosan enhanced the germination index and increased shoot height, root length, and shoot and root dry weights of maize under low temperature stress (Guan et al., 2009). Thus, chitosan coating after priming has the potential improve seed germination and seedling establishment in rice.

Seed priming with $CaCl_2$ has been known to enhance seed vigor and stand establishment as well as yield performance in direct-seeded rice (Farooq et al., 2006; Rehman et al., 2011). However, its efficacy in combination with various seed coating materials on the germination and seedling establishment of direct-seeded hybrid rice needs investigation. The present study assessed the effects of seed priming with $CaCl_2$ and seed coating with chitosan, iron powder, GA_3, and captan on seed germination and seedling establishment of Mestiso 19 direct-seeded under submerged condition in the laboratory and screenhouse.

Materials and Methods

Seed Source and Experimental Details

Seeds of two-line hybrid rice Mestiso 19 (NSIC Rc202H) were obtained from the Philippine Rice Research Institute (PhilRice), Central Experiment Station (CES), Nueva Ecija, Philippines. It is one of the two thermosensitive genetic male sterile hybrids (TGMS) released in the Philippines in 2009. The initial seed moisture content was approximately 12%. Seed samples were surface-sterilized with 2.63 % NaOCl solution (household bleach diluted to 1:1 with sterile water) for 30 min and rinsed thrice with sterile distilled water. The seeds were air-dried at ambient temperature until the initial seed moisture content was reached.

The experiment was conducted at the PhilRice Seed Technology Division Laboratory. There were 18 treatments that included the Control (non-primed and non-coated). Seed coating materials used were calcium chloride ($CaCl_2$) (Merck, Germany), chitosan powder or flakes obtained from the Philippine Nuclear Research Institute (PNRI), captan (Captan WP, Arysta Lifescience Mexico), and iron powder (Techno Pharmchem, India). This study investigated the effects of different factors namely: seed priming (priming with $CaCl_2$ and no priming); seed coating with fungicide [4%

chitosan (w/w), 0.4% captan (w/w), no coating]; seed coating for seedling establishment [GA_3 (1000 mg/L), 0.5 iron powder (iron oxide) ratio on seed weight, no coating]. Non-primed non-coated seeds were the Control. The factorial experiment was laid out in a randomized complete block design (RCBD) with four replications.

Seed Priming

The seeds were soaked in priming solution of $CaCl_2$ (22.2 g/L = -1.25 MPa pressure potential) at 1 g of seeds per 5 mL of solution in a container at room temperature in the dark for 24 h. The soaking solution was changed every 6 h. Then, the seeds were washed thrice with distilled water followed by redrying at ambient temperature to initial moisture.

Seed Coating Treatments

The primed and non-primed seeds were coated alone with fungicide coating captan (0.4% or 4 g of captan per 1 kg of the seeds) or 4% chitosan (w/v); coated with 0.4% captan or 4% chitosan in combination with GA_3 coating for seedling establishment (1000mg/L solution) or coating with iron powder (0.5 iron powder ratio on seed weight), and coated only with GA_3 or iron powder. Chitosan was prepared by dissolving it into an aqueous solution of acetic acid at 1% (w/v). The coatings were mixed with the binder 10% polyvinyl alcohol (Technical grade, Chemline Scientific) at 5 ml/g of seeds and seed coating was done by mixing the coatings and seeds in a container using a spatula. After coating, the seeds were allowed to dry at ambient temperature to initial moisture.

Germination Rate and Seedling Establishment Assessment

Germination percentage (GP) was measured using the roll paper towel method at 28°C after 14 days based on ISTA (2006) and was calculated as:

$$\text{GP} = \frac{\text{Total seed germination after 14 days}}{\text{Total number of seeds investigated}} \times 100\%$$

For seedling establishment parameters, a total of 25 primed and non-primed coated seeds were sown and submerged in circular plastic basins (7 cm depth x 30 cm diameter) under screenhouse condition. The basins contained paddy soil from PhilRice CES. Soil was classified as Maligaya clay soil, characterized as typically fine, montmorillionitic, isohyperthermic Ustic Epiaquerts (Carating et al., 2014). Each treatment had 4 replications. Emergence was recorded daily according to Association of Official Seed Analysts or AOSA (1990) . The speed of seedling emergence was calculated using the emergence index (EI):

$$\text{EI} = \sum \frac{E_t}{D_t}$$

which is the summation of mean number of emerged seedlings per day for t days where Et is the number of seedlings emerged and Dt is the number of days after planting (Yang et al., 2005).

Mean emergence time (MET) was calculated based on the equation of Ellis and Roberts (1981):

$$\text{MET} = \frac{\sum D_n}{\sum n}$$

where n is the number of seeds that emerge on day D, and D is the number of days counted from the beginning of emergence.

Five seedlings per replicate were evaluated for shoot length (SL) and root length (RL) at 7, 14, and 21 days after sowing (DAS) and seedling dry weight at 21 DAS using the standard procedure of AOSA (1983). The vigor index (VI) at 21 DAS was calculated as the product of seedling length (cm) by emergence percentage. Dry weight of seedling was determined after oven drying at 70°C for 48 h.

Statistical Analysis

Analysis of variance was used to compare the effects of the treatments on seed germination and seedling performance. Shapiro–Wilk test for normality and Bartlett's test for homogeneity of variances were used to test the assumptions for the three-way Factorial ANOVA for RCBD. Mean comparison procedure using LSD was done to detect differences between means. All statistical analyses were done using Statistical Tool for Agricultural Research (STAR, version: 2.0.1) International Rice Research Institute (IRRI).

Results

Effects of Seed Priming and Coating on Germination, Mean Emergence Time, Final Emergence and Emergence Index

Analysis of variance showed that priming significantly affected germination percentage (GP), mean emergence time (MET), final emergence (FE), and emergence index (EI) while seed coating treatments (fungicide coating and establishment coating) only significantly affected MET, FE, and EI but not GP of Mestiso 19 (Table 1). The two-way interaction effects of priming plus fungicide coating and fungicide plus establishment coating were significant in terms of MET, FE, and EI. A three-way interaction (priming plus fungicide and seedling establishment coatings) was significant only for MET and FE.

Germination Percentage

Seed priming with $CaCl_2$ (-1.25 MPa moisture absorption potential) had a highly positive effect on GP while the various seed coating treatments had no effect on germination. Primed seeds had 97% germination while non-primed seeds only had 95% (Figure 1).

Emergence Index

EI of the non-primed seeds coated with 0.4% captan (19.85) was significantly higher than the EI

Table 1. Analysis of variance of priming, fungicide coating, establishment coating, combinations, and their effect on germination percentage (GP), mean emergence time (MET), final emergence (FE) and emergence index (EI) of direct-seeded hybrid rice Mestiso 19.

Source of Variation	Mean Square			
	GP	MET	FE	EI
Priming (A)	0.148*	0.258*	6.125*	121.776*
Fungicide coating (B)	0.001ns	0.277*	5.931*	40.145*
Establishment coating (C)	0.019 ns	0.172*	4.014*	17.289*
A x B	0.033 ns	0.157*	7.042*	56.954*
A x C	0.003 ns	0.009 ns	2.042 ns	7.221 ns
B x C	0.015 ns	0.025*	2.181*	16.848*
A x B x C	0.020 ns	0.036*	2.833*	6.696 ns
CV (%)	2.39	1.54	0.94	10.95

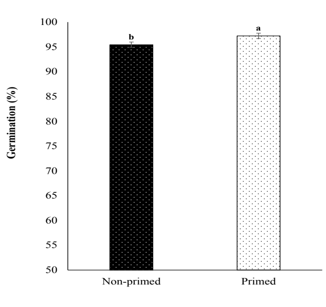

Figure 1. Effect of seed priming on the germination percentage of Mestiso 19 (NSIC Rc202H) after 14 days using the roll paper towel method (ISTA 2006). Same letter within each treatment is not significantly different at P<0.05 according to LSD. Error bars indicate standard error (n =36).

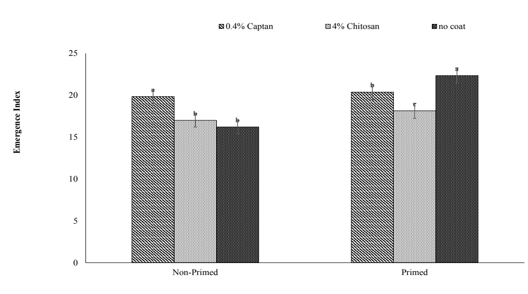

Figure 2. The interaction effects of priming x fungicide coating on the emergence index (EI) of direct-seeded hybrid rice Mestiso 19. Same letters within each treatment are not significantly different at P<0.05 by LSD. Error bars indicate standard error (n =36).

of the non-primed seeds coated with 4% chitosan (17.01) and without fungicide coat (16.22) (Figure 2). EIs of non-primed seeds coated with chitosan and non-primed seeds without fungicide coat were not significantly different. EIs of primed seeds with each fungicide coating differed significantly. EI of primed seeds without fungicide coat (22.36) was significantly higher than primed seeds coated with captan (20.38) or chitosan (18.15) while EI with captan was significantly higher than with chitosan.

There was no significant difference in the EI of seeds coated with GA_3, iron powder, or without establishment coat under 0.4% captan (Figure 3). EIs of seeds coated with iron powder (18.15) and without establishment coat (19.35) were significantly higher than the EI of seeds coated with GA_3 under 4% chitosan (15.24). Among the treatments without fungicide coat, EI of seeds coated with iron powder (20.10) was significantly higher than EI of seeds that were not applied with establishment coat (18.05).

Mean Emergence Time and Final Emergence

There were significant differences in MET and FE among seeds coated with GA_3, iron powder, and without coat under primed and non-primed seeds with a specific fungicide coat (captan, chitosan, and no coat) (Figure 4). Among the non-primed seeds coated with 0.4% captan and 4% chitosan, there were no significant difference between MET of seeds coated with iron powder (4.79 days and 5.01 days, respectively) and MET of no establishment coat (4.81 days and 5.09 days, respectively). However, both had significantly shorter MET than seeds coated with GA_3 (4.96 days and 5.21 days, respectively).

There was no significant difference in MET among the three seedling establishment treatments under non-primed and without fungicide coat. In primed seeds coated with 0.4% captan, seeds coated with iron powder and seeds without establishment coat had significantly shorter MET (4.82 days and 4.84 days,

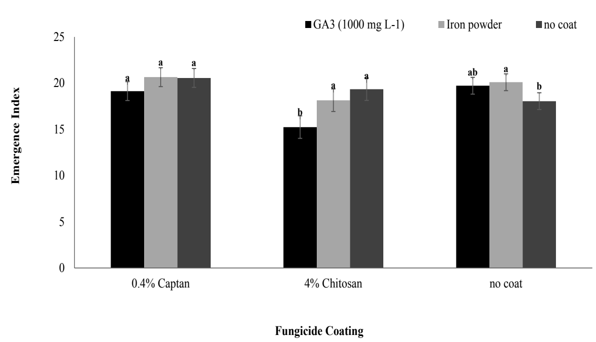

Figure 3. The interaction effects of fungicide coating x seedling establishment coating on the emergence index (EI) of direct-seeded Mestiso 19. Same letters within each treatment are not significantly different at P<0.05 by LSD. Error bars indicate standard error (n =36).

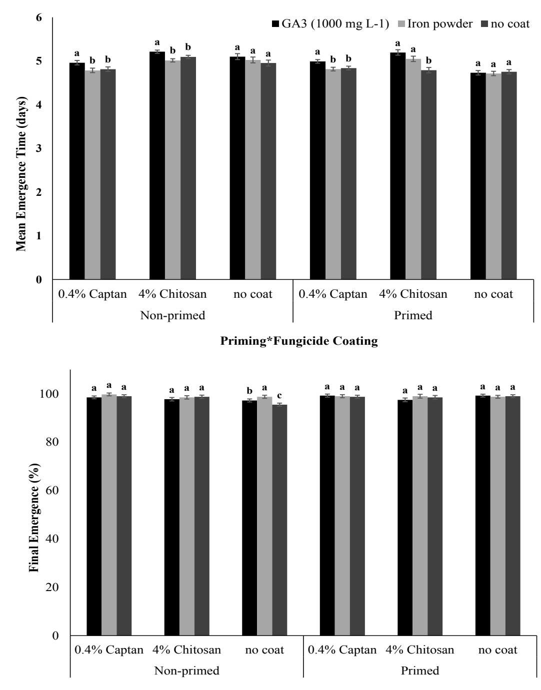

Figure 4. The interaction effects of priming x fungicide coating x seedling establishment coating on the mean emergence time (MET) and final emergence (FE) of direct seeded Mestiso 19. Same letters within each treatment are not significantly different at P<0.05 by LSD. Error bars indicate standard error (n =36).

respectively) than seeds coated with GA3 (4.99 days).

Primed seeds coated with 4% chitosan seeds and without establishment coat had significantly shorter MET (4.79 days) than coating with GA3 (5.20 days) and iron powder (5.05 days). There was no significant difference in MET among seeds with different establishment coats in non-primed and primed treatments (Figure 4). The FEs from the combinative establishment coatings with priming did not differ significantly. Among the non-primed seeds without fungicide coat, seeds coated with iron powder had the highest FE (98.75 %) followed by seeds coated with GA3 (97.25%), and seeds without establishment coat (95.5%). Under priming, MET and FE did not differ significantly in the different fungicide establishment coatings (Figure 4).

Effects of Seed Priming and Coating on Shoot and Root Lengths, Vigor Index and Seedling Dry Weight

The effect of priming was significant for shoot length (SL) and root length (RL) at 7, 14, and 21 days after sowing (DAS), and for vigor index (VI) and seedling dry weight (SDW) at 21 DAS (Table 2). The effect of fungicide coatings was found signicant for SL and RL at 7, 14, and 21 DAS, and for VI at 21 DAS but not SDW. The seedling establishment coating was found significant for SL at 7 DAS, RL at 21 DAS, and SDW. Significant two-way interactions were observed in most traits except for RL at 14 DAS. While priming x fungicide coating was significant in VI, it was not significant in SDW. Three-way interactions were significant in all traits.

Shoot Length

In the non-primed seeds with 0.4% captan, seeds coated with GA3 had significantly longer SL at 7 DAS (8.98 cm) than seeds coated with iron powder (8.42 cm) and seeds without estabishment coat (6.59 cm) (Figure 5). No significant difference was observed among the establishment coatings under non-primed and 0.4% captan at 14 DAS. At 21 DAS, seeds coated with GA3 had significantly longer SL (35.97 cm) than seeds without establishment coat (34.26 cm), but not significantly different with seeds coated with iron powder (34.77 cm). In non-primed seeds with 4% chitosan, seeds without establishment coat had longer SL at 7 and 21 DAS (9.76 cm and 35.1 cm, respectively) than seeds coated with GA3 (6.65 cm and 32.66 cm, respectively) and iron powder (6.61 cm and 31.69 cm, respectively). At 14 DAS, treatment effects with GA3 were significant but not with iron powder. In non-primed seeds without fungicide coating, seeds coated with iron powder had longer SL (9.06 cm) at 7 DAS than seeds coated with GA3 (7.99 cm), and seeds without establishment coat (7.94 cm). At 14 DAS, SL of seeds coated with iron powder was not significantly different from SL of seeds coated with GA3. There was no significant difference among the establishment coatings at 21 DAS (Figure 5). In primed seeds with 0.4% captan, SLs of seeds

Table 2. Analysis of variance of priming, fungicide coating, establishment coating, and their interaction on shoot length (SL), root length (RL) at 7, 14, and 21 days after sowing (DAS), vigor index, and seedling dry weight at 21 DAS for direct-seeded hybrid rice Mestiso 19.

Source of Variation	Mean Square							
	SL (cm)	SL (cm)	SL (cm)	RL (cm)	RL (cm)	RL (cm)	Vigor	Seedling
	7 DAS	14 DAS	21 DAS	7 DAS	14 DAS	21 DAS	Index	Dry Weight
Priming (A)	32.400*	33.003*	54.702*	9.409*	4.556*	33.449*	466127.309*	0.183*
Fungicide coating (B)	28.703*	34.104*	22.790*	16.670*	13.478*	9.584*	146362.543*	0.008 ns
Establishment coating (C)	2.677*	2.433 ns	7.650 ns	0.884 ns	1.665 ns	9.185*	47178.873 ns	0.019*
A x B	3.288*	26.482*	20.127*	13.210*	0.603 ns	18.675*	194491.115*	0.008 ns
A x C	7.852*	24.295*	23.547*	5.292*	0.767 ns	23.448*	30408.762 ns	0.032*
B x C	23.423*	25.143*	23.911*	7.258*	1.136 ns	9.991*	66207.384 ns	0.052*
A x B x C	31.506*	29.023*	14.163*	6.302*	2.999*	16.755*	177131.822*	0.066*
CV (%)	7.83	8.56	4.95	6.36	6.77	9.22	6.89	7.08

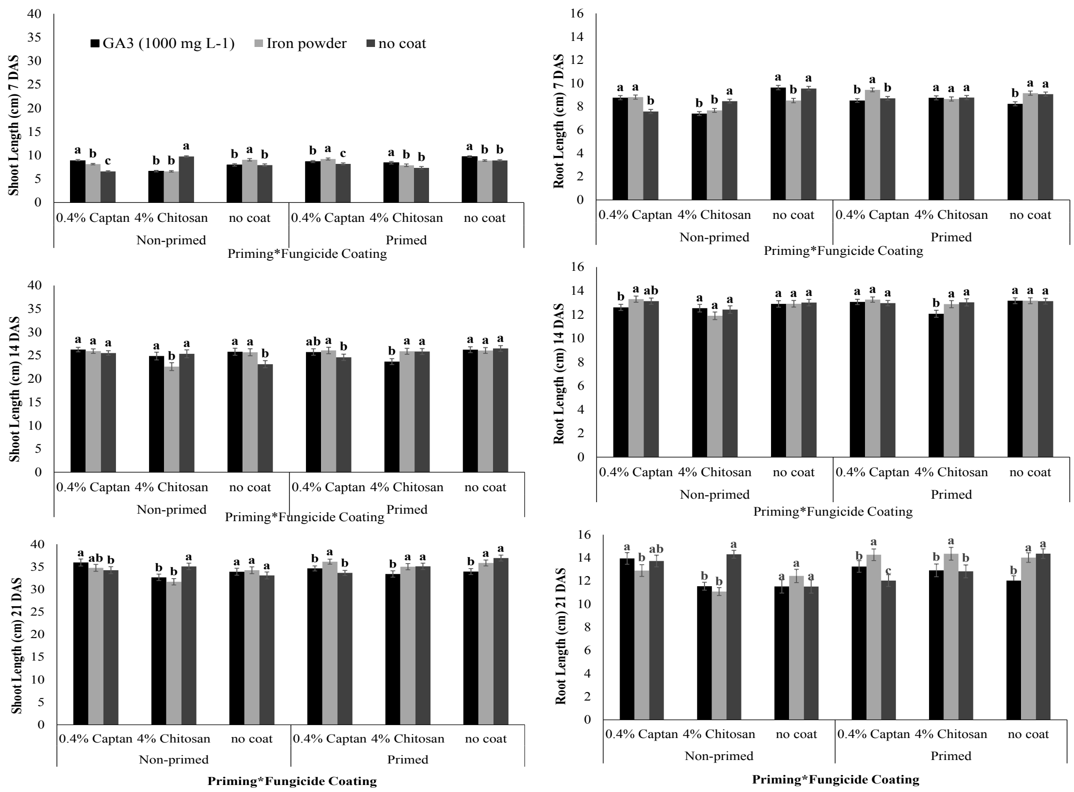

Figure 5. The interaction effects of priming x fungicide coating x seedling establishment coating on shoot length, root length at 7, 14, and 21 days after sowing (DAS) of direct seeded Mestiso 19. Same letters within each treatment are not significantly different at P<0.05 by LSD. Error bars indicate standard error (n =36).

coated with iron powder at 7 and 21 DAS (9.22 cm and 36.14 cm, respectively) were longer than the SLs of seeds coated with GA_3 (8.66 cm and 34.65 cm, respectively) and seeds without establishment coat (8.2 cm and 33.65 cm, respectively). In primed seeds with 4% chitosan, seeds coated with GA_3 had longer shoot length at 7 DAS (8.45 cm) than seeds coated with iron powder and no establishment coat. However, at 14 and 21 DAS, SLs were shorter. Among the primed seeds with no fungicide coat, seeds coated with GA_3 had longer SL at 7 DAS (9.74 cm) than the seeds coated with iron powder (8.91 cm) and without establishment coat (8.93 cm). No significant difference in SL was observed among the establishment coatings at 14 DAS (Figure 5).

