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Agrodiversity for in situ Conservation and Management of Thailand’s Native Rice Germplasm
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Executive summary
This project aims to find ways to help improve the return from rice farming while maintaining genetic diversity of the native rice germplasm. This fourth year brought more understanding into structure of genetic diversity in local rice varieties and changes contributed by gene flow and seed flow and farmers’ management affecting these. The structure of variation studies covered varieties adapted to uniform environment (wetland rice for the mid elevations) and those varieties adapted to more variable environments (acid soils, deep water and different altitudes). We proved that much genetic variation, in useful traits (grain iron, adaptation to soil acidity, resistance to insect pest) as well as at the level diversity measured with microsatellite markers, can exist within outwardly uniform local varieties. The continuum between wild and cultivated rice was found in ‘wild rice’ in natural habitats that (1) were obviously wild-cultivated hybrids to those almost identical to cultivated rice, and (2) possess modern traits such as photoperiod insensitivity and resistance to brown planthopper. Wild rice populations that occur within the cultivated rice landscape are genetically much less diverse, with genetic background much closer to cultivated rice, than those from large and isolated naturalized habitats. We continued to develop and evaluate methodology for collaborating with farmers and local communities. A pilot training program on biodiversity and livelihoods was developed and tested. Promising local varieties for areas not served by national breeding program were evaluated for gall midge resistance, early maturity, tolerance to soil acidity and adaptation to deep water. Our focus village in weedy rice area is now effectively clean of weedy rice; a group of farmers in neighbouring province has promised to keep their village weedy rice free. The private and public sector in national rice research system for the control of weedy rice have begun to contribute to the control of weedy rice. We have expanded the partnership to Lao PDR and Cambodia.
Project objectives

This project has two general goals.

- To develop strategies for the management of rice genetics that will help to improve local livelihood and at the same time maintain/enhance in situ genetic diversity.
- To develop the interdisciplinary capacity necessary to accomplish this within the centre of diversity of rice in Thailand.

These goals are expected to be attained through three specific objectives.

- To characterize genetic diversity, its structure and dynamics, in local domesticated and wild rice populations and its ecological and agroecological context.
- To identify the economic and other incentives and reasons for local rice germplasm conservation.
- To develop participatory procedures crop research and management that will contribute towards an improvement of local community’s capacity for increasing crop productivity and germplasm conservation.

Main findings

1. Characterization of genetic diversity and its ecological and agroecological context

   i. Extent and nature of diversity in the germplasm

      a. Structure of genetic variation in cultivated rice

         - The hypothesis that genetic distance (with microsatellite markers: RM1, RM6, RM164, RM241, RM253, OSR28) in Bue Chomee (uniform habitat at about 600 m, generally with good water control) is closely related to geographical distance of the seed source has been confirmed with additional seed samples to cover the variety’s entire geographical range.
         - Genetic diversity has also been evaluated in other named varieties adapted to more diverse agroecological conditions, namely, Bue Polo (adapted to more varying altitudes), Moey Nong (a gall midge resistant variety, but of which different accessions have shown variation in responses to gall midge in different locations), and others with different adaptation to acid soil and grain iron contents.
         - Twenty microsatellite markers have been identified, and more are under way to cover the whole 12 rice chromosomes for use in diversity analysis.

      b. Wild rice

         - Wild rice that occur naturally have been found to fall into three groups: wild (similar to large, naturalized, perennial populations), like cultivated (similar to single genotype KDML105 and SPR1) and hybrids (those in between wild and cultivated).
         - Those wild rice populations that occur near the rice field (irrigation channels, farm ditches, ponds, roadside next to rice field, abandoned rice fields, etc) are genetically much less diverse than those in naturalized populations. Genetic background of these basically on-farm wild rice populations are much closer to cultivated rice than those from naturalized habitats.
ii. Dynamics in the gene pool

