Improvement of Local Rice Productivity in the Thai Highland Areas

Janjira Rungcharoen[1*], Siripong Hungspreug[1], Suthat Pleumpanya[2], and Nednapa Insalud[3]

[1] *Highland Research and Development Institute (Public Organization), Thailand*
[2] *Royal Project Foundation, Thailand*
[3]*Department of Agronomy, Maejo University,Thailand*

Abstract

Rice is the most important staple food crop for hill tribe farmers in the Thai highland areas. Low yields result in insufficient production to meet household consumption needs. The research objectives of this project are: (1) to use pure-line selection methods to improve local rice yields, (2) to study methods to reduce water needs for paddy field production. The research was conducted in paddy fields with the cooperation of hill tribe farmers. The experiment used two seedling aged, 15- and 30-days-old and two soil moisture conditions, flooded and non-flooded. Single rice seedlings were transplanted and then rogued to remove off types, at four stages; tillering, booting, flowering, and pre-harvesting. Results showed that Li-ka, a local cultivar grown at 600 above mean sea level (MSL), produced 445 kg/1,600 m^2 in flooded soil and 454 kg/1,600 m^2 in non-flooded soil conditions. Bua-bor-bae, a local cultivar planted above 1,000 MSL, produced 540 kg/ 1,600 m^2 under non-flooded soil conditions and 480 kg/1,600 m^2 in flooded soils. The 12.5% yield reduction of Bua-bor-bae in flooded soil was the result of bacterial leaf blight disease, which was more severe in flooded than non-flooded soil. Yields did not differ between the two different seedling ages. The experiment shows that the local rice cultivars Li-ka and Bua-bor-bae can be grown in non-flooded soils with yields equal to or greater that those in flooded soils. Cultivation under non-flooded soil conditions can help to conserve water resources, because non-flooded cultivation consumes 40% less water than flooded soil cultivation. Action research and participatory demonstration projects with cultivation under flooded soils should be undertaken to build trust and confidence among farmers so they are willing to adopt non-flooded soil rice cultivation technologies.

Keywords*:*Aerobic soils/Hill tribe farmer/Highland rice/Local rice seed /Yield stability/Water use efficiency

1. Introduction

Rice (*Oryza sativa*) is the most widely grown main food crop in the Thai highlands. In Thai highlands, Karen tribe members comprise 42% of the total hill tribe people. The Karen people grow rice for livelihood and food security, but rice yields are often low and insufficient to meet needs for household consumption. Hill tribe farmers often grow upland rice rather than terraced paddy rice, which is highly susceptible to erosion in these sloping lands. Moreover, soils in highland paddy fields are generally acidic and nutrient depleted, with P deficiencies being common (Buresh *et al*., 1997;Fairhurst *et al*., 1999; Kirk *et al*., 1998). Because highland farmers grow rice for household consumption rather than for sale, they generally do not purchase inputs such as chemical fertilizers, relying instead on manures or other natural or nutrient sources. Efforts to improve soil quality for rice cultivation has proven challenging because of the obstacles of transporting fertilizers to these areas. An alternative approach to increasing productivity is to use high quality, pure line seed of local varieties that the hill tribe farmers can maintain themselves.

Farmers in the highlands cultivate a produce in the range of rice cultivars, including local and introduced cultivars as well as specialty rices such as sticky rice, black rice, and purple rice.Hill tribe farmers plant at least two rice cultivars each season in order to minimize risks from climate variability. However, growing 2 or 3 cultivars has led to a confusion of genotypes so rouging (Virmani and Sharma, 1993) is needed to conserve the quality of rice seeds used in highland paddy fields. From a single planting it is easy to select pure line seed (1 seed to 1 plant) and then refine the line through rouging, or removal of off-type plants, in the paddy field.

Most highland areas are planted with photosensitive rice cultivars, with planting during April and May and harvest during November and December. Thus, the rice season is about 6 to 7 months. Hill tribe farmers transplant seedlings about 25-45 days after seeding. Unfortunately, if the rainy season starts late seedlings become too old, sometimes as much as 60-days-old, before rains are sufficient to puddle the fields. The transplanting of younger seedlings is recommended to avoid risk from water-deficit and to reduce disease outbreak and insect pests in the seedbed.