Root Length

In non-primed seeds with 0.4% captan, root lengths (RLs) of seeds coated with iron powder and GA_3 were significantly longer than RL of seeds without establishment coat (Figure 5). At 14 DAS, seeds coated with iron powder had longer RL (13.30 cm) than the RL of seeds coated with GA3 (12.6 cm). However, at 21 DAS, RL of seeds coated with GA_3 (13.94 cm) was significantly longer than RL of seeds coated with iron powder (12.9 cm). Among non-primed seeds with 4% chitosan, RLs of seeds without establishment coat at 7 and 21 DAS (8.46 cm and 14.31 cm, respectively) were longer than the RLs of seeds coated with iron powder (7.68 cm and 11.08 cm, respectively) or GA_3 (7.41 cm and 11.54 cm, respectively). No significant difference in RL was observed at 14 DAS. In non-primed seeds without fungicide coat, RLs of seeds coated GA_3 and seeds without establishment coating at 7 DAS (9.64 cm and 9.56 cm, respectively) were longer than RL of seeds coated with iron powder (8.53 cm). There was no significant difference in RL at 14 and 21

DAS among the seedling establishment coatings (Figure 5). In primed seeds with 0.4% captan, RLs of seeds coated with iron powder at 7 and 21 DAS (9.44 cm and 14.27 cm, respectively) were significantly longer than the seeds coated with GA3 (8.53 cm and 13.25 cm, respectivey), and in treatment without establishment coat (8.72 cm and 12.03 cm, respectively). Rls were not significanly in the different seed establishment coating treatments at 14 DAS. In primed seeds with 4% chitosan, there was no significant difference among the establishment coating treatments at 7 DAS. At 14 DAS, RLs of seeds without establishment coat (13.03 cm) and seeds coated with iron powder (12.88 cm) were longer than RL of seeds coated with GA3 (12.06 cm). At 21 DAS, seeds coated with iron powder had longer RL (14.35 cm) than the RLs of seeds with GA3 (12.92 cm) and seeds without establishment coat (12.83 cm). In primed seeds without fungicide coat, RLs of seeds coated with iron powder at 7 and 21 DAS (9.17 cm and 14.02 cm, respectively) and without establishment coat (9.08 cm and 14.36 cm, respectively) were longer than the RLs of seeds coated with GA3.

Seedling Dry Weight

In non-primed seeds with 0.4% captan, seeds coated with GA3 had a higher SDW (0.79 g) at 21 DAS than SDW (0.73 g) of seedling of seeds coated with iron powder, and SDW of no establishment coat (Figure 6). Among non-primed seeds with 4% chitosan, seeds without establishment coat had higher SDW (0.77 g) than SDW of seeds coated with GA3, but not significantly different than SDW of seeds coated with iron powder. There was no significant difference among the SDWs of seeds with various establishment coating treatments under non-primed and without fungicide coat. In primed seeds with 0.4% captan and primed seeds with 4% chitosan, seeds coated with iron powder had a significantly higher SDW than seeds coated with GA3, and in treatment without establishment coat. In primed seeds untreated with fungicide coat, seeds without establishment coat had a higher SDW than seeds coated with iron powder.

Vigor Index

VIs of seedlings among different establishment coatings in non-primed seeds and 0.4% captan and in non-primed seeds 4% chitosan did not differ significantly (Figure 6). In non-primed seeds without fungicide coating, VI of seedlings from seeds coated with iron powder was significantly higher than the VI of seedlings from seeds coated with GA3, and in treatment without establishment coat. In primed seeds with 0.4% captan and primed seeds without fungicide coat, there was no significant difference in VI. In primed seeds with 4% chitosan, VI of seedlings from seeds coated with iron powder was significantly higher than VI of seedlings from seeds coated with GA3, but not significantly different from VI of seeds without establishment coat.

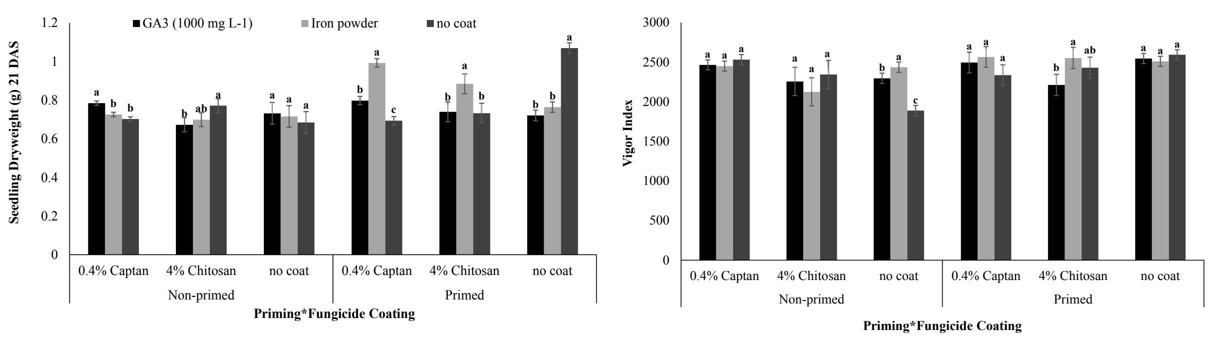

Figure 6. The interaction effects of priming x fungicide coating x seedling establishment coating on vigor index and seedling dry weight at 21 days after sowing of direct seeded Mestiso 19. Same letters within each treatment are not significantly different at P<0.05 by LSD. Error bars indicate standard error (n =36).

Discussion

The positive effects of priming with $CaCl_2$ on hybrid rice seed germination are confirmed in this study. Primed seeds had significantly higher germination percentage and improved seedling establishment traits than non-primed seeds based on our screenhouse studies. We have shown that seed priming can be independently used to improve germination, mean seedling emergence index, and other seedling growth parameters. Seed priming is a well-established method that can effectively improve seed vigor, uniformity in seed germination, and the overall competitive ability of seedlings. Mukhtar et al. (2013) showed that $CaCl_2$ was most effective in improving the seedling performance of marigold (*Tagetes patula* L.). However, the mechanism on how seed priming improves seed performance is not completely understood. Priming can trigger the physiological, biochemical, and molecular changes in seeds. Physiological and biochemical changes include the increase in activities of enzymes that break down the seed reserves and synthesis of some other metabolites, while molecular changes include the increase in protein and nucleic acid synthesis (Farooq et al., 2009).

This study provided insights on the combined effects of seed priming and coating techniques using GA_3, captan, chitosan, and iron powder to identify an effective seed coating treatment for the improved seedling performance of direct-seeded hybrid rice Mestiso 19 under submerged soil condition. Combining priming with seed coating is an approach at the seed-level that can serve as a delivery system for biological and chemical treatments for enhancing seed germination and seedling establishment.

Gibberellic acid (GA_3) is a popular plant growth promoting-agent used in agricultural systems including hybrid seed production. Gevrek et al. (2012) reported that coating rice seeds with GA_3 improved seed germination and seedling performance. However, our results showed GA_3- and captan-coated seeds did not significantly improve seedling mean emergence time and final emergence. GA_3 alone failed to improve shoot length, root length, and dry weight of seedlings at 21 days after sowing when compared to seedlings with uncoated seeds. Other techniques for coating seeds with GA_3 prior to seeding in submerged condition should be explored, one of which is the film coating method reported by Gevrek et al. (2012). Captan coating in combination with other seed coating treatments such as GA_3 and iron powder produced positive effects on seedling growth parameters such as emergence index, mean emergence time, shoot length, root length, and dry weight. However, when used alone, captan underperformed. Captan is also a toxic chemical (Thobunluepop et al., 2008) that can deleteriously affect seeds of hybrid rice that are partially open, making them more vulnerable to damage.

Results of the three-way interaction (priming x fungicide coating x establishment coating) showed that seeds coated with iron powder and seeds without establishment coat had shorter mean emergence time than seeds coated with GA_3 in non-primed seeds and seeds coated with captan and chitosan. However, the effects of the three establishment coatings did not differ significantly in non-primed and primed seeds without fungicide coating. This suggests the interaction of the establishment coating with the fungicide coating among the non-primed and primed seeds. In terms of final emergence, there was no significant difference among treatments except for the non-primed seeds without fungicide coating, in which iron powder had higher final emergence than seeds coated with GA_3 and in the control treatment without establishment coat. The high final emergence of iron-coated seeds can be explained by the increase in specific gravity of the seeds when coated with iron powder that can improve anchorage under submerged condition. In Japan, iron coating is an emerging seed coating technique for direct-seeded rice under submerged paddy field condition due to its effectiveness in overcoming seed floating and lodging in rice seedlings, and in improving seedling emergence and establishment (Yamauchi, 2005; Mori et al., 2012). However, iron coating did not improve shoot length and root length. This may be due to the physical inhibition caused by the iron coat on the seeds (Mori et al., 2012). When iron powder was used in combination with another coating material such as chitosan, germination and seedling establishment traits were significantly improved. Coating seeds with chitosan and iron powder improved seedling emergence. This could be attributed to the plant growth-promoting effects of chitosan and improvement of anchorage in seeds coated with iron powder (Katiyar et al., 2015; Yamauchi, 2004). The effects of priming and coating with either chitosan or iron powder or its combination enhanced final emergence, shoot and root lenghts of seedlings, seedling dry weight, and vigor index. This suggests that seed priming and coating with chitosan and iron powder are useful seed pre-treatments for improving seed germination and seedling establishment of hybrid rice Mestiso 19 direct-seeded under submerged soil condition.

The use of natural and biodegradable product as a biological control for fungi in rice has been explored (Thobunluepop, 2009). Chitosan is a natural biopolymer used as seed treatment and plant growth regulator in rice, maize and strawberry (Boonlertnirun et al., 2012). Chitosan when combined with a lignosulphonate polymer had inhibitory activity against seed-borne fungi. Thus, it will be worthwhile to assess the influence of seed coating with chitosan on the germination and seedling growth of other rice genotypes and in inhibiting seed-borne pathogens in controlled condition in the screenhouse and in the natural field condition.

Conclusion

This paper has shown the practicability of seed priming alone or in combination with seed coating materials such as chitosan and iron powder prior to direct seeding hybrid rice Mestiso 19 under submerged soil condition. Priming significantly improved germination percentage, mean emergence time, final emergence, emergence index, shoot length, root length, seedling vigor index, and seedling dry weight of direct-seeded hybrid rice Mestiso 19. Among the seed coating treatments, coating with iron powder significantly improved final emergence. The combination of seed priming and seed coating with chitosan and iron powder has been demonstrated under screenhouse condition as an effective method for improving seed germination and seedling establishment of direct-seeded Mestiso 19. These combinative treatments can be used as alternative approaches for rice farmers to boost seed germination and overall seedling performance of direct-seeded hybrid rice as well as inbred rice. Hence, research efforts focused on field evaluation of seed priming, seed priming in combination with biodegrable coating materials such as chitosan-lignosulphonate to boost germination and seedling growth, and inhibit seed-borne pathogens in direct-seeded rice system, are needed. The mechanisms of the interactions among the different factors: seed priming, seed coating with a growth-promoter and fungicide, and seed coating for good seedling establishment, also merit further study.

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Effects of Steaming on the Milling Yield, Quality, and Antioxidant Activity of Parboiled Black Rice (*Oryza sativa* L.)

Marilou Ang-Lopez*, Carissa Saldaña, and Naomi Carnaje

School of Technology, University of the Philippines Visayas, Miagao, 5023, Iloilo, Philippines
*Corresponding author: mjanglopez@gmail.com

Abstract Black rice is a traditional pigmented variety known for its health value. However, black rice has low consumer acceptability owing to its texture, peculiar flavor, and poor eating quality. Parboiling is the partial boiling of rice (i.e., soaking, steaming, and drying) before milling and has been reported to improve some grain quality characteristics. A laboratory-scale method of parboiling black rice was used to assess the effect of steaming time on milling yield, sensory attributes, cooking properties, and antioxidant activity. The 6 month-stored *Bingawan* black rice was soaked at 65°C for 4 h, steamed at 15 psi for 3, 5, and 8 min, and air-dried under shade for 24 h. De-hulling and head rice yields significantly increased with parboiling, but these were not affected by steaming time. Likewise, sensory attributes and eating quality improved with parboiling but were not affected by steaming time. However, eating quality with intermediate gelatinization temperature was improved by steaming for 3 and 5 min. The anthocyanin DPPH radical scavenging activity, an estimate of the antioxidant capacity, was 87% for the Control or non-parboiled rice and ranged from 70.6 to 81.1% across the three steaming times. The anthocyanin content and DPPH radical scavenging activity decreased as steaming time increased. Parboiling process may be optimized to reduce loss of anthocyanins and improve free radical scavenging activity.

Keywords: Anthocyanins, Black Rice, Gelatinization Temperature, Head Rice Yield, Parboiling, Sensory Attributes, 2,2-diphenylpicylhydrazyl (DPPH) Radical Scavenging Activity.

Introduction

Pigmented rice is distinguished by the pink, red, brown, or dark purple color of the covering layers of the grains (Yodmanee et al., 2011). Purple or black rice is considered an heirloom variety and has been cultivated for a long time in Asia. Black rice, considered as "forbidden rice" in China was grown exclusively for the emperors to enrich their health and ensure longevity (Axe, 2016).

Production of black rice is affected by cultivar and location of production (Suzuki et al., 2004). Recently, black rice has been grown in the Philippine lowlands. The Department of Agriculture (DA) of the Philippines exported black rice to Hongkong and United Arab Emirates for its premium quality (Villafania, 2013). Black rice has health-promoting properties (Prakash, 2007) and can be used as a natural food colorant (Deng, 2013). It has nutritional advantages over common rice as it has higher protein, vitamin, fiber, fat, and mineral contents (Staub, 1982).

The bran is the hard outer layer of the cereal grain consisting of the aleurone layer and the pericarp. The color of black rice is due to its anthocyanin content (Ryu et al., 1998; Hu et al., 2003; Abdel-Aal et. al, 2006), a phenolic compound known for antioxidative and radical scavenging properties (Kuppatarat, 2012; Hu et al., 2003). This pigment is mostly located in the aleuronic layer of the rice grain. The health-related effects of anthocyanin as an antioxidant include the prevention or reduction of degenerative diseases (Prakash, 2007), diseases associated with oxidative stress such as cancer (Nam et al., 2006; Chen et al., 2006), and cardiovascular disease (Jerzy et al., 2003). Despite claims of health benefits and nutraceutical values, the preference for black rice remains low because of its unlikeable peculiar flavor, texture, and poor eating quality.

The bran contains much of the pigments and nutrients; thus, removing the bran through milling and processing with prolonged heat treatment can result to physical degradation and nutritional losses (Rutledge and Islam, 1973).

Parboiling is an age-old process practiced in many parts of Asia and in other countries to improve the milling recovery of rice, salvage poor quality or spoiled paddy, and to meet the demands of consumer preferences. Due to the commercial and market advantages of parboiled rice, it accounts for one fourth of the rice consumed worldwide (Bhattacharya, 2004). Parboiling is a hydrothermal process, in which rice is soaked with the husk still on and then steam-cooked before drying and milling (Wimberly, 1983; Riceland International Limited, 2011). Parboiling does not allow the kernel to swell during cooking by controlling the temperature and absorption of moisture. Soaking plays a big role in the success of parboiling. The absorbed moisture up to 30% facilitates cooking and heat transfer during the succeeding parboiling step (Wimberly, 1983). Moisture content also affects the extent of the formation of amylose-lipid complexes that determine the firmness of the cooked parboiled rice and forms a barrier that prevents the starch granules from swelling (Derycke, 2011). Migration of essential nutrients such as thiamine from the bran into the kernel of the grain is attained in soaking.

Steaming is an important process in parboiling, in which most of the changes in the physico-chemical and textural properties occur (Wimberly, 1983). Steaming induces starch gelatinization in the grain. Starch gelatinization is a process that breaks down the intermolecular bonds of starch molecules in the presence of water and heat; allowing the hydrogen bonding sites to engage more water (Belitz et al., 2009). Use of steam for gelatinizing the starch is preferred over other methods of heating as it does not remove moisture from rice. The moisture content of the paddy increases to about 38% during steaming (Wimberly, 1983).

When heating paddy with non-pressurized steam, small variations are found in color, quantity of soluble starch, and the amount of swelling of the milled parboiled rice. When the steaming temperature exceeds $100^{o}C$, it results in deeper color and harder grains. Longer steaming also causes the grains to be harder and darker in color (Wimberly, 1983).

The manner of drying also affects the milling quality. Drying of parboiled paddy may be done under the shade, under the sun, or with hot air. Shade drying takes a longer time but results in excellent milling quality. Rapid sun drying or with hot air causes higher breakage during milling (Wimberly, 1983). In shade drying, the parboiled grain endosperm hardens, that results in firmer and easier to de-husk grains. Breakage is also minimal when milled. This change is attributed to retrogradation of the starch granules in the rice grain. Retrogradation refers to the re-association of starch granules to a more crystalline structure; leading to hardening of the rice grains (Wani et al., 2012). This process results in better milling yield and more separate grains that can withstand long cooking time without becoming undesirably sticky (Riceland International Limited, 2011).