- We have identified two major and distinct processes that influence genetic diversity in the rice gene pool: (1) seed flow and (2) gene flow.
- Seed flow is mediated by the management rice seed stock, which is highly dynamic and diverse among farmers, even when keeping to one named variety (Figure 1). Major movements of rice seed from field to field and over distances of hundreds of kilometers are associated with recent introduction and movement of combined harvesters, especially from the Central Plain to the north and northeast.
- Evidence of gene flow between cultivated and wild rice has been found with (1) the ease at which wild and cultivated rice hybridize and fertility of the progenies, (2) cultivated rice genes found in wild rice populations and (3) mixing of wild and cultivated alleles in weedy rice.

iii. Relationship between genetic diversity and ecological and agroecological variation

- Variation in the ecological and agroecological conditions associated with some of the genetic diversity has been further defined.
- The variety Moey Nong is preferred by some farmers for its better adaptation to exceptional cold weather as well as for gall midge resistance. A whole spectrum of responses to gall midge populations by different accessions of the variety has been described. Variation has also been found among the gall midges themselves. Two sources of deterioration in its grain quality have been confirmed: (1) contamination of non-waxy grains, and (2) presence of these non-waxy grains with high alkali spreading values (6 or higher).
- Tolerance to soil acidity has been found among upland rice and also in deep water rice on acid sulphate soils. Ability to keep growing roots in high Al is one strategy for adaptation to soil acidity identified. Other varieties avoid the acidity by increasing root growth in the surface soil with pH elevated by the ash, into which rice in slash and burn system is sown. (This is a risky strategy when/where the surface soil moisture becomes depleted). A variety can be quite sensitive to Al toxicity and sustain high percentage of yield depression due to soil acidity, but may still gives comparable yield in acid soil, because of its higher growth potential in non-acidic condition.
- We have established that grain Fe varies largely by genotype and only slightly by environment (3 locations X 2 years). Genetic control of grain Fe begins to be elucidated. Within seed lot variation is being investigated in two local varieties, Chao Khaw and Nam Roo, to see if they contain individual genotypes with exceptionally high Fe.
- Phosphorus nutrition has been found to play a key role in adaptation to aerobic/anaerobic condition of rainfed rice. On going experiments evaluate how rice genotypes may differ in their P uptake efficiency under aerobic condition and in the speed of morphological and physiological changes to acclimate to alternate aeration and anaeration of the roots.
- Arbuscular mycorrhizal (AM) fungi have been found to increase nutrient uptake and enhanced the concentration of nitrogen (by 9%) and phosphorus (22%) in the grain of upland rice in acidic low P soil, although in general, because of its very fine roots, rice has a much lower AM dependency than other cereals (e.g. corn, sorghum).

iv. Databases

- We now have two sets of databases of cultivated and wild rice and some of the associated cropping systems: (1) broad survey and (2) detail information.
• The broad survey databases contain (a) cultivated rice databases germplasm from the uplands (upland and wetland rice) and lowlands (wetland and deepwater rice), (b) georeferenced wild and weedy rice populations located in the country’s main rice growing regions: northern, northeastern and central provinces.
• Detailed databases include selected, sometimes interconnected sets of in depth information on specific aspects of specific populations, sets of germplasm and cropping systems (a) named varieties with special characteristics and their variation; (b) wild rice; (c) weedy rice; (d) cropping systems; (e) farmers’ seed management and seed exchange networks.

2. Mechanisms, economic and other incentives and reasons for local rice germplasm management and conservation
• Factors and processes that contribute to the maintenance of genetic diversity in local rice germplasm have been found associated with (1) the key roles that local varieties play in some cropping systems and (2) the way in which farmers manage their rice seed.
• Two aspects of ‘economic incentives’ for farmers’ to continue to use local varieties have been identified: (1) better adaptation of local varieties in areas not reached by national breeding program; (2) ability of genetically diverse local varieties to meet requirements of farmers in crop management and consumers in grain quality.
• Our assessment that invasive weedy rice constitutes a serious economic loss has been confirmed on the national and provincial scale in consultative meetings with groups of farmers and others in the national rice research and extension system. The problem is exacerbated by weedy rice contamination of farmers’ rice seed.