Irrigation water is limited in highland areas, but the hill tribe farmers often cultivate flooded rice because they believe that rice plants grow better in flooded soils and because flooding can help control weeds. Currently, rice cultivation leads to a high amount of surface runoff, and seepage and percolation accounts for about 50–80 % of the total water input to the field (Sharma, 1989). Previous research has shown that non-

*Corresponding author:
E-mail: puntase@hotmail.com

flooded rice can improve the efficiency of water use and stabilize yields in highland areas (Li, 2001; Bouman and Tuong, 2001; Bouman1 *et al*., 2002). Grassi *et al*. (2009) reported that rice yields under non-flooded soil conditions were lower than those in flooded soils. Nevertheless, when non-flooded (drained) conditions alternate with anaerobic (flooded) conditions or a fallow period, rice yields under non-flooded soils conditions are good. Nitrogen application in non-flooded soils increases yield and water use efficiency, partially compensating for the lack of water in non-flooded fields. Rice production in non-flooded soils might also be more environmentally sound as they emit less methane than flooded soils, thereby reducing the production of powerful greenhouse gasses. Minamikawa and Sakai (2006) reported that the Alternate Wetting and Drying (AWD) in paddy filed had reduced methane emission by 64% comparing with flooding condition and there were no effected on the rice yield. Some of the advantages observed in non-flooded rice cultivation include more vigorous plant growth, more efficient fertilizer use, and less pest /disease incidence (Parthasarathi *et al.,* 2012).

Our hypothesis is that a single planting of young seedlings in non-flooded soil conditions will improve local rice yield production in the Thai highland areas. In order to test this hypothesis, the first objective of this research is to study methods for improvement of local rice yield by single planting and rouging for pure line selection under non-flooded conditions and to observe water usage reduction of the upland rice cultivars. Thus, the experiment design would be cooperating with farmers, durinng farmer's conduct on the paddy field, therefore the study process would be a two way learning process.

2. Methodology

2.1 Studying of improvement local rice yield in highland paddy field under non-flooded conditions

This experiment was conducted in cooperation with hill tribe farmers in the Chiang Mai Province Thai highland areas of Pa-Tak village, Mae-Taeng district at 600 and Mae-Ma-Lo village, Mae-Chaem district at 1,000 MSL. Both villages are Karen tribes, who grow rice every year as a subsistence food crop. They also grow cash-crops such as corn, soybean, and vegetables.

A randomized complete block 2 × 2 factorials in design with two blocks was used with two rice seedling ages – 15-day-old (Figure 1) and 30-day-old (Figure 2) – and two water regimes as flooded and non-flooded soil conditions (5 cm level of flooded irrigation followed by no watering or drainage when raining). The conventional farming practice uses flooded soil, at least 5 seedlings per hill, 30- to 60-day-old seedlings and continuously flooded soil conditions.

Figure 1:15-day-old seedling

Figure 2:30-day-old seedlings (conventional)

Seedbeds were 1 to 2 m wide and of any convenient length with drainage channels between seedbeds to remove excess water. Seeds of local rice cultivar were soaked in water for 24 hours. Seeds were stirred regularly and floating seeds were discarded. Seeds were then placed in a warm and shady place for 24 hrs. and allowed to germinate. Seeds can be germinated in moist jute sacks if there is sufficient aeration to meet the needs of seeds for respiration during germination.

One seedling per hill at a spacing 30 x 30 cm was transplanted by hand (Figure 3). Then the field was saturated until plants recovered from transplanting and after 4 or 5 days the flood water depth was increased to 5 cm. and missing hills were replanted within 7 days after transplanting (DAP). Weeds were controlled by hand pulling and herbicides.

Water regime treatments were initiated at 15-20 DAP. Flooded treatments were kept at 5 cm of water above the soil surface. The non-flooded treatment was allowed to flood up to 5 cm deep during rains and was not irrigated and allowed to drain during rainless periods (Figure 4).The flooded treatment was controlled at a constant 5 cm depth and drained about 7 to 10 days before expected harvesting.

Figure 3: Single seedling planting flooded conditions by hand

Figure 4: Water regimes were non-flooded and flooded conditions

We used roguing to remove undesirable rice plants from the local rice seed production plots. Undesirable rice plants were those that differed from plants that were true to type. Off-type plants might be volunteer plants from an earlier crop or out-crossed progeny. Roguing can be done at any time. The most important stages for roguing are maximum tillering, booting, flowering, and before harvesting.