This laboratory-scale study assessed the effect of parboiling on the milling yield, sensory attributes, cooking properties, and antioxidant activity of black rice. The application of parboiling can be useful to the emerging "fancy" rice industry, particularly the farmers and millers who aim for higher yield, and the health-conscious consumers who prefer black rice for health enrichment.

Materials and Methods

This laboratory-scale parboiling study used a Randomized Complete Block Design (RCBD) with three replications. Three steaming times were applied after soaking and before drying. Treatments were Parboiling-Steaming for 3 min (PS-3), Parboiling-Steaming for 5 min (PS-5), and Parboiling-Steaming for 8 min (PS-8). The non-parboiled (NP) treatment was designated as Control. One-way Analysis of Variance (ANOVA) at P0.05 tested the effects of different steaming times on milling yield, sensory characteristics, and antioxidant activity of parboiled black rice. Least Square Difference (LSD) test at P0.05 was applied to compare the means. Sensory attributes were determined by descriptive tests such as the Kramer's Rank Sum and Hedonic scale rating. Mean scores were further tested for differences by the Kruskall Wallis test at P0.05. Determination of the most preferred treatment and general acceptability (Gatchalian and Brannan, 2011) were performed in three runs by a panel of ten sensory evaluators. Data analyses were done using Microsoft Excel and MINITAB Statistical Package Version 15.

Black rice samples were obtained from the Department of Agriculture, Iloilo Provincial Office. The *Bingawan* black rice was organically grown in Barangay Dacutan, Dumangas, Iloilo. Samples were harvested and stored for 6 months before conducting the study.

Parboiling

The parboiling process adopted the method of Cherati et al., (2012) with modifications on steaming duration. After cleaning and washing, the rice was soaked in water at 65°C for 4 h then drained, steamed under 15 psi for 3, 5, and 8 min then spread on trays to dry at ambient conditions for 24 h. After parboiling, grain samples were assessed for dehulling yield, head rice yield, gelatinization temperature, cooking quality, sensory characteristics, anthocyanin content, and radical scavenging activity.

Dehulling Yield

Four hundred grams of parboiled and non-parboiled black rice were subjected to the traditional method of dehulling by pounding the unhulled grains using a wooden mortar and pestle. Manual dehulling was implemented due to the limited amount of black rice seeds. The dehulled grains were separated from the hulls and re-weighed. The dehulling yield was calculated using the formula of the International Rice Research Institute (IRRI) (2009).

Dehulling yield (%) = (Mass dehulled grains)/ (Mass paddy rice) x 100

Gelatinization Temperature

Gelatinization temperature (GT) of starch granules refers to the water temperature at which at least 90% of the starch granules have gelatinized or lost birefringence (Maltese cross) or swollen irreversibly in hot water. The time required for cooking rice is determined by GT. Rice with low GT has softer texture and retrogrades less than rice with high GT. GT was determined using the Alkali Spreading Value (ASV), a standard assay used to classify the processing and cooking quality of rice cultivars. Six grains of each sample were placed in a Petri dish containing 10 mL of 1.0% KOH solution, soaked for 12 h, and then incubated at 30°C. The degree of dispersion was measured using the seven-point scale of IRRI (2009).

1 Grain not affected
2 Grain swollen
3 Grain swollen, collar incomplete and narrow
4 Grain swollen, collar complete and wide
5 Grain split or segmented, collar complete and wide
6 Grain dispersed, merging with collar
7 Grain completely dispersed and intermingled

Rice was classified into high, intermediate, and low GT types based on the extent of grain dispersion. The ASV was related to GT based on the scale of IRRI (2009).

ASV		GT
1-3	high	75.0 - 79.0°C
4-5	intermediate	70.0 - 74.0°C
6-7	low	55.0 - 69.5°C

ASV is inversely related to the temperature at which the rice starch granules gelatinize. The ASV indicates the degree of parboiling (Juliano, 2007). Preference for rice with intermediate GT is common in Asia. Many food processing applications also prefer rice with intermediate GT.

Cooking Quality

Water Absorption Ratio

Water absorption is the amount of water absorbed by the grains when cooked for any length of time. It is also referred to eating consistency. Water absorption ratio is expressed as the ratio of the final to the initial volume or weight of rice. Five grams of the sample was immersed in a beaker containing 40 mL distilled water. The beaker was then immersed in a boiling water bath for 23 min. Excess water was drained off and the sample was blotted dry and re-weighed. The water absorption of rice was based on the increase in weight.

Volume Expansion Ratio

The volume expansion ratio or swelling capacity was determined by comparing the length-breadth ratio of the cooked and uncooked rice grains. Twenty whole grains were obtained from each sample before and after cooking. The length and breadth were measured using a Vernier caliper. The length-breadth ratio was calculated using this formula:

L-B ratio = Length of grain/ Breadth of Grain

Sensory Attributes, Preference, and General Acceptability

The parboiled and untreated samples were subjected to sensory evaluation by a panel of 10 Food Technology students of senior standing who had undertaken sensory evaluation course. Thirty grams of rice from each treatment were placed in 50 mL water in a beaker and cooked for 20 min. The treatments were subjected to sensory evaluation for color, aroma, dispersibility and tenderness, preference ranking, and general acceptability.

Anthocyanin Content

Prior to determination of the anthocyanin content, moisture content of the powdered grain sample was measured by gravimetric method.

Anthocyanin, the major pigment in black rice (Hu et al., 2003), becomes highly unstable and can change when black rice is subjected to heating such as in parboiling. The method for pigment extraction adapted the pH Differential method of Lee (2010), in which the samples were soaked in 1% acidified methanol for three days at 4^oC prior to extraction. The anthocyanin concentration was measured by absorbance at 520 nm and 700 nm wavelengths at pH levels of 1.0 and 4.5. The appropriate dilution for each formulation was determined by diluting the anthocyanin extracts with potassium chloride buffer (pH 1.0) at 520 nm absorbance. The dilution was identified as within linear range if absorbance was between 0.2 and 1.4 AU.

DPPH Radical Scavenging Activity

The 2,2-diphenylpicrylhydrazyl (DPPH) radical scavenging activity (DPPH RSA) of the rice extract, taken as a measure of its antioxidant activity, was determined based on the method of Que et al. (2006). Five dilutions ranging from 100 ppm to 500 ppm from each treatment were prepared and mixed with the DPPH. After 30 min, absorbance was read at 517 nm with the UV-VIS spectrophotometer. The dilution where DPPH (purple) was completely converted to diphenylpicrylhydrazine (yellow) was selected as the working dilution (Sampietro et al., 2009). The scavenging of DPPH radical in percentage was calculated by the following equation:

$$\%\ \text{DPPH RSA} = ((Ao-Ac))/Ao \times 100$$

Where:

Ao - is the absorbance of a DPPH solution without extract

Ac - is the absorbance of the sample, which is equal to the absorbance of the sample solution plus DPPH minus the absorbance of the solution without DPPH solution at the same concentration (ppm).

Results

Dehulling and Head Rice Yields

For the Control or non-parboiled black rice, dehulling yield was 67.1% (Table 1). Dehulling yield increased to an average of 72.2% and did not differ significantly in response to steaming times of 3, 5, and 8 min. The increase in dehulling yield due to parboiling only ranged from 5 to 9%. The increase in head rice yield due to parboiling was much more and ranged from 294 to 318% (Table 1). Likewise, head rice yields did not differ significantly in response to steaming times of 3, 5, and 8 min.

It was observed that parboiled rice was glossy or less chalky than the Control or non-parboiled rice. A very low amount of broken grains was also observed in the parboiled treatment (Figure 1).

Table 1. Dehulling and head rice yields of the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min, PS-5 min, and PS-8 min).

Treatment	Dehulling yield, %	Head rice yield, %
Control	67.62a ± 0.51	22.12a ± 5.60
PS-3 min	73.65b ± 1.17	92.46b ± 1.11
PS-5 min	70.73b ± 2.10	87.15b ± 6.16
PS-8 min	72.32b ± 2.02	88.88b ± 5.82
CV	2.24%	7.00%

In a column, means with the same letter superscripts were not significantly different at P0.05by LSD. Each mean was followed by the standard error + SE.

Figure 1. Broken grains (left) and head rice yield (right) of parboiled black rice.

Alkali Spreading Value and Gelatinization Temperature

Alkali spreading value was scored visually based on a seven-point scale. Parboiled black rice samples steamed for 3 and 5 min scored 5 because the grains appeared split or segmented with the collar complete and wide. With a score of 5, gelatinization temperatures were 70 to 74^{o}C. Parboiled black rice samples steamed for 8 min appeared dispersed and had a score of 6. The intact Control samples had a score of 1 with gelatinization temperatures of 74.5 to 80^{o}C (Table 2).

Cooking and Eating Quality

Water Absorption Ratio and Volume Expansion Ratio

Parboiling significantly reduced the water absorption ratio, volume expansion ratio, and moisture content in black rice (Table 3). However, these parameters did not differ significantly in response to steaming times of 3, 5, and 8 min.

Sensory Attributes

Color

The Control appeared brownish red while the black rice samples were brown to dark brown in response to the different steaming times (Figure 2). The Control was "brownish red" and acceptability was "extremely like". The parboiled samples were "brown" to "dark brown" and acceptability "like very much" (Table 4).

Aroma

The Control had a "slightly strong" aroma while the parboiled treatments had "slightly weak" to "weak" aroma in response to steaming times of 3 or 5 min and 8 min, respectively (Table 4). However, the level of acceptability was "like moderately" for all treatments.

Dispersibility

The descriptive value of 2.54 for the Control was significantly lower than the parboiled-steamed treatments having dispersibility values of 9.54 to 10.2 (Kruskal Wallis' test at P = 0.015). The Control samples were "slightly separated" while all the parboiled samples were within the range of being "moderately separated".

Tenderness

Tenderness was described as soft or had a yielding texture. The parboiled samples were "slightly tough" while the Control samples were

Table 2. Alkali spreading value (ASV) scores and gelatinization temperature (GT) of the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

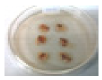
Treatment	Image	ASV	Description	Gelatinization Temperature (°C)
Control		1	Grain not affected	74.5 - 80
PS-3 min		5	Grain split or segmented, collar complete and wide	70-74
PS-5 min		5	Grain split or segmented, collar complete and wide	70-74
PS-8 min		6	Grain dispersed, merging with collar	<70

Table 3. Water absorption ratio, volume expansion ratio, and moisture content of the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

Treatment	Water Absorption Ratio	Volume Expansion Ratio	Moisture, Content, %
Control	2.29a ± 0.16	3.53a	35.2a
PS-3 min	1.97b ± 0.08	2.80b	27.0b
PS-5 min	1.80b ± 0.16	2.73b	28.2b
PS-8 min	1.71b ± 0.12	2.79b	29.2b

Note: In a column, means with the same letter superscripts were not significantly different at P0.05 by LSD. Each mean was followed by the standard error ± SE.

Figure 2. Colors of the Control or non-parboiled samples and parboiled black rice samples steamed for 3, 5, and 8 min.

"slightly soft and sticky (Kruskal Wallis' test at P = 0.014).

Most Preferred Treatment

With the least sum, the parboiled rice steamed for 8 min was the most preferred treatment. However, the three steaming times fell on the Kramer's Rank Sum range of 15 to 25 (n =10); thus, they were not significantly different in terms of preference (Table 5).

General Acceptability Test

The test on general acceptability showed that the Control had a Hedonic rating of "like slightly" or the least preferred while the parboiled-steamed treatments had a similar rating of "like moderately" (Table 6).

Table 4. Sensory attributes and acceptability for the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

Treatments	Attributes							
	Color		Aroma		Dispersibility		Tenderness	
	Description	Acceptability	Description	Acceptability	Description	Acceptability	Description	Acceptability
Control	brownish red	Like extremely	Slightly strong	Like moderately	Slightly separated	Neither like nor dislike	Slightly soft and sticky	Like Slightly
PS-3 min	brown	Like very much	Slightly weak	Like moderately	Moderately separated	Like extremely	Slightly tough	Like Moderately
PS-5 min	brown	Like very much	Slightly weak	Like moderately	Moderately separated	Like extremely	Slightly tough	Like Moderately
PS-8 min	dark brown	Like very much	Weak	Like moderately	moderately separated.	Like extremely	Slightly tough	Like Moderately

Table 5. Kramer's rank sum for preference for the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

Treatment	Sum	Rank
Control	32.0 a	4
PS-3 min	23.7 b	3
PS-5 min	22.3 b	2
PS-8 min	22.0 b	1

Note: In a column, means with similar letter superscripts were not significantly different based on a rank test range of 15 to 25 (for n = 10; R = 4).

Table 6. General acceptability rating for the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

Treatment	Grand Median Score	Hedonic Rating
Control	6.0 a	Like Slightly
PS-3 min	6.7 b	Like Moderately
PS-5 min	7.0 b	Like Moderately
PS-8 min	7.0 b	Like Moderately

Note: In a column, means with similar letter superscripts were not significantly different at P0.05 by Kruskal Walli's test.

Table 7. Anthocyanin contents and DPPH radical scavenging activities of the Control or non-parboiled black rice and parboiled black rice steamed for 3, 5, and 8 min (i.e., PS-3 min; PS-5 min; and PS-8 min).

Treatment	pH	Anthocyanin Content, (mg L^{-1})	Radical Scavenging Activity, (%)
Control	6.54a ± 0.03	17.7a ± 0.06	87.0a ±2.3
PS-3 min	6 .03b ± 0.03	13.3ac ± 0.01	81.1b ±1.1
PS-5 min	6.06b ± 0.03	9.77bc ± 0.03	76.5c ±1.0
PS-8 min	6.03b ± 0.02	6.75b ± 0.03	70.6d ±1.1

Note: In a column, means with the same letter superscripts were not significantly different at P0.05 by LSD. Each mean was followed by the standard error ± SE.

Anthocyanin Content and DPPH Radical Scavenging Activity

The anthocyanin content, 2,2-diphenylpicrylhydrazyl (DPPH) radical scavenging activity, and pH of the parboiled black rice were lower than the Control (Table 7). For the parboiled-steamed treatments, pH close to 6.0 did not differ significantly in response to the three steaming times. However, at steaming times of 3, 5, and 8 min, anthocyanin contents decreased from 13.3 to 6.75 mg L-1. Similarly, the DPPH radical scavenging activity decreased from 81.1 to 70.6% as steaming time increased (Table 7).

Discussion

Dehulling Yield

Manual dehulling was implemented in this study because of the limited supply of black rice seeds. Baig (2012) explained that the pulverization of the non-parboiled rice samples could be due to the weak cohesion of the starch molecules inside the rice kernel with voids or spaces between them. The increase in dehulling yield may result from the loosening of kernel attachment to the husk. This occurs at the steaming stage with processes on kernel gelatinization, retrogradation and compaction, and pulling-off of the kernel from the husk during drying. Thus, dehulling becomes easier as the kernel inside the husk has softened with the processes (Ayamdoo et al., 2013).

Head Rice Yield

Head rice yield is one of the most important parameters in determining the economic and processing value of the rice crop. Improved head rice yield translates into higher profits because unbroken kernels command a higher price in the market place than broken kernels. In the present study, head rice yield increased significantly in response to parboiling but did not differ across steaming times of 3, 5, and 8 min. This finding confirms the results of earlier studies (Bhattacharya, 2004; Danbaba et al., 2014). After soaking with warm water below the gelatinization temperature (<70°C), steaming or heating gelatinizes the starch; preventing cracks in the rice grains after drying. Thus, a good head rice yield is obtained (Bhattacharya, 2004; Min et al., 2014).

Chalkiness was observed in the non-parboiled grains. Juliano (2007) explained that the chalky regions contribute to grain breakage during milling. The starch granules in the chalky rice endosperm are loosely packed and the resulting air spaces impact refraction of light through the grain. The glossiness of the parboiled rice may be due to the gelatinization of the starch granules and hardening of the endosperm that caused the air spaces to disappear. That way, light cannot pass through resulting in a glossy appearance of the grain.

Alkali Spreading Value (ASV)

ASV is directly proportional to degree of parboiling. ASV measures the gel type of rice, that allows an estimate of the gelatinization temperature (GT). GT refers to the water temperature, in which at least 90% of the starch granules have gelatinized or lost birefringence. Rice with low GT tends to cook faster and lose its structure, while rice with a higher GT has a more stable structure during processing. It also has a harder texture. A distinct preference for rice with intermediate GT or with ASV scores of 4 to 5 was observed in many rice-growing countries (Bhattacharya, 2011). The ASV score of 5 (Table 2) indicates that 3-min and 5-min steaming times are effective in obtaining intermediate gelatinization of black rice for the improvement of its eating quality.

Cooking and Eating Quality

Water Absorption Ratio

Due to parboiling, the starch granules develop stronger structure and limits water penetration into the kernel. Results confirm previous reports that parboiled rice has lower water absorption capacity than raw rice; thus, parboiled rice retains better shape, is fluffier, less sticky, more consistent, and loses less solids during cooking (Juliano, 1985). However, water absorption and volume expansion ratios in black rice were not significantly affected by the duration of steaming.

Volume Expansion Ratio

The volume expansion ratio, sometimes called the swelling capacity, is the ratio of the final volume of cooked rice to the original volume. It indicates how well the grains will swell when cooked. The three steaming times could have had created greater gelatinization network in the grain; thus, limiting the volume expansion in the grain due to lower absorption of water.

Sensory Attributes

Color

The non-parboiled and parboiled black rice samples were evaluated for color, aroma, dispersibility, and tenderness as these attributes are affected by parboiling (Wimberly, 1983). Gariboldi (1984) reported that the pigments in the husk that were dissolved in water and pushed into the endosperm through heat (Gariboldi, 1984) caused the dark of color of the parboiled black rice.

Aroma

The slightly strong aroma of the Control, slightly weak aroma of parboiled rice steamed for 3 and 5 min, and weak aroma of parboiled rice steamed for 8 min all received a similar acceptability level of "like moderately". While longer steaming time tends to diminish aroma, the level of acceptability for aroma is not easy to distinguish for non-parboiled and parboiled treatments. However, on the basis of general acceptability rating (Table 6), the three parboiled-steaming treatments are more acceptable than the Control or non-parboiled treatment.

Anthocyanin Content and DPPH Radical Scavenging Activity

The anthocyanin content and DPPH radical scavenging activity (DPPH RSA) were lower than the Control or non-parboiled black rice, and decreased in response to steaming times of 3, 5, and 8 min (Table 7). The ability of phenolic compound in black rice to quench reactive species by hydrogen donation was measured through the DPPH RSA assay (Que et al., 2006). The DPPH RSA method was found to be mostly used for evaluating *in vitro* antioxidant activity (Alam et al., 2013). However, the antioxidant capacities in whole grain rice were evaluated by DPPH RSA and oxygen radical absorbance capacity (ORAC) assays, both commonly used to measure *in vitro* antioxidant capacity using plant sources (Min et al., 2014). These two assays measure different mechanisms of antioxidants: the reducing capacity by the DPPH assay and the hydrogen atom donating capacity to break the free radical chain reactions by the ORAC assay. Thus, both assays provide useful information about the antioxidant properties in whole grain rice.

