The Integral Effect of Seed Enhancement Technique and the Production System on Growth and Yield Productivity Under Acid Soils for Sustainability of Organic Rice Production

Mgaya A.M[1]., Thobuniuepop P[1]., Sriwongchai T[1]., Sarobol E[1]., and Onwimol D[1]

Abstract

"Rice" is the staple food in Thailand. The most important rice producing areas is in central part of Thailand. Soil acidity in the area makes it unsuitable for rice production, this limits rice yield, especially on organic rice production system. On the other hand, the rectification of those problematic soils needs high cost of management. Since the rectifying method is non-organic, so the production of rice is not sustainable. Thus, this study was aimed to determine an alternative way for growing rice in that area by integrating seed enhancement technique and the organic production system to eliminate the effect of soil acidity on growth and yield of organic rice production in central Thailand. The experiment was conducted by a factorial in CRD. Firstly, rice seeds (Oryza sativa L. var. indica cv Pathumthani1) was primed by deionized water for 24 hours at 25 C and non-primed seeds were used as control. Then, both primed and control seeds were taken for germination tests and finally grown organically by two difference production systems. The System of rice intensification (SRI) and conventional system (continuously water flooded system; CN) into pots filled with acid soil under greenhouse condition with three replications. The experiment found that primed seeds had a significant ($p<0.05$) improvement on seed germination percentage, mean germination time, speed of seed germination, germination energy, tillering capacity, leaf area, leaf, and plant dry weight as well as total grain yield over the control for both production systems. Interestingly, the integral of seed enhancement technique and SRI system was significantly reduced the water used efficiency (WUE) over that conventional system.

Keywords : Hydropriming, SRI-organic, acid soils, sustainable rice production

[1] Faculty of Agriculture, Sustainable Agriculture International Program Kasetsart University Bangkok, Thailand

Introduction

Thailand is the top three leading countries for rice production and export in the world (Titapiwatanakun, 2012; Vanichanont, 2004). About 55% of rice produced is for export and the remaining 45% are sold in local market for daily consumption. About 91% of people in Thailand consume rice two or three times daily (Walker, 1996). Among the important rice producing areas in the country is central Thailand. Though the Central Thailand is an important area among rice producing area in the country, acidic soil in this area is not much favorable for ensure the high productivity. Acid soil causes serious problem on rice yield, delayed seed set, poor seed germination, poor uniformity and weak plants which lead to low production. High cost in rectifying this problematic soil affects the sustainability of the rice production. Pathumthani rice research station develop the rice variety which tolerate soil acidic condition(Sangwijit et al., 2012). However the new developed variety of Pathumthani1 (*Oryza sativa* L. var. *indica*) is doing well but still the management of the soil acidity for better germination needs frequently application of lime and large amount of in organic fertilizer for better crop harvest (Attanandana and Vacharotayan, 1986). Not only the application of lime and fertilizer increase production costs and affect sustainability, but the management practice also is non-organic. It increase environmental contaminations on water, soil, and affecting ecosystem of soil biota in general (Haynes and Mokolobate, 2001). Therefore the study of the integral effect of seed enhancement technique, seed priming, and the production systems, aimed at finding alternative sustainable organic method of rice production under acid soil to eliminate effect on rice growth and yield productivity. Further more, the water use efficient (WUE) was applied through system of rice intensification (SRI). Hence, promising results of integral management of rice seed enhancement and SRI may lead to rectify those problematic acidity soil conditions to improve yield productivity as well as ensure the sustainability method of organic rice production.

Materials and Methodology

Priming treatment; Rice seeds (*Oryza sativa* L. var. *indica* cv Pathumthani1) was primed by using deionized water , so called hydropriming, for 24 hours in the germinator chamber at 25^{0}C with oxygen provider. Non–primed seeds were used as a control. Seed initial moisture content (SMC) was determined using high constant temperature oven method at 130°C before soaking(ISTA, 2010), and found to be 12%, then the moisture were equilibrated to 20% by adding water. The quantity of adding water, in milliliter, was calculated by using the following equation;

Weight of subsample at 20% MC = [initial weight] × [(100 – Initial SMC) / (100 – desired SMC)]

Then 60g of rice seeds, at ~ 20 %SMC, was soaked in 600 ml of deionized water and pushed into the germinator chamber. After stop soaking, primed seeds were dried to initial SMC then stored for six day before exposure to germination and growth experiment.