At maximum tillering and booting we removed any plants outside the rows that were significantly taller or shorter than the majority of plants, that had off-type leaf blade size or shape, and that had off-type color of leaf sheath or leaf collar.

At flowering we removed off-type plants that flowered too early or too late, that were off-type in leaf size, leaf angle, panicle shape and size, and all diseased plants from the seed production plot. Pre-harvest we removed plants that have different grain shape, grain size, or off-type presence or absence of awns.

Plots were harvested when 90% of the grains in the main panicles were clear, firm, and straw colored. Harvesting of rice seed were kept separated from grain during harvesting, threshing, drying, and bagging.

2.2 Water using efficiency under non-flooded conditions and flooded conditions

The experiment was conducted in a greenhouse at the Department of Agronomy, Maejo University, Thailand. Two soil water regimes were imposed on upland rice cultivars. Soil treatments were flooded (W+, 5 cm. of water level above soil surface) and non-flooded (W0, no water standing in the pot and watering as plants required). Three upland rice cultivars were Kai-Pa, Dad-Karn, and Leb-Nok. There were three replicates for each treatment. Seeds were imbibed for 24 hours and incubated for 48 hours. One 2 day-old rice seedling was transplanted in each pot one week before the treatments were imposed. Each pot was lined with a plastic bag and contained 10 kg of soil (San Sai series). Basal fertilizer was applied at the rate of 0.37 g N/pot as urea, 0.26 g P/pot and 0.26 g K/pot four weeks after transplanting and repeated four weeks later. The volume of water of each pot throughout the experiment was recorded and calculated for water use efficiency.

3. Results

3.1 Improvement rice yield in highland paddy fields

Li-ka cultivar, a famous local rice cultivar at Pa-Tak village in Chiang Mai Province was grown at 600 MSL an produced 445 kg/1,600m^2 under flooded conditions and 454 kg/1,600m^2 under non-flooded conditions. The results supported our hypothesis that local rice cultivation can be grown in non-flooded conditions without any adverse affect on yield. There were no significant differences of yield between the transplanting 15-and 30-day-old seedlings (445 and 454 kg/1,600m^2 respectively). Similarly, rice yields did not differ significantly when grown under non-flooded and flooded conditions.

Bua-bor-bae cultivar was cultivated in 1,000 MSL at Mae-Ma-Lo village. Non-flooded rice yielded 540 kg/1,600m^2 and flooded rice yielded 480 kg/1,600m^2. The difference was attributed to bacterial leaf blight disease, which was more severe under flooded conditions, was evident by tillering, and reduced yields by 12.5% (Figure 5). There was no difference in seed yield between one and more than 5 seedlings per hill.

Figure 5: Bacterial leaf blight disease spread under flooded conditions at tillering stage

A single planting can easily be used to select rice seed that will be planted in the next season. Rouging reduced off-types and prevented off-types from cross pollinating. At harvest, off-types were removed from seed production plots thereby reducing seed contamination by 20-25%. The single seedling per hill with wide spacing, as compared with the conventional planting practice of multiple seedlings per hill, greatly facilitated field operations such as weeding, spraying, fertilizing, and roguing.

Figure 6: Tillering under non-flooded conditions

Figure 7: Tillering under flooded conditions

Figure 8: Active root in non-flooded conditions

A single planting can easily be used to select rice seed that will be planted in the next season. Rouging reduced off-types and prevented off-types from cross pollinating. At harvest, off-types were removed from seed production plots thereby reducing seed contamination by 20-25%. The single seedling per hill with wide spacing, as compared with the conventional planting practice of multiple seedlings per hill, greatly facilitated field operations such as weeding, spraying, fertilizing, and roguing.

3.2 Water use efficiency of the upland rice cultivars

Flooding, as opposed to non- flooding, significantly promoted growth and development of all rice cultivars. However, there were different growth rates among the different types of cultivars. The 20-30 days earlier harvesting was in rice plants under flooding by Dad-Karn was the earliest, Leb-Nok and Kai-Pa were later, respectively. All three rice cultivars under flooded conditions were harvested at 93 days after transplanting. All rice plants under well-drained conditions were harvested at 127 days after transplanting. The total water use for the flooded treatment was 74.5 L, or 0.80 L/day. Non-flooded rice used a total of 60.7 L or 0.48 L/day. Thus, non-flooded rice used 40% less water than flooded rice (Table 1).