The parboiling process includes soaking, steaming or heating, and drying (Bhattacharya, 2004). By changing the drying method, from a one-step continuous drying method to a two-step drying method incorporating a hot-temperature tempering step in-between that reduces the moisture gradient in the drying grain, eliminates grain cracking. Hence, a 2-min steaming at atmospheric pressure could achieve starch gelatinization (Bhattacharya, 2004). These milder conditions for parboiling might improve the retention of the water soluble phenolics that are heat-sensitive (Min et al., 2014).

Conclusion

Steaming is an important part of parboiling as it is a major factor in most of the changes in the physical and chemical properties of the grain. Results showed the positive effects of parboiling black rice in terms of reducing broken grains and improving head rice yield, cooking and eating quality, and general acceptability.

The parboiled rice steamed for 3 and 5 min demonstrated similar degree of heat treatment to achieve an intermediate starch gelatinization and a more stable structure that regulated water absorption and swelling. However, in response to parboiling with steaming times of 3, 5, and 8 min, the anthocyanin content and DPPH radical scavenging activity decreased. Parboiling process may be optimized to reduce loss of anthocyanins and improve free radical scavenging activity.

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Productivity and Profitability Outcomes of Seed Choice Behavior of Rice Farmers in Quezon, Palawan, Albay and Camarines Sur, Philippines

Agnes C. Rola[1,*], Merlyne M. Paunlagui[1], Dhanicca Amor M. Domingo[1], Therese R. Olviga[1], Sancho G. Bon[2], Danilo J. Lalican[2] and Jose E. Hernandez[2]

[1]College of Public Affairs and Development, University of the Philippines Los Baños, College, Laguna; [2]College of Agriculture, University of the Philippines Los Baños, College, 4031, Laguna, Philippines
*Corresponding author: acrola@up.edu.ph; agnescrola@gmail.com

Abstract Use of good seeds contributes to an increase in rice crop productivity. However, poor farming communities usually do not have access to good seeds. The Government addressed the problem through subsidized certified seeds to improve the seed stock. This paper determined changes in seed technologies and corresponding yield and net returns of rice farmers in 2009 (with certified seed subsidy) and 2012 (without certified seed subsidy) from three seed sources: certified seed program, exchanged seeds, and farm-saved seeds, which were known to be utilized in community seed banks. Data were obtained from two sets of survey: baseline survey of 150 farmer respondents of the Collaborative Research Development and Extension Services (CRDES) Program in 2009 and a follow-up survey in 2013 of 115 rice farmers from the list of 2009 CRDES respondents in Quezon (in Region 4A), Palawan (in Region 4B), Albay and Camarines Sur (in Region 5). Results showed no significant change in the seed technology during the study period. In general, net returns from certified seeds and farm-saved seeds were higher than exchanged seeds. Results imply the need to integrate extension messages on seed management with seed distribution programs. National agencies should strengthen their link with local municipal offices found to be the preferred seed sources.

Keywords: Certified Seeds, Costs and Returns, Exchanged Seeds, Farm-Saved Seeds, Philippines, Rice.

Introduction

For the past several decades, the Philippine Department of Agriculture (DA) has poured significant investments into Research, Development and Extension (RDE) to improve the rice seed stock of the farming communities in the country; thus, contributing to food security of the predominantly rice-eating Filipinos.

Since the start of the "Green Revolution" in the 1960s (Galero et al., 2014), seeds became the centerpiece of rice extension program packages. From 1990s to 2000s, rice seed subsidy programs introduced the hybrid seeds to farmers. Studies showed that the hybrid rice seed technology increased yields by 15 to 30% (Santaguiel and Quipot, 2012); boosting productivity of hybrid seed adopters. Both hybrid and inbred seeds were introduced through the seed subsidy program during the term of Pres. Gloria Macapagal-Arroyo.

To intensify the use of hybrid rice, the Hybrid Rice Commercialization Program (HRCP) was officially implemented in 2002 (Casimero and Dimaano, 2009). The seed subsidy programs implemented by the national government and local government units had different provisions but normally, the subsidy amounted to PhP 1,200.00 per 20 kg of rice seeds. If farmers did not adopt or lacked enthusiasm, the subsidy was increased to as high as PhP 2,400.00 per kg seeds (David, 2007). Partial budget analysis made by Cataquiz et al. (2006) showed that farmers in irrigated areas obtained an added benefit of at least PhP 2,500.00 per ha provided that they did not exceed the recommended seeding rates. The estimated net benefit of the certified seeds program was PhP 2.8

million in 1.27 million ha of the 2004 program area, and equivalent to a social benefit-cost ratio of around 3:1 However, seed subsidies must be well-targeted and of limited duration (Cataquiz et al., 2006). This relied on the premise that upon seeing the advantages of using certified seeds, farmers would continue to use certified seeds even without government seed subsidies. However, the use of certified seeds was difficult to sustain without seed subsidy because sale of seeds depended highly on government procurement. Even with 50% price subsidy, farmers have difficulty on paying the subsidized certified seeds (Rola and Paunlagui, 2012).

After the introduction of certified seeds, a 0.34 ton per hectare (or 0.34 t/ha) increase in the national average yield was observed. Based on surveys conducted by Philippine Rice Research Institute (PhilRice) and Bureau of Agricultural Statistics (BAS), as reported by Cataquiz et al. (2006), the average yield advantage of using quality or certified seeds over farm-saved seeds was 300-470 kg per hectare (0.30-0.47 t/ha) in irrigated areas and 500-650 kg per hectare (0.50-0.65 t/ha) in rainfed areas. Based on data from experiments conducted in Nueva Ecija, the yield advantage of certified seeds over farm-saved seeds ranged from 7 to 13%. Based on analysis of the data from PhilRice and BAS, Cataquiz et al. (2006) reported that 9% of the increase in the national average yield in 2002 can be attributed to the use of certified seeds while the 91% increase can be attributed to farmer's practices and weather.

Cataquiz et al. (2006) suggested that instead of seed subsidy, the government should prioritize productivity-enhancing investments such as agricultural research, information dissemination, and infrastructure. Cataquiz et al. (2006) added that the main rationale of seed subsidy was to foster farmer experimentation and increase knowledge on seed selection and proper farming practices. The ideal platform that the government must promote was a program that would encourage farmers to adopt better seeds to ensure stability in rice seed system. To ensure stability in seed system and rice production, there should not only be seed sufficiency but also seed security; thus, a mechanism that can improve farmers' access to high quality seeds was needed (Rola and Paunlagui, 2012).

During the administration of President Benigno S. Aquino III, a policy shift on seed provision was observed, subsidies were scrapped, and community seed banks were promoted. Community seed bank was an extension tool to increase farmer's access to quality seeds, which were controlled and operated by farmers in the community. Seed production and exchange were both encouraged among farmers within and outside the community.

In the community seed bank model, public funds were used for the procurement of starter seeds, which could either be registered seeds (slightly more pure than certified seeds) or upland traditional rice seeds. The seeds were then distributed to qualified Irrigators' Associations (IAs), Farmers' Associations (FAs), and Non-Government Organizations (NGOs) (Department of Agriculture, 2011). The selected farmer reproduced the registered seeds. The harvested seeds were routinely checked by authorized staff from seed laboratories to ensure quality before the seeds were stored in the seed bank.

The aforementioned government seed programs offered rice farmers the choice of seed sources. This paper analyzed the farm level effects of the seed source choices through changes in farm practices, yields, and farm profits. Specifically, this paper aimed to: 1) determine whether temporally, rice farmers' seed varieties have indeed changed, and whether farm practices have correspondingly changed; 2) compare rice farmers' production performance by seed source, (i.e., subsidized certified seeds, exchanged seeds, and farm-saved seeds), and 3) analyze the farm level profitability of the farmer's choice of seeds.

Materials and Methods

This study used the data from CRDES farmer-beneficiaries of Rice Self-Sufficiency Program in Regions 4A, 4B, and 5 – a program funded by the Department of Agriculture-Bureau of Agricultural Research (DA-BAR) to determine productivity and profitability outcomes of the farmer seed choice behavior. The program's strategy was to provide technical assistance, training, and seed production services in the regions of study to achieve at least a ton per ha increase in rice yield.

The analysis consisted of two distinct parts. First, it aimed to explain whether there were changes in the practices, yield, and profit of farmers from the baseline survey in 2009 (with government subsidy) until 2012 (without subsidy). Second, considering the seed intervention program promoted by the government (seed subsidy and community seed banking), this study analyzed the productivity and profitability performance of the two types of seed sources: certified seeds from the subsidy program and the exchanged seeds (among farmers). A third seed source, the farm-saved seeds (from one's farm) served as the control.

Data Collection

Primary and secondary data were used in this study. In-depth interviews with key-stakeholders were conducted to gain a profound understanding of the preferences and practices of farmers.

The temporal analysis used the 2009 baseline survey data conducted by CRDES Staff while the 2013 survey data were generated using a subset of the sample respondents in 2009. Methodology for data collection was described by Rola et al. (2012). Data from the baseline survey was used to evaluate the changes in the practices, preferences, and crop harvest of farmers given the time lapse and the change in rice program policy. For this second set of information, a follow up survey tracking the CRDES respondents was done in 2013, in which 115 rice farmers from Quezon in Region 4A; Palawan, 4B; and Albay and Camarines Sur, Region 5, were re-interviewed.

Farmers' socio-economic profiles, common rice cultivation practices, nutrient and pest management practices, and sources of technical information on improved rice cultivation techniques were obtained. Data on type of seed planted for the specified season, reasons for using the specified source of seeds, seeding rate, and preferred seed source were obtained. The farmer-respondents were asked to specify their rice-cultivation techniques per cropping season.

The following data were collected from the respondents who received certified seeds from the CRDES Program: rice variety and quantity (in bags), impressions on supplied certified seeds, yield and crop management practices used for the supplied certified seeds.

Analytical Procedures

Descriptive statistics such as frequencies and percentages were used to describe the socio-economic characteristics of the farmer-respondents and their commonly practiced rice cultivation techniques.

Cost and return analysis per seed source (certified seed, exchanged seed, and farm-saved seed) was done to determine which seed source gave the highest productivity and profitability. The variables included in the estimation of gross returns were yield per hectare and farm price of palay, and cash cost data that included cost of seeds, fertilizers, pesticides, and labor. Net returns were computed by subtracting the total cash costs from the gross returns.

T-test was used to examine the differences between certified and exchanged seeds in terms of yield and cost and net returns; and between farm-saved seeds and exchanged and farm-saved seeds.

Results

This section was divided into three parts. The first part presented comparative analysis of rice production practices in Wet and Dry Seasons (WS and DS) in 2008-2009 and WS and DS in 2012-2013. For the computation of average yield, only farm-saved seeds were included in planting season 2012-2013 as they were the only treatment in the 2008-2009 baseline survey. The second part of this section compared the production performance of certified seeds, exchanged seeds, and farm-saved seeds, using the data from the 2012-2013 planting seasons. The third part was a comparative analysis of farm level profits across the seed sources using the same data set.

A. Comparative Analysis of Rice Production Practices in 2008-2009 and 2012-2013 Planting Seasons

The most preferred rice variety did not change through time as farmers still planted PSB Rc18 (Table 1). Other preferred varieties were PSB Rc10

Table 1. Rice varieties preferred by farmers and top problems in seeds in Quezon (Region 4A), Palawan (Region 4B), and Albay and Camarines Sur (Region 5) for two periods.

Concern	2008 – 2009			2012 – 2013		
	Region 4A	Region 4B	Region 5	Region 4A	Region 4B	Region 5
Most popular rice variety	PSB Rc18	PSB Rc18	PSB Rc18 (Blondie)	PSB Rc18	PSB Rc18, PSB Rc10 (Blondie)	NSIC Rc 222
Top problem in seeds	Poor germination	Poor germination	Low resistance to diseases, poor germination	Low resistance to pests and diseases	Poor germination; Low resistance to lodging and drought	Low resistance to pests and diseases

Table 2. Rice yields (metric tons/hectare or t/ha) in irrigated and rainfed areas across seasons for two periods.

Concern	2008 – 2009			2012 – 2013		
	Region 4A	Region 4B	Region 5	Region 4A	Region 4B	Region 5*
Irrigated (WS-DS)	3.1 – 3.4	3.4 – 3.6	3.0 – 3.5	4.0 – 5.3	7.4 – 5.0	0.8 – 3.8
Rainfed (WS-DS)	3.6 – 3.1	2.8 – 2.9	2.3 – 2.4	1.4 – 1.8	3.6 – 2.9	N/A

(Blondie) in Quezon and Palawan and NSIC Rc222 in Albay and Camarines Sur for 5. Farmers did not plant the varieties from the national seed subsidy program.

The major seed problems that farmers reported in the early year included poor germination and low resistance to diseases. In 2012-2013, low resistance to lodging and drought were the other problems (Table 1).

Complete fertilizer (14-14-14) and urea (46-0-0) were frequently applied by farmers in the three regions for both periods. Region 5 recorded the highest application of urea, followed by Region 4B. Region 4B recorded the highest application of complete fertilizer, followed by Region 5.

Region 4A suffered from infestation of rice black bugs (atangya or Scotinophara coarctata) and rats during the 2008-2009 planting seasons. In Region 4B, snails and rats were the top pests while snails, rats, and army worms were more prevalent in Region 5. In 2012-2013 planting seasons, all farmers reported worms, snails, and bugs as common pests. However, 8% of the farmers in WS and 14% of the farmers in DS did not apply pesticides. Eighty six percent of the farmers interviewed used a range of well-established brands of pesticides such as Karate for atangya; Zinc Phosphide and Racumin for rats; Bayluscide, Bayonet, and Snailmate for snails; Tobli, Knockout and Scorpio for bugs, and Karat, Brodan, and Malathion for worms. Seventy six percent of the farmers applied branded pesticides in DS 2008-2009. Less than 20% of the farmers used manual labor in weeding their farms in both years.

Rice yields in irrigated farms in Region 4A increased from 3.1 mt/ha in WS and 3.4 mt/ha in DS of 2008-2009 to 4.0 mt/ha in WS and 5.3 mt/ha in DS 2012-2013, respectively (Table 2). Yields of irrigated farms from Region 4B also increased during the two periods, but yields of irrigated farms in Region 5 decreased.

Rice yields in rainfed areas in Regions 4A and 4B in WS and DS decreased in 2008-2009 and 2012-2013 (Table 2). Yields in Region 5 increased from 2.3 mt/ha in WS 2008-2009 to 2.4 mt/ha in DS 2008-2009. Yield reductions in Regions 4A and 4B were attributed to pests. Some of these pests were not known to farmers; hence, difficult to manage. The effect of climate change was felt, especially the change in rainfall patterns in the rainfed areas. In irrigated areas, increases in yields were attributed to increase in fertilizer use.

B. Comparative Analysis of Rice Production Performance by Source of Seeds, 2012-2013

The seed subsidy and community seed banking programs served as the context in the following analysis: sources and preferences of seeds, use of exchanged seeds, and use of farm-saved seeds.

Sources and Preferences of Seeds

Some local government units continued to subsidize farm inputs despite the national government scrapping its major seed subsidy program in late 2010. Not all farmers availed of these subsidies, nor all local government units offered seed subsidy. Forty-four percent of the farmers who availed of the subsidy often used farm-saved seeds, while 33% sourced seeds through the municipal agriculture office, and 10% obtained seeds from the neighbors. The rest chose seed producers or other sources such as politicians and non-government organizations. However, farmers had some preferences on the seed source. Twenty-seven percent chose the agriculture office and used their own farm-saved seeds while 12% obtained seeds from fellow farmers (Table 3).

Use of Certified Seeds

Fifty percent of the farmers planted certified seeds in WS and 29% planted certified seeds in DS. In Regions where training on seed entrepreneurship for seed producers was held, it was noticeable that farmer-respondents preferred certified seeds than other seed sources. Meanwhile, farmer-respondents from Palawan stated that they preferred farm-saved seeds (Table 4).

Thirty three percent of the farmers planted the certified seeds that came from the subsidies provided by their respective municipalities. This was one of the factors that affected farmer's decision on sourcing their seeds or in using certified seeds for the current cropping season. Farmers considered the municipal agriculture office and their neighboring farmers reliable; implying that farmers have yet to trust the rice seed industry.

Seed price was considered an important factor in the choice of seed source. Other reasons included seed availability, expected yield, and newness of the variety.

Not all farmers had access to high quality seeds or certified seeds. This was evident on how farmers frequently used them as presented in Table 5. Overall, 18% of the farmers used certified seeds every cropping season while the rest either rarely (22%) or occasionally (60%) used them.

In WS 2012, the average seeding rates for certified seeds were 94.89 kilograms per hectare (or in kg/ha) in rainfed areas and 56.92 kg/ha in

Table 3. Survey on farmer preference of seed source in the different regions in 2013.

Source	Region 4A (N = 48)		Region 4B (N = 50)		Region 5 (N = 17)		Total (N = 115)	
	No.	%	No.	%	No.	%	No.	%
Agriculture office	11	22.92	10	20.83	10	58.82	31	26.96
Own farm-saved seed	12	25.00	15	31.25	4	23.53	31	26.96
Other farmers	4	8.33	10	20.83	0	0.00	14	12.17
Seed producers	2	4.17	9	18.75	2	11.76	13	11.30
Farmers' Association	6	12.50	0	0.00	1	5.88	7	6.09
Undecided	13	27.08	6	12.50	0	0.00	19	16.52

Table 4. Use of certified seeds (%) in in the different regions in WS 2012 and DS 2013.

Concern	Region 4A (n=48)				Region 4B (n=50)				Region 5 (n=17)				Total (n=115)			
	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS	WS	DS
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Used certified seeds	30	63	21	44	14	28	4	8	14	82	8	47	58	50	30	29
Did not use certified seeds	13	27	27	56	34	68	36	72	3	18	7	41	50	43	70	61
Did not plant	5	10	0	0	2	4	10	20	0	0	2	12	7	6	12	10

Table 5. Frequency and percentage of certified seed use in the different regions in 2012.

Use of Certified Seeds	Region 4A (n=48)		Region 4B (n=50)		Region 5 (n=17)		Total (N=115)	
	No.	%	No.	%	No.	%	No.	%
Every season	15	31.25	1	2.00	5	29.41	21	18.26
Occasional	28	58.33	32	64.00	9	52.94	69	60.00
Rare	5	10.42	17	34.00	3	17.65	25	21.74

Table 6. Average area planted, seeding rate, selling price, and grain yield for certified seeds in wet and dry seasons (WS and DS) in the different regions in 2012.