Germination test, growth and yield experiment; field emergence test between primed and controlled, non-primed seeds were carried out in the green house condition under acid soil which mixed with organic (cow dung) as growing media, with four replications of 100 seeds each at Agronomy department, Kasetsart University. After germination, 14 days old seedling was transplanted into the pots for SRI experiment and 28 days seedling into pot for conventional method experiment, the pots was arranged in CRD with three replications. Before transplanting, 5 cm (800ml) of water was added in the experimental pot filled with acid soil which was mixed with cow manure at the rate of 12 tonne·ha^{-1} and left to stand for 21 days to allow the better release of nutrient from organic. Then single seedling was transplanted per pot while the soil was moisture wet in SRI pots spacing 25 x 25 cm and four seedlings were transplanted into the conventional pots spacing 10 x 10 cm with 30 cm flooded.

WUE; 7 days after transplanting on SRI the drying was done until makes the soil crakes around 0.5-1.5 cm below and then water added again up 800 ml (5 cm). Therefore makes the interval of 7 days watering and 7 days drying. Continuous flooding of 800 ml was maintained from the day one until harvesting time for conventional methods. Soil nutrient content and pH was analyzed before and after acid soil sample mixed with organic (Table 1).

Table 1 The soil properties of samples collected before and after mixed with organic and after crop harvest labeled S11-2, S11-1, S270-1, and S269-1, respectively

Soil properties	Before mixed with organic	After mixed with organic	After Harvesting	
	S11-2	S11-1	SRI (S270-1)	CN (269-1)
pH	6.1	7.3	6.7	6.7
%Clay	65	65	60	60
Organic matter (OM)	5.94	7.47	6.43	6.6
Phosphorus (mg.kg^{-1})	85	109	57	54
Extractable Fe (mg.kg^{-1})	18.19	94.1	127.87	119.06
Extractable Al (mg.kg^{-1})	1.6	1.8	nd*	nd

**nd is not detected*

Data collection procedure; radical emergence, about 2 mm in length, and germination (normal seedling) were determined at 24 hour intervals for 24 days. Normal seedling was evaluated in accordance with the ISTA rules for seed testing (ISTA, 2010). Germination–normal seedling, indices including maximum radical emergence (MaxRE, %), mean radical emergence time (MRET; hours), radical emergence time (T50, hours) was calculated using GERMINATOR software (curve-fitting program designed for the analysis of radical emergence data) (Joosen et al., 2010). Seeds germination speed in percentage was calculated as (Krishnasamy and Seshu, 1990)

$$\frac{\text{Number of seeds germinated at 72 hours}}{\text{Number of seeds germinated at 168 hours}} \text{ X } 100\%$$

germination energy was taken as total percentage of seeds germinated at 72 hours according to Bam et al., (2006). Shoot and root of 100 representative seedlings were randomly recorded in centimeter. Number of leaf, tillers and panicles were counted as well as filled and unfilled grain in panicle was determined then the percentage of filled grain was computed to obtain total yield per treatment per hectare.

Statistical data analysis; The research was designed as a factorial arrangement in Completely Randomized Design (CRD). Data was presented as mean values of four and three replication where analysis of variance (ANOVA) method was used to compare mean among treatments. Statistix 8.0 computer software was used to carry out statistical analysis. The significance of differences among means was compared by using Less Significant Difference (LSD).