Table 1 Water use in three highland rice cultivars when grown under non-flooded and flooded conditions

Parameters	Non-flooded	Flooded
Time to harvest (days after transplanting)	127	93
Total water use (L/plant)	60.7	74.5
Average water using (L/plant/day)	0.48	0.80
SDW/ total water volume (g/L)		
Kai-Pa	1.15	0.77
Dad-Kan	1.02	0.53
Leb-Nok	0.69	0.52

4. Discussion

Results supported the hypothesis, that highland local rice can be grown in non-flooded conditions without any yield loss. Non-flooded conditions economize water use, which can be particularly important if hill tribe farmers are more concerned with insects and diseases than water deficit. The advantage of cultivation without flooding for farmers, is that it not only saves water, but also reduces pest and disease incidence. In addition, plants in non-flooded treatments have strong shoots and less lodging than those in flooded treatments

These results were collected from the hill tribe farmers' paddy fields and recorded, so data had great variability and it was difficult to control the management factors. In addition, the hill tribes have resisted experiments because they have a strong tradition of rice cultivation, and they rigidly adhere to their established practices.

Non-flooded conditions yielded more rice than flooded rice, largely because of differences in bacterial leaf blight. However, Belder *et al.* (2005) reported relatively low uptake of nitrogen under non-flooded conditions as compared to flooded conditions, which was reflected by the relatively low fertilizer-N recovery under non-flooded conditions. It appears that the alternation of flooded (during rainy periods) and well-drained conditions (during interruptions of rains) can increase the N uptake in the Thai highland paddy fields.

In general, bacterial leaf blight disease favours temperatures of 25−34°C with relative humidity above 70%. Highland fields generally have high humidity and low sunshine during the rainy season, which would promote bacterial leaf blight. Flooding would further exacerbate the disease. Non-flooded conditions, on the other hand, might keep humidity in the fields low enough to reduce bacterial leaf blight, but this would need to be confirmed with future research.

Moreover, in highland villages there is high humidity, more rain and less sunshine in the rainy season which causes a high incidence of disease. The flooding had affected the spread of disease at the tillering stage which reduced photosynthesis because there was yellow coloring of the leaf blade. The plant morphology in the non-flooded conditions was straight and upright leaves. There were fewer planthopper attacks and bacterial leaf blight disease in the non-flooded than in the flooded treatments. In non-flooded conditions, plants produced new roots (white color), which actively take up water and nutrients.

Results show that the well-drained conditions of highland rice cultivars consume 40% less water than flooded rice. Parthasarathi *et al*., (2012) reported that non-flooded rice saved 56% during the crop growth period. Guerra *et al*. (1998) also supported that the potential for producing more rice should be precedence with less water in irrigated systems. The challenge will be to develop effective integrated natural resource management interventions, which allows profitable rice cultivation with increased soil aeration while maintaining the productivity, environmental services, and sustainability of rice ecosystems (Tuong and Bouman, 2003).

Single seedling per hill planting and roguing were accepted by hill tribe farmers because they can easily select desirable rice seed for the next farming season. These techniques are not complicated and relatively inexpensive. The hill tribe farmers traditionally do not transplant a single seedling because they do not believe a hill with a single seedling will grow well. Nonetheless, the project demonstrated that single seedling planting had sufficient advantages to give famers confidence because there were no differerences of rice growth and yield between plantings with single and 5 types of seedling per hill.

The local rice varieties were used in this research because the hill tribe farmers of the highland area prefer their taste and other characteristics. The results show that the hill tribe farmers of both communities can keep rice seed produced from plot experiments to use as seeds in the next season. Unfortunately, if the farmers planted the old seedlings (more than 60 days), they had reduced rice tillering and rice yield decreased. Farmers recognized that there was no difference in growth of rice plants between a single seedling plot or mixed seedling plot per hill because the rice panicle of single plants was large and long. Partha and Samsul (2011) supported that productive tillers are very important because the final yield is mainly a function of the number of panicles bearing tillers per unit area. More tillering provides more photosynthesis to support root growth; both contribute to greater grain filling and larger grains. Moreover, the planting of 15-day seedling was also accepted because when planting is delayed by a late start of rains they adjust the planting date.