Parameter	Region 4A				Region 4B				Region 5			
	WS (n = 30)		DS (n = 21)		WS (n = 14)		DS (n = 4)		WS (n = 14)		DS (n = 8)	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Average area planted (ha)*	1	1	1	1	2	3	2	4	5	1	0	2
Average seeding rate (kg/ha)	87	53	94	42	110	100	95	50	50	51	0	49
Price/kg (Php)	14	14	14	13	12	10	13	12	17	13	0	14
Average yield (kg/ha)*	2106	3068	2514	2422	1636	2000	2356	3749	1500	3417	0	3000

Notes: * Certified seeds per variety planted
Numbers were rounded off to the nearest whole number. 1,000 kg/ha = 1 t/ha.
Farmers in rainfed areas in Region 5 interviewed did not plant certified seeds in DS.

irrigated areas. Recommended seeding rates for certified seeds were the same for rainfed and irrigated areas but different for particular crop establishment practices: 40 kg/ha for transplanting and 60-80 kg/ha for direct seeding. In DS 2013, the average seeding rates were 74.07 kg/ha in rainfed areas and 51.73 kg/ha in irrigated areas. Farmers in rainfed areas tended to use 30% more of the certified seeds than the farmers in the irrigated areas. This was due to farmers' perception that high seeding rate ensured good germination and crop stand. In WS, Region 4B had the highest average seeding rates of 110 kg/ha in rainfed areas and 100 kg/ha in irrigated areas (Table 6). Region 5 had the lowest average seeding rate in DS and WS.

Yields were higher in DS than in WS especially in the rainfed areas (Table 6). The lower WS yield, particularly in the Region 4B, was attributed to black bug infestation.

The selling price of certified seeds was higher in rainfed than in irrigated areas while price of harvested seeds varied in different regions and ecosystems. Usually, the price was higher in DS in Regions 4A, 4B, and 5. In as much as higher seeding rates meant higher costs for buying seeds, farmers incurred more expenses in rainfed areas than in irrigated areas. Furthermore, yields of certified seeds in rainfed areas were lower than in irrigated areas. Farmers may have limited training on the use of certified seeds in rainfed areas.

Use of Exchanged Seeds

Farmer-respondents without access to subsidized certified seeds used own-saved seeds or through seed exchange with neighboring farmers. They based their decision on the previous field performance of the rice variety. From this scheme, rice seeds circulated among the farmers within a community. That was the mechanism of a community-based seed bank. Of the 115 farmers interviewed, 28 farmers in WS and 31 farmers in DS planted exchanged seeds in 2012-2013.

The average seeding rates of exchanged seeds in WS were 103.58 kg/ha and 67 kg/ha in rainfed and irrigated areas, respectively. In DS, average seeding rates were 83 kg/ha in rainfed areas and 66.67 kg/ha in irrigated areas. Yields in rainfed areas were higher than yields in irrigated areas in

WS, but the opposite was obtained in DS. Exchanged seeds had lower yields than certified seeds and were sold at lower prices (Table 7).

Among the three regions, farmers in Region 4B recorded the highest seeding rates of 103 kg/ha in WS and 100 kg/ha in DS. Region 4A registered the highest selling price for harvested seeds at PhP 13.00 – PhP 15.00/kg while Region 4B had the lowest selling price of PhP 12.00/kg.

Farmers in Region 5 had the highest average rice yields of 3,167 to 3,973 kg per ha or about 3.2 to 4.0 tons per hectare (or in t/ha). Farmers in Region 4A and Region 4B had the lowest average rice yields in WS and DS.

Use of Farm-Saved Seeds

Aside from using exchanged seeds, farmers used farm-saved seeds or seeds they set aside from the last cropping season. In WS 2012, the average seeding rates for farm-saved seeds were 87.73 kg/ha in rainfed areas and 60 kg/ha in irrigated areas. In DS 2013, the average seeding rates for farm-saved seeds were 76.90 kg/ha in rainfed areas and 46.67 kg/ha in irrigated areas.

Farmers who planted farm-saved seeds in rainfed areas in WS 2012 had an average rice yield of 2, 385.16 kg/ha or about 2.4 t/ha. Regardless of season, yields in irrigated areas were higher than yields in rainfed areas (Table 8).

A regional comparative analysis revealed that Region 4B had the highest average seeding rate for farm-saved seeds while Region 5 had the lowest seeding rate. Region 4B had the highest average yields ranging from 2,757 to 4,313 kg/ha (2.8 to 4.3 t/ha) in WS and 2,135 to 5,000 kg/ha (2.1 to 5.0 t/ ha) in DS. Seeds were more expensive in Region 4A than in Regions 4B and 5. A kilo of farm-saved seeds had an average selling price of P14.25/kg in Region 4A, P11.25/kg in Region 4B, and P14.00/kg in Region 5. Farmers who planted certified seeds

Table 7. Average area planted, seeding rate, selling price, and yield for exchanged seeds in the different regions in wet and dry seasons (WS and DS) in 2012.

Parameter	Region 4A				Region 4B				Region 5			
	WS (n = 8)		DS (n = 9)		WS (n = 18)		DS (n = 19)		WS (n = 2)		DS (n = 3)	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Average area planted (ha)*	0.5	3	0.7	2	2	0	1	3	0	1	0	1
Average seeding rate (kg/ha)	88	50	49	70	103	0	100	100	0	83	0	100
Price/kg (Php)	15	14	13	14	12	0	12	12	0	13	0	14
Average yield (kg/ ha)*	3480	500	1146	3142	2611	0	1897	1500	0	3167	0	3973

Notes: * Exchanged seeds per variety planted
Numbers were rounded off to the nearest whole number. 1,000 kg/ha = 1 t/ha.
Farmers in Region 4B twho managed irrigated farms and famers in rainfed areas in Region 5 who did not plant exchanged seeds in WS.

Table 8. Average area planted, seeding rate, selling price, and yield for farm-saved seeds in wet and dry seasons (WS and DS) in 2012.

Parameter	Region 4A				Region 4B				Region 5			
	WS (n = 9)		DS (n = 22)		WS (n = 20)		DS (n = 18)		WS (n = 1)		Dry (n = 4)	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Average area planted (ha)*	1	.3	1	.5	2	3	2	1	0	3	0	2
Average seeding rate (kg/ha)	69	200	54	75	110	65	104	160	0	20	0	40
Price/kg (Php)	14	14	14	15	11	10	12	12	0	14	0	14
Average yield (kg/ha)*	1354	4000	1631	3507	2757	4313	2135	5000	0	760	0	3299

Notes: * Farm-saved seeds per variety planted
Numbers were rounded off to the nearest whole number. 1,000 kg/ha = 1 t/ha.
Farmers interviewed rainfed areas in Region 5 did not plant farm-saved seeds in WS and DS.

in DS had the lowest yield due to the late arrival of seeds. Farmers that planted farm-saved seeds in irrigated areas in WS had the highest yield of 3, 272.50 kg/ha (3.3 t/ha). Farm-saved seeds had the highest average yield among the other seed sources in DS and WS, followed by certified seeds. Other factors considered in evaluating the efficacy of the seed sources were irrigation facilities/water supply, weather, presence of pests and diseases, and availability of inputs.

C. Comparative Analysis of Farm Level Profitability by Source of Seeds, 2012-2013

The cost and return analysis showed that net returns for using certified seeds were higher in DS than in WS for irrigated and rainfed areas (Table 9). However, farmers using exchanged seeds had varied net returns. This could be due to pest attacks and extreme climate-related events. For farmers using farm-saved seeds, net returns were higher in irrigated areas than in rainfed areas in WS and DS. A comparative analysis of profitability among the various seed sources is shown in the succeeding sections.

Certified Seeds vs. Exchanged Seeds

In terms of gross returns, certified seeds had significantly higher returns over exchanged seeds in WS in irrigated areas, and in DS in rainfed areas (Tables 10A). Farmers who planted certified seeds and exchanged seeds invested on material inputs to enhance crop yield performance; thus, total costs were not statistically different across seasons in irrigated and rainfed areas. Net returns were positive and statistically significant in irrigated areas in DS and WS while net returns in rainfed areas were good only in DS. Differences in net returns between certified seeds and exchanged seeds were negative in WS in rainfed areas as crops were infested with black bugs.

Certified Seeds vs. Farm-Saved Seeds

Yields between certified seeds and farm saved-seeds in WS and DS in rainfed and irrigated areas did not differ significantly (Table 10B). In terms of costs, certified seeds were more expensive than farm-saved seeds in three out of four instances. Hence, net returns from planting certified seeds over farm-saved seeds had a negative difference in rainfed areas in WS. It was observed that farmers who bought certified seeds spent more on other material inputs than users of farm-saved seeds.

Exchanged Seeds vs. Farm-saved Seeds

Yields and gross returns between exchanged

Table 9. Average yield and cost and return per hectare of palay production by seed source in wet season (WS) 2012 and dry season (DS) 2013 for Regions 4A, 4B, and 5.

Parameter	Certified Seeds				Exchanged Seeds				Farm-Saved Seeds			
	WS (n=60)		DS (n=35)		WS (n=28)		DS (n=31)		WS (n=30)		DS (n=44)	
	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
Yield (kg/ha)	2, 071.06	3, 211.46	2, 426.04	3, 221.97	2, 712.19	1, 566.67	1, 788.99	2, 924.33	2, 385.16	3, 272.50	1, 829.04	3, 179.04
Price/kg (Php)	13.75	13.12	13.85	13.34	12.15	12.26	12.22	13.44	11.170	11.47	12.69	14.29
Total Cost (P/kg)	23, 191.05	30, 546.28	23, 435.57	27, 180.31	18, 690.29	26, 480.66	19, 316.34	34, 730.49	15, 176.18	18, 621.04	14, 170.83	28, 903.61
Gross Return (P/ha)*	28, 477.02	42, 134.29	33, 601.13	42, 981.08	32, 953.03	19, 207.33	21, 861.51	39, 303.04	27, 906.38	37, 535.59	23, 210.48	45, 428.46
Net Return (P/ha)	5, 285.97	11, 588.01	10, 165.56	15, 800.77	14, 262.74	(7, 273.33)	2, 545.17	4, 572.55	12, 730.20	18, 914.55	9, 039.65	16, 524.85
ROI	0.23	0.34	0.43	0.58	0.76	(0.27)	0.13	0.13	0.84	1.02	0.64	0.57

Notes: *For the computation of the gross income of the farmers, the price used was the average price per kilogram (P/kg) of all the respondents per season and ecosystem for comparison.
For yield, 1,000 kg/ha = 1 t/ha.
It was assumed that all crop harvests were sold.

Table 10. Comparative t-statistics of key indicators among the seed sources in wet and dry seasons in rainfed and irrigated rice areas.

A. Certified Seeds vs. Exchanged Seeds

	Wet Season				**Dry Season**			
	Rainfed		**Irrigated**		**Rainfed**		**Irrigated**	
	t-stat	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**
Yield	-1.30	0.20	2.16	0.08	1.48	0.15	0.33	0.75
Gross return	-0.71	0.48	2.43	0.05	2.03	0.05	0.72	0.49
Total cost	1.34	0.19	0.64	0.54	1.00	0.32	-1.01	0.34
Net return	-1.77	0.08	2.60	0.04	1.75	0.09	1.76	0.10

B. Certified Seeds vs. Farm-Saved Seeds

	Wet Season				**Dry Season**			
	Rainfed		**Irrigated**		**Rainfed**		**Irrigated**	
	t-stat	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**
Yield	-0.89	0.37	-0.09	0.93	1.28	0.21	0.06	0.95
Gross return	0.12	0.90	0.56	0.59	1.66	0.10	-0.92	0.37
Total cost	2.57	0.01	2.28	0.04	2.57	0.01	-0.29	0.77
Net return	-1.95	0.05	-1.44	0.17	0.23	0.82	-0.10	0.92

C. Exchanged Seeds vs Farm-Saved Seeds

	Wet Season				**Dry Season**			
	Rainfed		**Irrigated**		**Rainfed**		**Irrigated**	
	t-stat	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**	**t-stat**	**P(T<=t) two-tail**
Yield	0.76	0.45	-1.81	0.10	-0.12	0.91	-0.25	0.81
Gross return	0.98	0.34	-1.63	0.14	-0.31	0.75	-1.24	0.23
Total cost	1.80	0.08	1.12	0.30	1.77	0.08	0.64	0.53
Net return	0.34	0.73	-3.61	0.01	-1.49	0.14	-1.54	0.14

seeds and farm-saved seeds did not differ significantly (Tables 10C). However, total cost of exchanged seeds was significantly higher than farm-saved seeds in rainfed areas in WS and DS. Net returns of farm-saved seeds were significantly higher in WS in irrigated areas.

Discussion

Results showed no change in seed variety used by farmers from 2009 to 2012. This indicates that any introduced new variety, including certified seeds and their progeny, were not reaching the farmers in the study sites in Regions 4A, 4B, and 5. Based on a large PhilRice-BAS random survey of rice farmers, Cataquiz et al. (2006) showed that the percentage of farmers who used quality seeds in at least one cropping season increased from 38% in 1996-1997 to 49% in 2001-2002. The average yield advantage of using quality seeds over farmers' seeds ranged from 300 to 470 kg/ha (0.30 to 0.47 t/ha) in irrigated areas and 500-650 kg/ha (0.50 to 0.65 t/ha) in rainfed areas. From 1997 to 2002, only 9% of the yield increase was due to increased use of high-quality seeds, and 91% of the gain must be due to other factors such as fertilizer and chemical use, improved irrigation, and weather.

Our comparative analysis of the performance of certified seeds, exchanged seeds, and farm-saved seeds showed that farm-saved seeds were more productive and profitable. This is in contrast to the findings using experimental data in Nueva Ecija. Data from experiments conducted in Nueva Ecija showed that the average yield advantage of using certified seeds over farmers' seeds ranged from 7 to 13%, depending on the variety and season (PhilRice, 1997 as cited in Cataquiz et al., 2006). The yield advantage of using certified seeds of PSB Rc14, for example, was reported to be 0.57 t/ha.

The reason for the high yields of farm-saved seeds in the current study could be due to farmers using their "good seeds", which they themselves selected. Farmers may have used good crop management practices for their farm-saved seeds.

The seed system used in most traditional farming systems is based on the local production of seeds by the farmers themselves (Worede, 2011). The low yield performance of certified seeds could be due to under investment by farmers on fertilizers that contribute to attainment of rice potential yield. These results imply the need for more innovative ways to increase yields through more holistic extension programs, and supports the contention of Cataquiz et al. (2006) that the government should prioritize productivity-enhancing investments such as agricultural research, information dissemination, and infrastructure, rather than just seed subsidy.

Certified seeds had significantly higher gross returns than exchanged seeds. Yields and gross returns between exchanged seeds and farm-saved seeds did not differ significantly. Farm-exchanged seeds were seen to perform well, income wise because farmers have better knowledge of the technologies and practices that best complement them.

Farm-exchanged seeds were considered to be a component of the community seed bank. The seed bank is at the center of the seed network and offers community services. Aside from seed exchange, it offers seed security in terms of storage, seed distribution, germplasm restoration, and introduction. It is the key component of the community seed network, representing a low-cost and low-technology demanding system that may be owned and managed by local communities. Farmers consistently retain seeds as a security measure to provide a back-up in case of crop failures; thus, seed exchange is also a good adaptation measure during extreme weather events (Worede, 2011; Vernoov et al., 2015). It can also be an equalizer in the community as farmers can have access to the good seeds, especially, the good farm- saved seeds of farmers in the community.

Giving farmers access to good seeds remains a major role of the agricultural extension system. The agricultural extension can introduce new seed varieties to improve the seed stock of the community.

The municipal agricultural office, which was found to be a trusted source of seeds, can serve as the main link of the national seed distribution programs to farmers. The DA regional offices and regional offices of PhilRice can support the seed needs of these local government offices by providing new seed stock and the corresponding crop management packages. National seed distribution programs should ensure that farmers' capacities to manage the seeds are improved through complementing the distribution with farmers' trainings and technological demonstrations.

Conclusion

There was no significant change in the seed technology used by farmers with and without the seed subsidy program. In many cases, yields were not significantly different among the seed sources, except for certified seeds over exchanged-seeds in irrigated areas in wet season. In general, net returns from certified seeds and farm-saved seeds were higher than exchanged seeds.

Seed distribution programs need to have more innovative strategies to improve the seed stock of farmers and farming communities for increased yields and profits. National agencies should link more with local municipal offices that were found to be the preferred seed sources. The agricultural extension's role is still to introduce new seed variety to improve community seed stock. The municipal agricultural office, found to be a trusted source of seeds, can facilitate the national seed distribution programs. The DA regional offices and PhilRice stations can support the seed needs of these local government offices. National seed distribution programs should ensure that farmers' capacities to manage the seeds are improved through seed management training programs.

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Constraints to Adoption of Organic Rice Production in Selected Areas in the Philippines

Blanquita R. Pantoja*, Gerdino G. Badayos, and Agnes C. Rola

College of Public Affairs and Development, University of the Philippines Los Baños, College, 4031, Laguna, Philippines
*Corresponding author: brpantoja@up.edu.ph

Abstract Despite the efforts of the Philippine government to promote organic agriculture, particularly for rice, its rate of adoption is still low. This paper identified the constraints to adoption of organic rice production in Camarines Sur, Iloilo, Negros Oriental, and Negros Occidental. It also described the productivity and profitability of organic rice production and encouragement for its adoption. Factors that hindered utilization of organic rice production practices were farmers' perceptions that yield declined with their use and that organic production practices were more laborious and time-consuming than conventional practices. These were aggravated by production problems (e.g., occurrence of pests and diseases, natural calamities, and lack of irrigation water), lack of workers competent in organic farming, and limitations on access to organic inputs such as fertilizer, seeds, and delay in the delivery of inputs. Using descriptive statistics, results showed that organic rice production, classified into Certified Organic and In-Conversion (into organic rice but product not certified), obtained lower average rice yields than conventional rice production. However, cost and return analysis indicated that organic rice production had higher mean gross income than conventional rice production due to higher prices received. To encourage organic rice production, the following were recommended: steady supply of organic inputs, continuous training of farm owners and farm hands, establishment of demonstration farms, and wider information campaign.

Keywords: Certified Organic, Conventional Rice Production, Cost and Return Analysis, In-Conversion, Organic Rice Production.

Introduction

Protection of environmental resources and sustainability are often considered in planning and strategizing activities to enhance agricultural production. A solution that is being promoted, especially in developing countries, is organic agriculture which sought to improve productivity of farmers, while attaining environmental sustainability in crop production. Data from FiBL-IFOAM (2014) showed that adoption of organic agriculture had risen as areas planted to organic rice in Asia rose from 23,814 ha in 2008 to 42,782 ha in 2012.

With current issues on sustainable agriculture, environmental degradation, and climate change, the Philippine government has been promoting the adoption of organic agriculture, particularly for rice. The Department of Agriculture (DA) targets five percent of the country's area to be devoted to organic farming. Data from the Philippine Statistics Authority showed that out of the Philippines' agricultural area of nearly 10 million ha in 2014, cropland area was around 4 million ha; thus, the 5% target was about 200,000 ha. However, a FiBL-IFOAM (2014) document showed that area devoted to organic agriculture in the Philippines was only 0.7% of total agricultural land or about 28,000 ha.