Result and Discussion

The results showed that hydropriming enhanced seed germination ability, speed and germination energy when grown under organic acid soil. Primed seeds had significantly effected on maximum germination percentage, germination energy, germination speed and mean germination time over non primed seeds (p<0.05). Soaking rice seed in water for 24 hours reduced mean germination time from 2.9 days to 1.9 days while giving maximum germination of 95%, and germination energy of 96% with germination speed of 98.5% (Table 2). The short germination time in the primed seed showed more uniformity of seedling and fast germination. So, rice seed might be able to reduce the problem of late seed onset due to acidity condition of the soil.

Table 2 Effect of hydropriming treatment on rice seeds germination, germination energy, speed and mean germination time

Treatments	Hydropriming	Control	F-test
Max. germination (%)	95^{a}	87.7^{b}	2.6*
Mean germination time (days)	1.9^{a}	2.7^{b}	10.5*
Germination energy (%)	96^{a}	$60.^{5}$b	4.6**
Germination speed (%)	98.5^{a}	70.6^{b}	7.9**
Seedling shoot length (cm)	124.2^{a}	102.8^{b}	6.7*
Seedling root length (cm)	69.9	66.3	7.3ns

*ns = not significant, * = significant, ** = highly significant*

Values for the certain parameter marked with the same letter are not significantly different at 0.05 (LSD test)

On the other hand, the seedling after hydropriming showed maximum germination energy which gives healthy seedling that could grow into maximum speed resulting including early flowering and maturity (Binang et al., 2012). The hydropriming treatment and SRI showed early flowering for 5 days compared to non-primed seed and within production system the different was 6 days (Table 4). However, there were no significantly different on plant height the SRI treated seeds shows higher tillering capacity of about 13.8 tillers compared to 7.7 tillers of CN treatment. Leaf area of 2,447 and 1,163 cm^2 were found on treated seeds for SRI and CN respectively. Like wise the leaf area of 1,819 and 808 cm^2 were found on control treatment for SRI and CN respectively (Table 4). Including other factors, the large leaf area maximizes light intensity - absorption capacity (canopy photosynthesis) hence stimulates formation of carbohydrate which results into high yield capacity of crops (Meziane & Shipley, 2001)

Table 3 The Integral effect of seed treatment and production system on plant growth characteristic

production system	SRI	CN	F-test
Plant height (cm)	120[a]	115[a]	ns
Number of tillers	13.8[a]	7.7[b]	10.0 *
Number of leaves	67.7[a]	34.5[b]	17.0 *
Leaf Area (cm^2)	2133[a]	985[b]	3.1 *
Leaf dry weight (g)	13.3[a]	10.6[b]	3.5 **
Plant dry weight (g)	24.6[a]	18.3[b]	1.5 **

*ns = not significant, * = significant, ** = highly significant*

Values for the certain parameter marked with the same letter are not significantly different at 0.05 (LSD test)

SRI crops shows high leaf area of 2,133 cm^2 compared to CN plant which was 985 cm^2 (Table 3). Large leaf area increase ability of photosynthesis and transport photosynthate, which is important substance for process of building organ in the plant and rice seed filling capacity (Meziane and Shipley, 2001). High leaf area may not increase yield if there high rate of leaf shading, but this problem is unlikely to happen in SRI method as the plant spacing is wide enough to reduce the competition of growth factors like light, water, nutrient and oxygen in the soil. The result of the integral effect of seed treatment and production system shows high significant difference, at $p<0.05$, on leaf area, leaf dry weight and total plant dry weight between primed and non-primed seeds and within production systems (Table 4).