5. Conclusions

Results from the study indicate that non-flooded conditions yielded more rice than flooded conditions, because there was less bacterial leaf blight disease, which is severe during flooded conditions on highland paddy field. In addition non-flooded rice 40% consumes less water than flooded rice. The hill tribe farmers recognized the potential advantages of the non-flooded rice production, particularly as it reduced bacterial wilt disease.

Furthermore a single planting can easily select rice seed which will be grown in the next farming season. Most farmers recognize the need for high quality rice seeds that are pure and disease free, so high quality seed will quickly disperse from experimental plots into those of relatives and neighbors after harvest. The research results generate appropriate technology that keeps hill tribe farmers acceptance. The action research and participatory demonstration would build trust and confidence among farmers to adopt this rice cultivation technology.

6. Acknowledgements

This research was financially supported by Highland Research and Development Institute (Public Organization), Thailand. The authors thank the hill tribe farmers in the Thai highland area for their cooperation in this research.

7. References

Belder P., Bouman, B.A.M., Spietz, J.H.J., Peng, S., Castaneda, A.R. and Vispearas, R.M. 2005. Crop performance, nitrogen and water use in flooded and aerobic rice. **J. Plant and Soil** 273: 167–182.

Buresh, R.J., Smithson P.C., and Hellums D.T. 1997. Building soil phosphorus capital in Africa. p. 111–149. *In* R.J. Buresh et al. (ed.) Replenishing soil fertility in Africa. **SSSA Spec. Publ**. 51. SSSA and ASA, Madison, WI.

Bouman, B.A.M. and Tuong, T.P. 2001. Field water management to save water and increase its productivity in irrigated rice. **J. Agricultural Water Management** 49(1): 11-30.

Bouman1, B.A.M., Yang X., Wang H., Wang Z., Zhao J., Wang C. and Cheng B. 2002. Aerobic rice (Han Dao): A new way of growing rice in water-short areas (pp. 175-181). **Proceedings of the 12th International Soil Conservation Organization Conference, 26-31 May, 2002, Beijing, China. Tsinghua University**.

Fairhurst, T., Lefroy R., Mutert E., and Batjes N. 1999. The importance, distribution and causes of phosphorus deficiency as a constraint to crop production in the tropics. **Agroforestry Forum** 9:2–8.

Grassi, C., Bas A., Maria B., Ambrocio R. C., Macro M., Vincenzo V. 2009. Aerobic rice: crop performance and water use efficiency. **J.Agriculture and Environment for International Development** 143 (4);259-270.

Guerra, L.C., Bhiyan, S.I., Tuong, T.P., and Barker, R. 1998. Producing More Rice with Less Water from Irrigated Systems: **SWIM Paper 5. International Water Management, Colombo, Sri Lanka.**

Kirk, G.J.D., George T., Courtois B., and Senadhira D. 1998. Opportunities to improve phosphorus efficiency and soil fertility in rainfed lowland and upland rice ecosystems. **Field Crops Res**. 56:73–92.

Li, Y. H. 2001. Research and Practice of Water-Saving Irrigation for Rice in China. Water-Saving Irrigation for Rice (pp. 23-25). **Proceedings of an International Workshop Held in Wuhan, China**.

Minamikawa, K., Sakai, N., and Yaki, K. 2006. Methane Emission from Paddy Fields and its Mitigation Options on a Field Scale**. Microbes and Environments** 21(3): 135-147.

Partha S. P. and Samsul H. 2011. Effect of seedling age on tillering patternand yield of rice (*Oryza sativa* L.) under system of rice intensification. **ARPN Journal of Agricultural and Biological Science** 6(11): 33-35.

Parthasarathi T., Vanitha K., Lakshamanakumar P. and Kalaiyarasi D. 2012. Aerobic rice-mitigating water stress for the future climate change. **J. Agronomy and Plant Production** 3 (7): 241-254.

Sharma, P.K. 1989. Effect of Period Moisture Stress on Water-Use Efficiency in Wetland Rice. **Oryza** 26: 252-257.

Tuong, T.P., and Bouman, B.A.M. 2003. Rice Production in Water-Scarce Environments. **Agricultural Water Management** 2: 13-42.

Virmani, S.S. and Sharma, H.L. 1993. **Manual for hybrid rice seed production** (pp. 53-55). International Rice Research Institute.