Organic rice farming in the Philippines has a steady stream of practitioners. MASIPAG (2001) as cited in PhilDHRRA (2004) claimed that 1,897 farmers covering 1,754 ha were fully adopting organic rice farming. Meanwhile, 11,052 farmers with an aggregate of 15,411 ha were adopting the low chemical practices.

The low adoption rate could be attributed to the mixed reviews on realized benefits, particularly on productivity and profitability of organic farming. Hence, this paper aimed to compare the productivity and income of rice farmers in four provinces in the Philippines, classified into Certified Organic, In- Conversion and Conventional. Specifically, the paper aimed to: (1) assess the distribution of respondents in terms of organic rice farmers and conventional or inorganic rice farmers in the provinces of Camarines Sur, Iloilo, Negros Oriental, and Negros Occidental, (2) compare the cultural management practices of organic and conventional rice farmers, (3) analyze the productivity and profitability of organic rice production and conventional rice production, (4) identify the problems related to production, labor and access to inputs encountered by organic rice farmers, and (5) discuss the perceptions of both organic and conventional farmer-respondents on the constraints of organic rice farming adoption.

Materials and Methods

Distribution of Farmer-Respondents

In 2013, a socio-economic survey of 197 rice farmers was conducted to generate farm level data. The data gathered covered the 2012 dry and wet seasons. The survey was conducted in purposively selected provinces that included Camarines Sur, Iloilo, Negros Oriental, and Negros Occidental using a structured interview schedule. The questionnaire probed on the respondents' profile, farm characteristics, production and cultural farm management practices adopted, constraints to adoption of organic rice production practices, farm production, income, and expenses. The respondents were originally classified into two: Organic rice producers and Conventional rice producers. However, during the survey, it was observed that a relatively large number of respondents had their produce certified by a third party; hence, the Organic farming practitioner-respondents were divided further into two types, i.e., Certified Organic and In-Conversion (before becoming Certified Organic). The Conventional rice grower-respondents practiced the common rice farming, in which inorganic fertilizers and agricultural chemicals (e.g., insecticides and herbicides) were applied.

Ideally, the names of Organic and Conventional farmer-respondents should have been drawn from a list of rice farmers who were adopting organic and non-organic practices. However, such data base did not exist in the Agricultural Offices of the provincial local government units (PLGUs) or the municipal local government units (MLGUs) covered in the study.

Cost and Return, and Descriptive Analysis

Cost and return analysis was done to analyze the profitability across respondent types (i.e., Certified Organic, In-Conversion, and Conventional).

Descriptive analysis was used in evaluating the following: (1) socio-demographic characteristics, (2) parcel characteristics, (3) cultural management practices, (4) problems on organic rice production, (5) labor constraints, (6) problems on input access, and (7) rice productivity, income, and expenses.

Framework of Analysis

Adoption of organic farming is affected by factors such as productivity, profitability, farm gate prices, labor, and access to organic inputs and perceptions on the general performance of organic rice production (Figure 1). Substantiated by review of literature, this paper analyzed the adoption constraints of organic farming, focused on rice. Production problems faced by organic rice farmers and their difficulties in accessing labor as well as organic inputs were discussed. Productivity and profitability of organic and conventional rice farms, and farm gate prices received, were examined. Furthermore, perceptions of both organic and conventional rice farmers on the yield performance of organic rice farming were discussed.

Organic rice farmers have two sub-classifications, the Certified Organic and In-Conversion. In the Philippines, compliance to standards is categorized into three types of certification: (1) First Party Certification where verification of standards are set, monitored and enforced by the group of farmers (e.g., participatory guarantee system) or the company organization itself, (2) Second Party Certification where the buyers or industry organizations verify the standards, and (3) Third Party Certification where an accredited independent organization

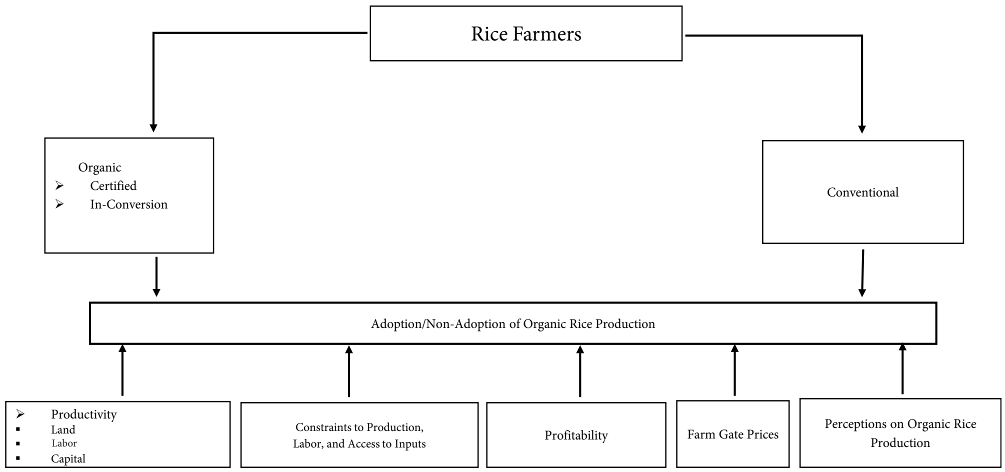

Figure 1. Framework of analysis for the adoption and non-adoption of organic rice production¬ in selected provinces in the Philippines.

does the verification. These standards are based on logical and scientific fundamentals that are frequently reviewed and improved as new technologies and knowledge come about (Maghirang et al., 2011). Certified Organic respondents refer to farmers whose farms obtained a Third Party Certification from either Organic Certification Center of the Philippines (OCCP) or Negros Island Certification Service (NICERT). Meanwhile, In-Conversion groups are those that practice organic farming but their produce has not been certified.

Results

Respondents and classification. Initially, there were 197 respondents; however, 15 respondents were excluded as they were considered pre-conversion because they were adopting organic farming practices but still apply agricultural chemicals.

Across the four provinces, 23.5% of the 182 respondents were Certified Organic rice producers, 40.0% were In-Conversion, and 36.2% were Conventional rice producers (Table 1). The largest number of respondents came from Camarines Sur with 86, followed by Iloilo 66; Negros Oriental 25; and Negros Occidental, 5. The largest percentage of the Certified Organic (19.2%) and Conventional rice respondents (18.1%) came from Camarines Sur. However, for the In-Conversion rice respondents, 18.1% came from Iloilo; 12.1% from Negros Oriental, and Camarines Sur, 9.8%.

Cultural Management Practices

The *dapog* system was the commonly adopted method of seedbed preparation across the three respondent types (Table 2). Some respondents used wet bed method. Farmers who planted organic rice planted red, 11-11-26, blonde, blonde red and black varieties. Conventional rice growers used varieties RC 30 and RS white. For fertilizer application, basal and side dress methods were used by all respondent types. The Organic rice grower-respondents applied natural materials while the Conventional rice grower-respondents used chemical or inorganic fertilizers.

The organic rice grower-respondents employed biological pest control. They used *tagbak*, a stout herbaceous plant, against rice tungro virus. Other plants such as kakawate and madre de cacao and organic concoctions were used by organic farmers to prevent infestation of insect pests. The Certified Organic and In-Conversion respondents used manual weeding and flood irrigation to control weeds.

The Conventional rice grower-respondents applied chemical pesticides such as Karate, Cymbush, and Machete. To control weeds, herbicides (e.g., Gramoxol) were used.

Table 1. Distribution of respondents (n) in 4 provinces and classification in terms of involvement in Organic and Conventional rice production in 2012. The Organic classification was subdivided into Certified Organic rice farmers and In-Conversion rice farmers (i.e., practicing organic rice farming but product not certified by OCCP or NICERT).

Classification	Province								All	
	Camarines Sur		Iloilo		Negros Oriental		Negros Occidental			
	n	%	n	%	n	%	n	%	n	%
Organic										
Certified Organic	35	19.2	0	0	3	1.6	5	2.7	43	23.5
In-Conversion	18	9.8	33	18.1	22	12.1	0	0	73	40.0
Conventional	33	18.1	33	18.1	0	0	0	0	66	36.2
Total	86	43.7	66	36.2	25	13.7	5	2.7	182	~100

Table 2. Cultural management practices by respondent classification in 2012.

Production Activity	Classification of Respondent		
	Organic Rice Production		Conventional Rice Production
	Certified Organic	In-Conversion	
Seedbed preparation	*Dapog* and wet bed most common, few practice dry bed	*Dapog* and wet bed most common	*Dapog* and wet bed most common, few practice dry bed
Seed variety	Red rice 11-11-26, blonde, blonde red, black rice	Black rice, red rice, blonde red, PSB Rc10 white, PSB Rc14	PSB Rc30, RS white
Seed establishment and planting	Direct seeding was common. Some practiced transplanting.	Direct seeding and transplanting were common. Pre-germinated seeds used for both methods.	Direct seeding and transplanting
Method of fertilizer application	Basal application of organic fertilizer; side dress and top dress applications	Basal application of organic fertilizer; side dress and top dress applications	Side dress application of chemical fertilizer, basal and top dress applications
Disease control	*Tagbak* was used against tungro virus. Increased water level in paddies and applied vermi tea	Monitored pest incidence; applied bio-fertilizers, organic concoctions, allowed the farm to dry out, and planted *tagbak*	Sprayed chemical pesticides such as Karate, Cymbush, and Machete.
Weed control	Manual removal of weeds; increased irrigation water level	Manual weeding; some use rotary weeder; continuous irrigation	Applied herbicides such as Gramoxol, Clear out, and Nominee.
Insect pest control	Used kakawate, madre cacao, and tagbak trees	Applied bio-chemicals, organic concoctions, planted madre cacao and *tagbak*	Sprayed chemical insecticides such as Magnum, Cypermethrin, and Top Kill
Rodent control	Used coconut leaves to scare away rats, talked to them and asked them not to damage the crop	Synchronized planting; talked to rodents and asked them not to damage the crop	Used rodenticide like racumin
Harvesting	Manual	Manual, few mechanized	Manual, few mechanized
Threshing	Mechanized, few manual	Mechanized, some manual	Mechanized, some manual

Socio-Demographic Characteristics of Respondents

The Conventional rice and the Organic rice grower-respondents had an average age of 56 years. The In-Conversion group had an average age of 53 years while those in the Certified Organic group had an average age of 48 years. Across all types of respondents, the majority were male, married, and Roman Catholics. Educational attainment differed by respondent type. More than a third of the In-Conversion respondents (37%) either reached or completed college education. High school education was the most dominant response, 35% for Certified Organic rice grower-respondents and 46% for the Conventional rice grower-respondents.

Characteristics of Land Cultivated by Respondents

Respondents till 1 ha with the In-Conversion group reported the lowest average parcel area of 1.28 ha. Certified Organic and Conventional rice grower-respondents had average parcel areas of 1.57 and 1.50 ha, respectively.

Problems on Production, Labor, and Access to Inputs

Majority of Certified Organic (63%) and In-Conversion (75%) respondents said they encountered production-related problems. However, the problems cited, i.e., occurrence of pests and diseases, natural calamities, and lack of irrigation water, did not specifically pertain to organic rice production but to rice production in general. It was notable that a sizeable proportion of In-Conversion respondents (20%) pointed out that nearby farms were yet to adopt organic rice production practices. Asked for possible solutions to the difficulties, Certified Organic rice grower-respondents stressed two things: 1) irrigation system should be constructed or improved, and 2) pest infestation problems be addressed. Some In-Conversion farmers mentioned that other farmers should be encouraged to adopt organic rice farming.

Labor constraints did not seem a major issue among majority of the organic rice grower-respondents. In-Conversion respondents suggested that organic farming should be taught or explained thoroughly to farm laborers while Certified Organic rice grower-respondents suggested that proper negotiation with laborers should be done to ensure availability.

Thirty percent of In-Conversion respondents and 12% of Certified Organic rice grower-respondents had problems with access to organic inputs. Availability of quality seeds and delay in delivery of inputs were the most frequently cited problems. Many of the In-Conversion respondents (36-45%) cited problems on availability of organic fertilizer, capital to undertake organic farming, and availability of quality seeds. Some respondents felt that the government should provide support in terms of capital to purchase organic inputs and improvement in the delivery of organic inputs.

Perceptions on Adoption Organic Farming

Majority of the farmer-respondents who applied organic farm inputs believed that conventional rice farmers did not shift to organic farming due to: (1) perception that organic farming lowered yield, (2) poorly-taught information on organic farming that led to misconceptions, and (3) perception that organic farming was time-consuming, particularly for farm workers and owners. Other reasons were reduction in profit, laborious farming, and attachment to the conventional rice farming practices.

Twenty-one percent of respondents who utilized organic inputs perceived that seminars can entice other farmers to shift to organic farming. Other farmer-respondents believed that awareness of the benefits, incentive on the price of the produce, and knowledge on the health benefits of organic farming can attract other farmers to shift to organic farming.

More than a fourth of the Conventional rice grower-respondents did not adopt organic farming because they have yet to attend training or seminar on organic farming. Around 24% of the respondents perceived that shifting to organic farming would lower their crop yield while 18% pointed to lack of capital as a deterrent for them to adopt organic farming. Some mentioned the difficulties of accessing the required labor and the materials needed for concocting organic inputs. However, the respondents would be motivated to adopt organic farming should it be proven to reduce farm expenditures. Others claimed that proven health benefits and higher crop yield and income would encourage them to shift to organic farming. Some respondents felt they needed to undergo training programs and seminars, and observe farm demonstration on organic farming.

Grain Yields, Costs and Returns

The Conventional rice grower-respondents reported the highest average grain yield 3,798.73 kg/ha (Table 3) or 3.8 t/ha. This was followed by the Certified Organic rice grower-respondents with a grain yield of 3.4 t/ha. The In-Conversion respondents had the lowest grain yield of 3.1 t/ha.

The Certified Organic rice grower-respondents had the highest gross income per

Table 3. Grain yields (kg/ha), costs and returns (pesos per hectare) by respondent classification in 2012. 1,000 kg/ha = 1 t/ha.

Item	Respondent Classification		
	Organic Rice Production		Conventional Rice Production
	Certified Organic	In-Conversion	
Yield (kg/ha)	3,410.09	3,119.9	3,798.73
Average Farm Gate Price (Php/kg)	17.60	18.21	13.92
	Pesos Per Hectare		
Gross Income	60,017.58	56,813.38	52,878.32
Total Expenses	25,595.72	34,362.86	27,621.18
Material inputs	5,912.96	8,803.70	9,918.11
Labor	16,779.86	21,839.39	15,996.38
Marketing	2,902.90	3,719.77	1,706.69
Net Income	34,421.86	22,450.52	25,257.14

hectare of PhP 60,017.58 although this group was second only in terms of average grain yield of 3,410 kg/ha (Table 3) or 3.4 t/ha. The In-Conversion rice respondents reported that the lowest mean yield of 3,119 kg/ha or 3.1 t/ha, had a gross income of PhP 56,813.38/ha. The Conventional rice grower-respondents, despite having reported the highest average grain yield of 3.8 t/ha, had the lowest gross income of PhP 52,878.32/ha. Trends in gross income were influenced by the farm gate prices of the harvest. Organic rice producers reported higher farm gate prices of PhP 18.21/kg grain for In-Conversion and PhP 17.60/kg grain for Certified Organic. Conventional rice had the lowest farm gate price of PhP 13.92/kg grain.

With a difference of 36.3%, Certified Organic farmers had the highest net income of PhP 34,421.86/ha, followed by the Conventional group with a net income of PhP 25,257.14/ha (Table 3). Cost of material inputs for Conventional rice was 67.7% higher than the Certified Organic rice. There was no significant difference in net income between the In-Conversion and Conventional group.

Discussion

Problems related to organic rice production and perceptions on adoption of organic rice farming were presented. Organic rice grower-respondents (i.e., Certified Organic and In-Conversion) cited problems on pests and diseases, natural calamities, and irrigation, which are also experienced in Conventional rice production. Meanwhile, the problems more unique to organic rice production are limitations on access to organic inputs such as seeds and fertilizers, delay in the delivery of organic inputs, and lack of workers competent in organic farming.

Many of the farmer-respondents believed that Conventional rice farmers did not shift to organic rice farming due to perceptions that it lowered rice yield, poor orientation on organic rice farming, attachment to conventional farming, and that organic farming was laborious and less profitable. Aquino (2005) as cited in Peñalba et al., (2007) enumerated the factors constraining the adoption of technologies on organic farming. Among these were: (a) observed decline in yield when farmers shifted to organic farming, (b) limited support services extended particularly the provision of inputs such as organic seeds and fertilizers, and (c) minimal conduct of training and extension services. Other constraints mentioned were marketing problems such as lack of market information system, lack of marketing strategies and pricing scheme, inappropriate packaging, lack of capital, inadequate government support for export of organic products, unorganized organic producers, low competencies in organic production, limited knowledge on national regulations, and limited skills on internal quality control systems. Subaldo and Villaluz (2012) mentioned some factors inhibiting rice farmers in Magsaysay, Davao del Sur, Philippines from adopting organic technology. The study pointed that conventional farmers regarded rice farming as laborious and that some materials needed for organic rice production were not available in the area. The farmers also stressed the low yield recovery during the early stage of adoption of organic rice production. On a positive note, farmers acknowledged that organic farming is beneficial to one's health and to the environment. This supports the clinical report that organic diets have been convincingly demonstrated to expose consumers to fewer pesticides associated with human disease (Forman and Silverstein, 2012). Organic farming was also shown to have less environmental impact than conventional approaches.

Bello (2008) mentioned that organic farming is confronted with the problem of higher labor input in its operation as the technology requires more labor to implement additional manual tasks. An analysis was done based on an exploratory agent-based model depicting Philippine smallholder farmer decisions to implement organic techniques in rice paddy systems (Olabisi et al., 2015). Results indicated that rates of organic farming adoption are highly sensitive to the yield drop after switchover to organic techniques, and to the speed of information spread through the existing social networks.

This study showed that Conventional rice production had higher grain yield than Certified Organic rice production (Table 3). However, Certified Organic rice production had higher gross and net income than Conventional rice production. The higher income from Certified Organic rice was attributed to the higher farm gate price for the product. Hence, on the basis of income, the shift to Certified Organic rice production could be encouraging. The present findings confirm the studies of Setboonsarng et al. (2006) and Surekha et al. (2013), which concluded that farmers who shifted to organic farming initially experienced a drop in production but yield increased after some time of adopting the technology. A similar case was observed by IFOAM (2006) wherein farmers who converted from a relatively intensive conventional practice to organic farming, experienced a drop in yield in the short-term. However, these farmers acquired a price premium for their produce in exchange. After some time, average grain yields increased.