Table 4 the effect of plant growth characteristic within production system

Production system	SRI		CN		F-test
Treatments	Hydropriming	Control	Hydropriming	Control	
Plant height (cm)	123.3	110.7	117.7	112.3	ns
Number of tillers	16.0[a]	10.7[b]	7.7[c]	4.7[d]	10.0 *
Number of leaves	73.0	62.3	37.3	31.7	ns
Leaf Area (cm2)	2447[a]	1819[b]	1163[c]	808[d]	2.4 **
Leaf dry weight (g)	16.3[a]	10.4[c]	12.0[b]	9.2[d]	3.5 **
Plant weight (g)	29.2[a]	20.0[b]	20.4[b]	16.2[c]	1.5 **
Flowering (DAP)	72	77	78	79	

*ns = not significant, * = significant, ** = highly significant*

Values for the certain parameter marked with the same letter are not significantly different at 0.05 (LSD test)

Even though SRI method perform better compare with CN methods but the integral of SRI organic with treated seeds (hydropriming) increase the yield difference of about 44% compared with SRI non primed treatment (Table 5 & 6). Tillering capacity on SRI treatment was over 48% compared to CN treatment. This implies that the seed used in CN is twice as much as that used in SRI. Under favorable growth condition if all tillers becomes to be productive tiller then the yield in SRI is highly expected to be twice of that of CN whereas less seeds were used and less water was applied compared to CN. Amount of water saved was 41% while the difference in rice yield was about 44% (Table 6). This indicators promise sustainability of organic rice production if the less water amount, less seeds and less agro input was used on SRI but still the yield output was doubled (Table 5).

Table 5 Integral effect of seed treatment and production system on yield characteristic

Production system	SRI		CN		F-test
Treatments	Hydropriming	Control	Hydropriming	Control	
Panicle length (cm)	29.2	28.2	27.0	27.1	ns
No. grain per panicle	124.6	123.1	101.3	111.5	ns
No. filled grain per panicle	101.3	93.0	96.0	79.7	ns
Total Grain per plant	1867^{a}	1228^{b}	642^{c}	629^{c}	9.2*
Filled grain (%)	84.2	77.0c	81.2	75.7	ns
1000grain weight (g)	22.9a	22.6	22.5	22.3	ns
Yield (kg·ha-1)	5425.8^{a}	3765.8^{b}	3264^{bc}	3065.9^{c}	6.3*

*ns = not significant, * = significant, ** = highly significant:*
Values for the certain parameter marked with the same letter are not significantly different at 0.05 (LSD test)

There are statically different on total grain per plant and total yield in kg·ha^{-1} but the panicle length, number of grain per panicle, filled grain percentage, and 1000grain weight result showed no statistically significant differences at p<0.05 (table 5). SRI together with hydroprimed seeds accounted yield of 5,425 kg·ha^{-1} where as SRI non-primed seeds was 3,765.8 kg·ha^{-1}. The greater difference on total number of grain between treated SRI (1,867 seeds) and non-treated SRI (1,228 seeds) and between SRI-hydro primed (1,867 seeds) and CN-hydro primed (642 seeds) per plant, respectively (Table 5). The better yield in SRI organic was contributed with higher tillering capacity of treated seeds and the management practice of soil, water, and nutrient the practice which promotes the root and plant to grow faster and healthier as the competition for nutrient was reduced due to wider spacing applied during transplanting.

Conclusion

This study determined an alternative way of growing rice under acid soil by integrating the seed enhancement technique and organic rice production system to improve soil quality and for sustainability of rice production. Results suggest that treated seeds increase tolerance ability of acidity stress by reducing germination time, germination speed, and increasing germination percentage and rice yield significantly when compared with non-treated seeds. Results also revealed that addition of organic into acid soil increase ability of seed germination, speed of seedling growth and better yield. Soaking rice seeds in water (hydropriming) for 24 hours can reduce germination time, days of flowering and increase yield significantly by 44% compared with non soaked seeds. For the selected rice variety (Pathumthani 1), the result of integral effect of rice seed enhancement and SRI may concluded as an alternative way to rectify those problematic acidity soil conditions to improve seeds germination and yield productivity as well as ensure the sustainable method of organic rice production. The research, however, was conducted in green house because of shorted of time and limitation of fund to conduct the research on the field condition. Further research is required to be done in actual field to determine the integral effect of priming process and SRI organic under acid soil before a general conclusion is drawn.

Table 6 Comparison of the water use efficiency (WUE) and yield of each production system

Treatment	Watering (DAP)	Drainage (DAP)	Amount of water	
			SRI	CN
Hydropriming and Control	18-24	25-31	800 ml	800 ml for 110 days
	001-7	008-14	800 ml	
	15-21	22-28	800 ml	
	001-7	008-14	800 ml	
	15-21	xxxxx	800 ml	
	March 22 - April 21	xxxxx	400 ml daily for 30 days	
Percentage of water used efficiency			52,000 ml (41%)	88,000 ml (100%)
Harvesting Date 30/04/2015		Yield (Field)*	5,425.8 kg·ha^{-1} (44%)	3,765.8 kg·ha^{-1}

**The yield was computed based on actual filed bases in kilogram per hector and expressed in percentage.*

Acknowledgement

The acknowledgement is made to the collaboration of Thailand and Tanzanian Government for awarding my scholarship and research fund for this study. Many thanks to Kasetsart University, Graduate School of Kasetsart University, Faculty of Agriculture, and Department of Agronomy, for provision of place equipment for research activities. Thanks to all seed technology and renewable energy laboratory members for their strong coorporation during this research work.

References

Attanandana, T., and S. Vacharotayan. 1986. Acid Sulfate Soils: Their Characteristics, Genesis, Amelioration and Utilization. (Special Issue,Problem Soils in Southeast Asia).Accessed 4 October 2015 Available http://repository.kulib.kyoto-u.ac.jp/dspace/handle/2433/56244.

Bam, R.K., F.K. Kumaga, K. Ofori, and E.A. Asiedu. 2006. Germination, vigour and dehydrogenase activity of naturally aged rice (Oryza sativa L.) seeds soaked in potassium and phosphorus salts. Asian Journal of Plant Sciences.Accessed % October 2015 Available http://agris.fao.org/agris-search/search.do?recordID=DJ2012050351.

Binang, W., J. Shiyam, and J. Ntia. 2012. Effect of Seed Priming Method on Agronomic Performance and Cost Effectiveness of Rainfed, Dry-seeded NERICA Rice. Research Journal Seed. Science. 5(4), 136-143.

Haynes, R., and M. Mokolobate. 2001. Amelioration of Al toxicity and P deficiency in acid soils by additions of organic residues: a critical review of the phenomenon and the mechanisms involved. Nutrient Cycling in Agroecosystems. 59(1), 47-63.

ISTA. 2003. International rules for seed testing: edition 2003. International Seed Testing Association.

Joosen, R. V., J. Kodde, L. A. Willems, W. Ligterink, L. H. van der Plas, and H. W Hilhorst. 2010. Germinator: a software package for high-throughput scoring and curve fitting of Arabidopsis seed germination. The Plant Journal. 62(1), 148-159.

Krishnasamy, V., and D. Seshu. 1990. Germination after accelerated ageing and associated characters in rice varieties. Seed Science and Technology (Switzerland). 18(1), 147-156.

Meziane, D., and B. Shipley. 2001. Direct and indirect relationships between specific leaf area, leaf nitrogen and leaf gas exchange. Effects of irradiance and nutrient supply. Annals of Botany, 88(5), 915-927.

Sangwijit, K., P. Thangsunan, R Cutler, and S. Anuntalabhochai. 2012. Development of SCAR Marker for Thai Fragrant Rice (Oryza sativa L. var. Indica cv. Pathumthani 1) Mutants Induced by Low Energy Ion Beam. Chiang Mai Journal of Science. 39, 1-9.

Titapiwatanakun, B. 2012. The Rice Situation in Thailand. Technical Assistance Consultant’s Report, ADB. Accessed 14 August 2014 Available http://www.adb.org/sites/default/files/project-document/73082/43430-012-reg-tacr-03.pdf

Vanichanont, P. 2004. Thai rice: Sustainable life for rice growers. In: FAO rice conference, Rome, Italy

Walker, M. 1996. A survey of food consumption in Thailand: UVic Centre for Asia-Pacific Initiatives, University of Victoria.