The results are also consistent with the findings of Mendoza (2004), which showed average yields of conventional and organic farms at 3.5 t/ha and 3.3 t/ha, respectively. Brown et al. (2015) showed that average yield from conventional farms (5.7 t/ha) was 40% higher than organic farms (3.5 t/ha) in Nueva Ecija, Philippines. Mendoza (2002) concluded that the break-even point of organic farming was higher than non-organic farming. Productivity of organic rice was also higher than the low external input sustainable agriculture (LEISA) and conventional methods.

Cruzada, Bachmann, and Wright (2009) discussed the results of a three-year survey conducted by Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG) on 840 rice-based farmers in the Philippines. They found that yields of the farmer-bred rice varieties for full organic farming practices were at par with the yields of 'high yielding rice varieties' grown under conventional farming practices. Rice yield and net income with organic farming practices also increased over time. Net income of full organic farming was 1.5 times higher than conventional farming. On the average, organic rice farmers had a positive household annual cash balance while the conventional rice farmers had a deficit household cash balance. Rubinos et al. (2007) compared the economics of production between organic and conventional lowland rice farming in Magsaysay, Davao del Sur. The study revealed that the yield of conventional rice farms was 23% higher than yield of organic rice farms, but the high input costs and lower farm gate price for conventional rice lowered the net returns. Ara (2002) indicated that production costs of rice farmers in the Philippines can be significantly reduced through adoption of organic farming.

In other countries, farmers adopting organic or conventional farming incurred different costs as a result of the farm management practices they adopted. In Laos, it was observed that organic farmers under contract growing arrangement achieved significantly higher profits than conventional rice farmers and that contract organic farming was likely to provide the highest positive change in the income of farmers performing below average (Setboonsarng et al., 2008). In Laos, production costs were higher for the contract organic farming than for the contract conventional rice farming (Ericson, 2011). However, yield and product price for organic rice production were higher; thereby, resulting in higher profit. Zundel and Kilcher (2007) reported that the premium prices attached to organic rice were required to make up for reduction in income during the two to three years of conversion period. In Thailand, cost of farm inputs for conventional rice was 176% lower than organic rice (Pompratansombat et al., 2011. However, labor costs escalated upon shifting to organic farming because of the more tedious labor requirements than the traditional method. Organic farming is labor-intensive; thus, it is probable that when farmers intensify labor inputs, the additional cost incurred is most likely offset by the increase in yield that increases gross income. This is consistent with the findings that an increase in the cost for labor was recovered by the yield performance (Mendoza 2014).

Conventional rice farmers did not shift to organic rice farming due to perceptions that organic farming lowered yield, was laborious, time-consuming, and less profitable. Farmers were also attached to conventional rice farming. However, such perceptions could change should organic rice fetches premium price and the benefit-cost ratio of organic system becomes similar to or higher than conventional system (Tashi and Wangchuk, 2015). Seminars on the incentive on product price, knowledge on the health benefits of organic farming, on-farm demonstration of organic rice farming, training of farm owners and workers, access to organic inputs and market information, and information dissemination through the social network can entice farmers to shift to this system. Scientific information such as the results of five-year field studies with organic farming and significant improvement in the soil physical, fertility, and biological properties (Surekha et al., 2013) should also be disseminated. With the expected full implementation of the Organic Agriculture Act in 2016, farmers should be equipped with the knowledge of practicing organic agriculture in the country (Piadozo et al. 2014). The farmers' level of awareness and accessibility to support services provided by both the government and private sector, and compliance with the Philippine National Standards for Organic Agriculture (PNSOA) should be strengthened. PNSOA standards cover conversion procedure, requirement on seeds, fertilization, pest and disease management, crop rotation and diversity, soil management practices, labelling, storage and transportation procedures, and processing (Piadozo et al., 2014).

Conclusion

The results confirm findings from other literature that rice farmers adopting organic rice production obtained lower grain yields than conventional rice production. However, the lower input cost and higher farm gate price especially for Certified Organic rice increased the net income of organic rice more than that of Conventional rice.

Problems related to organic rice production are limitations on access to organic inputs, delay in the delivery of organic inputs, and lack of workers competent in organic rice production.

Knowledge of the premium price for organic rice, health and environmental benefits of organic farming, on-farm demonstration of organic rice production, training of farm owners and workers in organic rice production, access to organic inputs, market information system, and support services provided by the government and private sectors, information on organic rice production disseminated through the social network, and knowledge of and compliance with the Philippine Standards for Organic Agriculture, can entice Conventional rice farmers to shift to organic rice production and address some of the problems related to organic rice production.

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Suitability Assessment of Maligaya Soil Series for Potential Enhancement of Rice-Based Cropping Systems

Sandro D. Cañete[1,*], Wilfredo B. Collado[1], Rodrigo B. Badayos[2], Pearl B. Sanchez[2], and Pompe C. Sta. Cruz[3]

[1]Agronomy, Soils and Plant Physiology Division, Philippine Rice Research Institute (PhilRice), Science City of Muñoz, 3119, Nueva Ecija; [2]Agricultural Systems Cluster, College of Agriculture, University of the Philippines, Los Baños, Laguna; [3]Crop Science Cluster, College of Agriculture, University of the Philippines, Los Baños, 4031, Laguna, Philippines
*Corresponding author: sandrodcanete@gmail.com

Abstract In support of the Philippine's drive for food self-sufficiency, prime agricultural lands must be evaluated to assess their suitability and identify management interventions to improve and sustain crop production. Based on the Food and Agriculture Organization (FAO) land evaluation framework, the Maligaya soil series was described for two land units and found to be well-suited for intensive rice farming. Nutrient management such as season-specific and site-specific fertilizer recommendations for irrigated lowland rice in Brgy. Maligaya and rainfed lowland rice supplemented by irrigation in Brgy. Fronda should be utilized. For both land units, non-rice crops showed moderate or marginal suitability due to constraints brought about by imperfect soil drainage and low level of soil organic carbon. Periodic incorporation of organic matter or farm biomass can enhance soil organic carbon. Employing interventions relative to the identified soil limitations can improve farm productivity and sustainability. Improved cropping sequence for rainfed lowland was recommended for efficient water use. The proposed rice + legume in wet season and rice + cucurbits or maize in dry season can be a more profitable enterprise than commercial palay production (harvest sold to millers and traders for milled rice) in both land units. However, if the farmer has enough resources, quality rice seed production (quality or certified seeds sold to farmers) can even be more profitable.

Keywords: Irrigated Lowland, Land Unit, Land Utilization Type, Maligaya Soil Series, Suitability Evaluation, Rainfed Lowland, Rice-based Cropping Systems.

Introduction

The productivity and profitability of individual farmers in lowland rice-based farming communities should be improved and sustained to keep pace with the government's drive on attaining food self-sufficiency. There are viable activities and practices which could provide viable solutions to the limited rice yields and income from rice farming alone. However, there is a need to identify and resolve some production constraints to come up with a more productive enterprise.

The suitability of a particular rice-based cropping system depends on environmental factors, which include land attributes and socio-economic condition. To overcome minor inherent limitations, proper matching of land qualities with the crops' requirement and recommended for practices, will be the most rational approach for propositioning productive and sustainable rice-based cropping systems. Furthermore, it establishes an appropriate land utilization type (LUT) based on spatial distribution and climatic variability. Thus, when a land unit is highly suitable to a crop, a good yield is expected at a lower cost of production.

Maligaya soil series is a typical lowland soil grown to lowland rice in Nueva Ecija. The soil series covers around 57,282 ha throughout the country (Fernandez et al., 1980). It is a deep soil, imperfectly drained, high content of the <2μ clay fraction, and originally high inherent fertility. It has slow to very slow permeability in water resulting to seasonal flooding. Maligaya series has typically high shrinkage and swelling property owing to its high content of clay dominated by 2:1

expanding silicate minerals. Degradation of soil structure due to puddling and loss of binding effect of soil organic matter forms massive structure Therefore, equally important as matching suitable rice-based cropping system is the identification of management interventions that will contribute to sustainable production.

This paper described the land qualities of Maligaya soil series, established physical and chemical constraints relative to crop production, suggested specific land management interventions associated with the identified limitations, and formulated viable land utilization type or farming system options that can increase farm productivity and profitability in irrigated lowlands and irrigation-supplemented rainfed lowlands.

Materials and Methods

Three important activities were involved in the study: (a) survey of existing land utilization types (LUTs) within the mapping unit of Maligaya series, (b) soil sampling and analysis, and (c) collection of secondary data such as weather and related soil properties. The LUT survey questionnaire was formulated based on the framework for land evaluation of the Food and Agriculture Organization (FAO, 1976). Soil samples were collected randomly from 0 to 20 cm depth within the reference site representing Maligaya series.

Sampling Area

Farmers' rice fields representing irrigated lowland in Brgy. (or village) Maligaya, Science City of Muñoz, Nueva Ecija and rainfed lowland with supplemental irrigation in Brgy. Fronda, Talugtog, Nueva Ecija, were selected as the sampling sites for the study. Existing land utilization types were identified and subjected to land evaluation (FAO, 1976). Figure 1 shows the map of the area covered by Maligaya soil series indicating the irrigated lowland rice areas (marked I), and rainfed lowland rice areas (marked R).

Existing LUTs were initially recognized through farm-walk along a transect within the irrigated lowland and rainfed lowland rice environments. Specific farms representing major LUTs were identified for thorough study and conduct of interviews. Ten randomly selected farmer-operators from the study sites were interviewed regarding their farm operations and production from 2011 to 2012 cropping seasons. Information on land management attributes describing the land quality requirements (LQRs) of the identified LUTs were asked. Information included land use, farm size, land tenure, crop varieties, cultural management practices particularly related to nutrient management (e.g., quantity and kinds of fertilizers used per crop/cropping) and pest management (e.g., amount, frequency, and kind of pesticides used), irrigation system, labor intensity, power, mechanization, farm inputs, crop yield, capital intensity, livestock, and farm sales. Farmers interviewed were assessed for the extent of technical knowledge acquired through the training programs of PhilRice.

Figure 1. Map showing the location of the sampling areas. I stands for irrigated lowland in Brgy. Maligaya R for rainfed lowland in Brgy. Fronda.

Soil Analysis

Soil samples were analyzed at the Soils Laboratory of the Department of Soil Science, University of the Philippines, Los Baños, Laguna. Soil texture was determined by hydrometer method after dispersion of the soil using sodium hexametaphosphate. Cation exchange capacity (CEC) was determined by equilibration with 1 N NH_4OAc (pH 7). Soil pH was determined using a pH meter with 1:1 soil: water mixture. Total nitrogen (N) was determined by Kjeldahl digestion, available phosphorus (P) by extraction with 0.5 M $NaHCO_3$ (Olsen or Bray P), and exchangeable potassium (K) by equilibration with 1 N NH_4OAc (pH 7). Concentration of K in solution was read by a flame photometer. The oxidizable organic matter content was determined by the method of Walkley and Black (1934).

Weather and other Secondary Data

Ten-year monthly average rainfall and temperature data were obtained from agro-meteorological station at PhilRice CES in Science City of Muñoz, Nueva Ecija. The weather station was situated a few blocks away from Brgy. Maligaya and less than 15 km radius from Brgy. Fronda in Talugtog. Climate data were matched with the crop's climatic requirement as part of the assessment of the crop's suitability to agro-climatic condition.

Other soil data were sourced out from the available benchmark researches of Miura et al. (1995) and Collado et al. (2008).

Land Evaluation

The land unit was evaluated using the FAO framework for land suitability classification. The qualities of the land units were matched with the land quality requirements of the crops. The analysis ascertained the degree of limitations or constraints associated with the identified land use. Good crop management strategies relative to the identified limitations were recommended. Moreover, the result of suitability analysis invoked the formulation of viable rice-based cropping systems as an option for development. Furthermore, suitability of other economically important crops aside from the existing major crops were assessed giving farmers alternative farming enterprises.

The FAO land suitability classification is presented in Table 1. Four categories were adapted from the framework namely: order, class, subclass and unit. Land Suitability Order indicated whether the land unit was suitable (S) or not suitable (N) for a specified use. Class (e.g., S1, S2) indicated the degree of suitability.

Subclass reflected the kind of limitations on topography, soil wetness (flooding and drainage), physical properties (texture, coarse fragments and soil depth), fertility, and climate. Letter suffixes were assigned for each subclass: "t" for topography; "w", wetness, "s", physical properties, "f", fertility, and "c", climate.

Economic Analysis

A simple cost and return analysis was calculated for existing and recommended cropping systems to determine the return of investment (ROI) of each cropping system analyzed. Costs and returns analyses of the existing and recommended cropping systems were assessed based on the prevailing farm costings and updated production

Table 1. The FAO land suitability classification (FAO 1976)

Order	Class	Description
Suitable	S1	Land is highly suitable – land units without limitations or with 2 or 3 slight limitations.
	S2	Land is moderately suitable – land units with 2 or 3 slight limitations and no more than 2 moderate limitations.
	S3	Land is marginally suitable – land units with more than 2 moderate limitations however does not exclude the use of the land.
Not Suitable	N1	Land is currently not suitable – land units with severe limitations excluding the use of the land or more than one severe limitation that can be corrected.
	N2	Land is permanently unsuitable – land units with severe or very severe limitations excluding the use of the land and that cannot be corrected.

manuals. The estimated ROIs of the proposed cropping systems were analyzed to project the profit advantage of the proposed cropping systems over the farmers' cropping systems. Farm expenses (i.e., labor, farm inputs, and other costs) were adjusted based on the 2011-2012 costs of labor and inputs.

Results

Description of the Land Unit

The land units belonged to the Maligaya soil series (Taxonomic classification: fine, smectitic, isohyperthermic, Typic Calciaquert). The high content of clay dominated by 2:1 expanding layer silicate minerals (smectite) made the soil exhibited vertic property with high degree of expansion and contraction.

The irrigated lowland Maligaya soil series in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija, located at 150 40.736' N, 1200 53.786' E, had very strong acidity with pH 4.9, medium content of organic matter (3.73%), total soil N of 0.19%, Bray P extractable P content of 2.9 ppm; and moderately low K (0.24 me per 100g soil). Soils in Brgy. Fronda, Talugtog, Nueva Ecija located at 150 44.406'N, 1200 53.593' E, had neutral pH (pH 6.7), low organic matter content (1.47%), very low total soil N (0.09%), high Olsen extractable P (30 ppm), and moderately low exchangeable K (0.22 me per 100g soil).

In the two areas studied, the dominant cropping systems were: irrigated lowland with two rice crops, and rainfed lowland with supplemental irrigation and two rice crops.
Vegetables were commonly grown within the homestead for subsistence.

Climate and Cropping Calendar

Nueva Ecija has Type I climate with distinct wet and dry seasons. The release of irrigation water normally fell on the months of June for wet season and December for dry season. In the rainfed lowland rice areas with supplemental irrigation, farmers normally commenced wet season planting when accumulated water from rainfall was sufficient enough for land preparation. Dry season cropping merely depended on pumped ground-water.

Data on rainfall distribution and the amount of rainfall available throughout the year are presented in Figure 2. In January to April, average rainfall ranged from 4 to 54 mm. In May to November, rainfall ranged from 99 to 244 mm. In December, rainfall decreased to 23 mm.

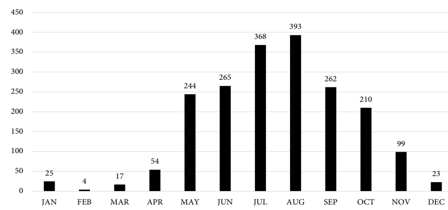

Figure 2. Ten-year monthly average rainfall (in mm) at PhilRice, Science City of Muñoz, Nueva Ecija (2003-2012)

Description of Land Utilization Types

A. LUTs for Irrigated Lowland in Brgy Maligaya, Science City of Muñoz, Nueva Ecija are presented in Table 2.

LUT1. Irrigated lowland rice farming intended for seed production using high quality seeds transplanted in areas ranging from 0.5 to 7 ha; fertilizers applied at rates of 66 kg nitrogen (N), 42 kg phosphorus (P_2O_5), and 32 kg potassium (K_2O) per ha in wet season (WS) and 99 kg N, 52 kg P_2O_5, and 43 kg K_2O/ha in dry season (DS); irrigation supplied by the National Irrigation Administration (NIA); partly mechanized farming in combination with human labor and animal power; intermediate material input; high labor and medium to high capital intensity; application of integrated pest management (IPM) practices; has an average yield of 5.77 t/ha in WS and 8.08 t/ha in DS; and rice sold as quality seeds to other farmers.

LUT2. Farming similar to LUT1 but produced commercial palay; quality seeds grown in 0.6 ha; fertilizers applied at rates of 83 kg N, 34 kg P_2O_5, and 34 kg K_2O/ha in WS and 125 kg N, 52 kg P_2O_5, and 35 kg K_2O/ha in DS; medium labor and capital intensity; grain yields of 5.22 t/ha in WS and 7.31 t/ha in DS for commercial and subsidiary subsistence.

LUT3. Farming similar to LUT1 with respect to

Table 2. Summary of the land utilization types (LUTs) of Maligaya Series in irrigated lowland in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija.

Attributes	LUT1	LUT2	LUT3
Cropping system and produce	1st rice crop (R1) – 2nd rice crop (R2)	R1 – R2	R1 – R2
	Harvest for commercial certified seeds	Harvest for commercial palay	Harvest for commercial palay
Size of land holding (ha)	0.5-7.0	0.6	1.3
Land tenure	Owner, leasee	Owner	Owner
Variety/seed class	Registered seeds	Certified seeds	Registered inbred seeds for R1
			Hybrid seeds for R2
Crop establishment	Transplanted	Transplanted	Transplanted
Seeding rate	104 kg seeds/ha for R1; 98 kg seeds/ha for R2	133 kg seeds/ha each for R1 and R2	61 kg seeds/hafor R1; 11.5 kg seeds/ha for R2
Irrigation source	National Irrigation Administration (NIA)	NIA	NIA
Average fertilizer usage per ha	66 kg N, 42 kg P_2O_5, & 34 kg K_2O/ha for R1	83 kg N, 34 kg P_2O_5, & 34 kg K_2O/ha for R1	75 kg N, 45 kg P_2O_5, & 22 kg K_2O/ha for R1
	99 kg N, 52kg P_2O_5, & 46 kg K_2O/ha for R2	125 kg N,52kg P_2O_5, & 35 kg K_2O/ha for R2	130 kg N, 60 kg P_2O_5, & 28 kg K_2O/ha for R2
Crop protection	IPM	Preventive	IPM
Labor intensity	High	Medium	High
Power*	3	3	3
Mechanization/ implement	Partly mechanized	Partly mechanized	Partly mechanized
Material input	Intermediate	Intermediate	Intermediate
Capital intensity	Medium (own or borrowed)	Medium (own and borrowed)	Medium (borrowed)
Average grain yield (t/ha)	5.77 for R1, 8.08 for R2	5.22 for R1, 7.31 for R2	3.80 for R1, 7.87 for R2
Market orientation**	4 (sold as quality seeds)	4	4
Poultry/livestock	Native carabao (draft), goats, ducks and chickens (buffer stock)	Native chickens and ducks (buffer stock)	Native chickens and ducks (buffer stock)
Technical knowledge	PalayCheck, seed growing seminar, PhilRice Field Days, reading materials from PhilRice and private companies.	Reading materials from PhilRice.	Reading materials from PhilRice.

* Power: 1 – human; 2 – human labor with animal; 3 – 1 & 2 with fuel driven machines
** Market orientation: 1 – subsistence; 2 – subsistence with commercial; 3 – commercial; 4 – commercial with subsistence
Note: N = elemental nitrogen. P_2O_5 = elemental phosphorus. K_2O = elemental potassium.

cultural management practices (irrigation source, crop protection, power, mechanization, labor and material inputs) but grew hybrid seeds in 1.3 ha in DS; with fertilizer usage of 75 kg N, 45 kg P_2O_5, and 22 kg K_2O/ha in WS and 130 kg N, 60 P_2O_5, and 28 kg K_2O/ha in DS; grain yields of 3.80 t/ha in WS and 7.87 t/ha in DS for commercial and subsidiary subsistence.

B. LUTs for Irrigation-Supplemented Rainfed Lowland in Brgy. Fronda, Talugtog, Nueva Ecija are presented in Table 3.

LUT1. Rainfed lowland rice farming using quality inbred or hybrid seeds transplanted twice a year; irrigation supplemented with shallow tube well (STW) or NIA deep well; IPM practices; partly mechanized in combination with human and animal labor; intermediate material inputs; medium to high labor intensity and medium capital intensity; yields for commercial or subsidiary subsistence.

Table 3. Summary of the land utilization types (LUTs) of Maligaya Series in rainfed lowland in Brgy. Fronda, Talugtog, Nueva Ecija

Attributes	LUT1A	LUT1B	LUT1C	LUT2
Cropping system & produce	1st rice crop (R1) – 2nd rice crop (R2)	R1 –R2	R1 – R2	Rice - Fallow
Size of land holding (ha)	1.0 -2.8	2.0-10.2	3.8	0.7
Land tenure	Owner	Owner	Owner	Owner
Variety/seed class	Certified seeds for R1 and R2	Certified inbred seeds for R1 Hybrid seeds for R2	Hybrid seeds for R1 and R2	Certified seeds
Crop establishment	Transplanted	Transplanted,	Transplanted	Transplanted
Seeding rate	61 kg seeds/ha for R1	69 kg seeds/ha for R1	15.6 kg seeds/ha each for R1 and R2	40 kg seeds/ha
	54 kg seeds/ha for R2	21 kg seeds/ha for R2		
Irrigation source	rain and shallow tube well (STW) and NIA deep well	rain, NIA deep well and STW	rain and STW	rain
Average fertilizer usage per ha	96 kg N, 42 kg P_2O_5, & 44 kg K_2O/ha for R1;	88 kg N, 42 kg P_2O_5, & 41 kg K_2O/ha (R1)	91 kg N, 51 kg P_2O_5, & 21 kg K_2O/ha for R1;	89 kg N, 71 kg P_2O_5, & 0 kg K_2O/ha for rice
	110 kg N, 52kg P_2O_5, & 53 kg K_2O/ha for R2; some used foliar fertilizer for R2	137 kg N, 51 kg P_2O_5, & 52 kg K_2O/ha for R2; some used foliar fertilizer for R2	76 kg N, 40 kg P_2O_5, & 33 kg K_2O/ha for R2	
Crop protection	Preventive, IPM	Preventive, IPM	Preventive	Preventive - high dose of pesticide
Labor intensity	Medium - high	Medium - high	High	High
Power*	3	3	3	3
Mechanization/Imple-ment	Partly mechanized	Partly mechanized	Partly mechanized	partly mechanized
Material input	Intermediate - high	Intermediate - high	Intermediate	intermediate
Capital intensity	Medium (own or borrowed)	Medium (own or bor-rowed)	Medium (own)	medium (borrowed)
Average grain yield (t/ha)	4.95 for R1; 6.66 for R2	4.68 for R1; 6.14 for R2	4.78 for R1; 6.91 for R2	5.20
Market orientation**	4, 3	4	4	4
Poultry/livestock	Native carabaos (draft), Brahman cow, ducks and chickens (buffer stocks)	Native carabaos (draft), cows, upgraded goats and native chickens, ducks, geese, turkeys (buffer stocks); sows and piglets (commercial)	None	Native goats and chickens (buffer)
Technical knowledge	Training on rice production, consultation with PhilRice, Department of Agriculture (DA) technician and sales representatives	Season-long training on rice production, consul-tation with DA technician and sales representatives, PhilRice field days, hybrid rice production, seed growing	Radio broadcast	Consultation with DA technician, read-ing materials from PhilRice, DA-LGU, training on rice pro-duction, Field Demo on rice at UPLB

* Power: 1 – human; 2 – human labor with animal; 3 – 1 & 2 with fuel-driven machines
** Market orientation: 1 – subsistence; 2 – subsistence with commercial; 3 – commercial; 4 – commercial with subsistence
Note: N = elemental nitrogen. P_2O_5 = elemental phosphorus. K_2O = elemental potassium. LGU = local govenment unit. UPLB = Univ. of the Phil. Los Baños.

Specific Differences in Land Attributes in LUT1 were identified as follows:

LUT1a. Rainfed lowland rice farming using quality inbred seeds grown in areas ranging from 1.0 to 2.8 ha; with fertilizer application of 96 kg N, 42 kg P_2O_5, and 44 kg K_2O/ha in WS and 110 kg N, 52 kg P_2O_5, and 53 kg K_2O/ha in DS; and yields of 4.95 t/ha in WS and 6.66 t/ha in DS.

LUT1b. Farming similar to LUT1a except for the use of hybrid seeds in the DS, grown in areas ranging from 2.0 to 10.2 ha; with fertilizer application of 88 kg N, 42 kg P_2O_5, and 41 kg K_2O/ha in WS and 137 kg N, 51 kg P_2O_5, and 52 kg K_2O/ha in DS; and yields 4.68 t/ha in WS and 6.14 t/ha in DS.

LUT1c. Farming similar to LUT1a but used hybrid seeds in 3.8 ha, with fertilizer application of 91 kg N, 51 kg P_2O_5, and 21 kg K_2O/ha in WS and 76 kg N, 40 kg P_2O_5, and 33 kg K_2O/ha in DS; and yields 4.78 t/ha in WS and 6.91 t/ha in DS.

LUT2. Rainfed lowland rice farming using certified seeds transplanted during the WS in 0.7 ha followed by fallow period; with fertilizer application of 89 kg N, 71 kg P_2O_5, and 0 kg K_2O/ha; used preventive crop protection; partly mechanized in combination with human and animal labor; intermediate material inputs; high labor intensity and medium capital intensity; with yields of 5.20 t/ha for commercial and subsidiary subsistence.

Suitability Evaluation

Evaluation of the suitability of crops to Maligaya soil series in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija is presented in Table 4. Among the crops evaluated, rice had high inherent suitability indicating that the land unit favored the cultivation of the commodity. Other crops showed moderate or marginal suitability due to imperfect drainage and soil pH. Except for favorable soil pH (neutral), the identified production constraints for specific crops in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija were similar to the limitations in Brgy. Fronda, Talugtog, Nueva Ecija.

Cost and Return Analysis

Brgy. Maligaya, Science City of Muñoz, Nueva Ecija

High ROI was attained in rice seed production (Table 5). This practice entailed high level of production cost in terms of labor and capital intensity. Seed growing also required accreditation from the Bureau of Plant Industry-National Seed Quality Control Services (BPI-NSQCS), which made this enterprise beyond the capacity of small farmers. However, farmers engaged in rice seed production earned up to five-fold higher income than the ordinary commercial rice production and more than twice as much of the return from rice seed production rotated with commercial hybrid rice. An annual ROI increase of 194.34% was obtained from seed production over the commercial palay production (Table 5). The recommended rice and legume combination rotated with hybrid rice, squash, and leafy vegetables can have an estimated ROI of 100%, and about 50% higher ROI than the commercial rice production.

Brgy. Fronda, Talugtog, Nueva Ecija

The growing non-rice crops such as legumes along rice bunds in wet season in rotation with hybrid rice and maize (sweet corn) in dry season (Table 6) is proposed as good option for the farmers in this land unit. This proposed cropping system can generate 5.83 to 16.3% advantage the usual rice-rice cropping system (Table 6).

Discussion

Land Units

The land units of Maligaya soil series are characterized as heavy clay soil. It is very sticky when wet and very hard when dry. The land unit is prepared following the conventional wet tillage cultivation. The soil is puddled for ease of planting, control of weeds, and to reduce percolation and maintain submergence. Puddling also eases establishment and early growth of transplanted rice seedlings. However, the puddling operation destroys the structure of the soil and transforms the surface soil into hard and compact mass with extremely high soil strength when dry, which can restrict root growth and seedling development of non-rice crops.

Table 4. Suitability evaluation for Maligaya Series in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija

Crop	Inherent Suitability	Adjusted Suitability	Constraint/ Limitation	Intervention
Irrigated rice	S1	S1		
Maize	S3fws	S2s	imperfect drainage, clay texture, soil pH	mix organic fertilizer (OF) through tillage, deep drainage around peripheries, liming.
Cowpea	S3w	S1	imperfect drainage, soil pH	mix OF through tillage, raised bed planting, liming
Sweet potato	S3fws	S2s	imperfect drainage, clay texture, soil pH	mix OF through tillage, improve drainage system, liming
Cassava	S3ws	S2s	heavy texture, imperfect drainage	raised plot planting, mix OF through tillage.
Groundnuts	S3fws	S2ws	heavy texture, imperfect drainage, soil pH	raised plot planting with good drainage system, mix OF through tillage, liming.
Onion	S3fws	S3s	high temperature, imperfect drainage, heavy texture, soil pH	interventions are impractical
Tomato	S2fcws	S2s	high temperature, imperfect drainage, heavy texture, soil pH	thoroughly mix OF in planting hole to improve porosity and organic carbon (OC), use heat tolerant varieties, liming
Watermelon	S2fs	S2s	heavy texture, soil pH	incorporate OF with soil in the planting hole to minimize the effect of soil cracking within the planting area; raised bed planting, liming.
Sorghum	S2fws	S2s	imperfect drainage; clay texture, soil pH	raised plot planting, improve drainage system, liming
Banana	S3fw	S1	imperfect drainage, soil pH	incorporate OF in planting holes, raised soil planting, liming
Papaya	S3fws	S2ws	heavy texture, imperfect drainage, soil pH	incorporate OF for soil aggregation and porosity; raised soil planting, liming.
Citrus	S3fws	S2ws	heavy texture, imperfect drainage, soil pH	incorporate organic fertilizer to improve soil aggregation and drainage; raised soil planting, liming.
Guava	S3fw	S2w	imperfect drainage, soil pH	mix OF in planting holes; raised soil planting, liming.
Mango	S3fws	S2s	heavy texture, imperfect drainage, soil pH	mix OF; raised soil planting, liming.

Note: S1-highly suitable; S2-moderately suitable; S3-marginally suitable; c-limitation due to climate; w-limitation due to drainage or flooding; s-limitation due to soil physical characteristics

Table 5. ROI of existing cropping systems versus recommended cropping systems of Maligaya Series irrigated lowland in Brgy. Maligaya, Science City of Muñoz, Nueva Ecija.

Existing Cropping System	ROI (%)	Recommended Cropping System	Estimated ROI (%)
LUT1.Rice-Rice (seed production)	245.11	R + cowpea – HR + squash-LV	100.04
LUT2.Rice-Rice (commercial)	50.77		
LUT3.Rice-Rice (seed production in WS and hybrid rice in DS)	100.95		

Notes: DS = dry season. WS = wet season. HR = hybrid rice. R = quality inbred rice. LV = leafy vegetables. Seed production – harvest sold as quality seeds. Commercial production – harvest sold to millers and palay buying station.

Table 6. Return of investment (ROI) of existing rice cropping systems for commercial production versus recommended cropping systems of Maligaya Series in rainfed lowland supplemented by irrigation in Brgy. Fronda, Talugtog, Nueva Ecija.

Existing Cropping System	ROI (%)	Recommended Cropping System	Estimated ROI (%)
LUT1.Rice - Rice			
LUT1a.CS - CS	113.31		
LUT1b. CS - HR	122.17	R + cowpea – HR + sweet corn	128.00
LUT1c. HR - HR	111.70		
LUT2.Rice (CS) - Fallow	50.00		

Notes: CS = certified seeds. HR = hybrid rice. R = quality inbred rice.

Therefore, shallow soil rotavation is recommended just after rice cropping to avoid soil cracking and reduce the high soil moisture loss owing to capillary rise. This practice will improve soil workability for the succeeding cropping.

The heavy texture, sticky consistency, and swelling and cracking of the soil when wetted and dried, respectively, influence the cropping pattern practiced in these land units. Farmers must not to allow the soil to dry below the shrinkage limit by growing irrigated lowland rice when irrigation water is available.

Suitability Analysis

The high suitability of rice in the land units can be translated to extensive rice production with the highest possible yield under best management practices.

In Brgy. Maligaya, majority of the farmers grow rice for seed production and sell their produce at a higher price while the rest grow quality inbred or hybrid rice and sold as commercial palay. On the average, inbred rice is fertilized with 75 kg N, 40 kg P_2O_5, and 30 kg K_2O/ha in wet season, and 112 kg N, 52 kg P_2O_5, and 41 kg K_2O/ha in dry season. The hybrid rice is fertilized with 130 kg N, 60 kg P_2O_5, and 28 kg K_2O/ha in dry season. The reported rice grain yields ranged from 5 to 8 t/ha. Based on the Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS) Model for irrigated rice (Dobermann and Fairhurst, 2000) for inherently high fertility type of soil, yield targets of 6 and 8 t/ha are attainable, with maximum attainable yields of 7.5 t/ha in wet season and 10 t/ha in dry season with the use of 60-80 kg N, 12-18 kg P_2O_5, and K_2O/ha in wet season and 120-150 kg N, 15-25 kg P_2O_5, and 60-80 K_2O/ha in dry season. Hence, improvement in fertilizer management and use of genotypes with high yield potentials can further increase rice yields.

Problems on internal and external soil drainage and strongly acid soil limit the suitability of other crops. This was based on recent soil analysis of the test sites belonging to Maligaya series. Thus, it is important to measure soil pH of irrigated lowland soils belonging to Maligaya series, which typically have higher soil pH. Flooding of the area followed by lime application is suggested prior to the establishment of non-rice crops to correct the problem on low soil pH.

Suitability analysis unveils opportunities for growing non-rice crops in combination with rice for small scale farmers and for those who did not meet the seed growers' qualifications. However, proper interventions associated to the soil limitations such as pH, drainage, and heavy texture should be addressed to improve yields of non-rice crops. Liming, deep plowing, incorporation of farm biomass or organic matter, and drainage improvement are recommended to address these production constrains. The establishment of cropping system involving the production of high quality inbred rice + legumes in bunds in wet season rotated with hybrid rice during the dry season in combination with cucurbits and leafy vegetables is relatively feasible and can project an increase of more than 50% in ROI than the existing commercial rice-rice cropping system. In commercial rice production, harvests are sold to millers or palay buying station. In rice production for quality seeds, the certified seed growers sell the seeds to farmers. Although the increase in ROI can be more than 200% for the rice-rice cropping system for the production of quality seeds, it may not be practical to recommend to farmers who lack resources. The production of quality seeds requires accreditation from a certifying body for a fee and higher cost of production.

Dry season cash crops such as watermelon or maize can be grown but it should be isolated within the cluster of rice areas to minimize the seepage effect. Liming, raised bed planting and good drainage canals are needed. Incorporation of organic matter may be placed in planting holes or mixed in furrows.

The irrigation-supplemented rainfed lowland in Brgy. Fronda, Talugtog, Nueva Ecija is hampered by the uncertainty of water supply during the dry season. Hence, better cropping calendar and water management strategies should be explored. The soil offers high potential for intensive rice production but good water management strategies should be carried out to increase water-use efficiency. The use of water saving technology such as the Alternate Wetting and Drying (AWD) can save water up to 15-25% without reducing yield. In pump irrigation systems, it reduces pumping cost and fuel consumption, and can generate an increased income of 67-97 USD per hectare (FAO, 2013).

In irrigation-supplemented rainfed lowland land unit, rice is fertilized with an average of 91 kg N, 52 kg P_2O_5, and 28 kg K_2O/ha for inbred rice and 91 kg N, 51 kg P_2O_5, and 21 kg K_2O/ha for hybrid rice in wet season, and 100 kg N, 62 kg P_2O_5, and 27 kg K_2O/ha for inbred rice and 107 kg N, 46 kg P_2O_5, and 43 kg K_2O/ha for hybrid rice in dry season. Using quality inbred seeds, yields close to 5.0 t/ha and 6.6 t/ha were attained in wet and dry seasons, respectively. With the current soil condition, the rates of phosphorus (as P_2O_5) applied in both seasons might be high. The inherent soil P and the availability of P under flooded condition are high (Fageria et al., 2011). The rate of potassium instead should be increased to ensure greater canopy photosynthesis and crop growth (Dobermann and Fairhurst, 2000). Having the same level of inherent soil fertility with that of Brgy. Maligaya, yield targets of 6 to 8 t/ha, are also attainable based the QUEFTS fertilizer recommendation for irrigated rice (Dobermann and Fairhurst, 2000).

The potential of the area in producing non-rice crops after wet season with favorable yields can be realized through (a) organic fertilizer or farm biomass incorporation to improve soil aggregation and increase porosity, and (b) good land preparation to offset the amount of moisture loss through soil cracking and reduce fuel consumption from pump irrigation.

Viable cropping system such as rice-legume combination in rotation with hybrid rice and maize (sweet corn) can be explored. However, a quick turnaround time is required to reduce the capillary rise and to optimize the cropping sequence and benefit from the previous rice cropping's high residual moisture. Farmers can save more on fuel as it requires minimal water usage compared to the rice-rice cropping system.

Conclusion

Maligaya soil series is best suited to intensive rice production due to its very high water holding capacity associated with its heavy texture. Rice production in this type of soil can be optimized and sustained through improved nutrient management practices such as season-specific and site-specific nutrient management. Other crops (e.g., cowpea, cucurbits, and maize) grown in combination or in rotation with rice can be highly suitable to this type of soil provided that problems on soil drainage and soil pH can be corrected.

When soil limitations are overcome, rice-based cropping systems such as the rice + legumes in wet season in rotation with hybrid rice + cucurbits or maize in dry season can be more profitable than commercial palay production. However, quality seed production requiring more resources or higher production cost, can be more profitable than commercial palay production or the recommended rice-based cropping systems.

Land suitability evaluation can be an effective tool to assess soil limitations, management interventions, and crop suitability to enhance and sustain rice and rice-based crop production. Management interventions associated with the identified soil limitations could be useful in other areas with similar soil characteristics.

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