3. Participatory procedures for crop research and management that will contribute towards an improvement of local community’s capacity for increasing crop productivity and germplasm conservation.
   The above findings and understanding have been used to develop participatory procedures to improve productivity of rice-based cropping systems while conserving local rice germplasm (Figure 2). Actual participatory activities focused at two levels: (1) farmers and local community (2) national rice research and extension system.
• Collaborative experiments with farmers have evaluated and verified local varieties for overcoming constraints including insect pest, deep water and acid soil.
• Collaboration with farmers and the community have effectively overcome the weedy rice problem at the village level.
• To scale up the use of project findings, we have engaged other actors (rice breeders, extension offices, NGOs promoting conservation and agricultural chemical suppliers) in the national rice research and extension system, for both the maintenance of genetic diversity in local rice germplasm and controlling weedy rice.

4. Workshops, meetings, training, publications and honours
   a) Workshops and meetings
   1) Project annual meeting, Chiang Mai July 30-31, 2005.
   3) A regional workshop on “Partnership and Collaboration on Local Rice Germplasm in the Centre of Diversity” was held at Agronomy Department, Chiang Mai University, on August 3 2005.
   4) Field workshop in Cambodia, December 19-24, 2004
5) A meeting with potential new partners from CARDI (Ouk Makara) and Lao (Phoumi Inthavong and Chay Bounphanousay) Agricultural Research Centre was held in Chiang Mai on May 9-10, 2005.

6) Project contributed the main technical information at national meetings on weedy rice (a) National Consultation to find solutions to the weedy rice problem, 19 September 2005; (b) Technical Symposium on Weedy Rice, Rama Gardens Hotel, Bangkok 21 October 2005

7) Paper “On-farm conservation of rice biodiversity as a model for *in situ* conservation of genetic diversity of agricultural species”, was contributed to an FAO international training workshop on *in situ* conservation in Bangkok on October 29 – November 2, 2005.

8) CMU team attended the 4th Annual Meeting of Crop Science Meso Groups, 26-27 October 2005, Rayong.

9) Six graduate students attended 3rd Graduate Seminar, Faculty of Agriculture, Chiang Mai University, 18 November 2005.

10) Researchers and students from project attended and presented their results at national (70 papers) and international (39 papers) conferences and meetings (Attachment 1).

b) Training

1) Graduate studies
   - 1 PhD completed (ML)
   - 2 M.Sc students (PO, NP) converted to PhD program
   - 2 Graduate students from the region commenced studies in association with project: one from Lao PDR (VP), one from Vietnam (DHT)

2) Short term training and transfer from overseas:
   - 1 researcher (AP1) in now being trained with CU and NYBG partners in New York on analysis of social processes and networks
   - 3 PhD students completed training in Australia: one on restoration ecology (NY), one on methods for studying rice adaptation to aerobic/anaerobic condition (NI), one in molecular studies of nutrient efficiency trait (SP)
   - 1 PhD student (NP) is now at Queensland University, to train in biochemical methods for studying acid tolerance in rice

3) Project results provided materials and case studies for a training course on “Conservation of Rice Genetic Diversity and Sustainable Rural Livelihood”. The training course was conducted in collaboration with United Nations University and the Office of Agricultural Development and Extension for Northern Region, with 60 participants, 3 from from Lao PDR, one from Vietnam and the rest from Thailand. UNISERV, Chiang Mai University, 30 March to 1 April 2005.

4) Local training
   - 1 graduate student (PO) was trained in a gall midge lab in Bangkok.
   - Two researchers (TS2, TA) from project were trained in GIS for biodiversity conservation as part of FAO’s international training workshop on in situ conservation in Bangkok on October 29 – November 2, 2005.

c) Publications and papers (See attachment 1)

1) Papers in Thai 20
2) Papers in English 69

d) Awards and honours

3 MSc students (Suwanee Laenoi, Pennapa Jaksomsak, Amena Promin) have been awarded research scholarships from Thailand Research Fund
3 PhD students have been awarded scholarships (Burapa University: Prateep Oupkeaw; Royal Golden Jubilee Scholarship from Thailand Research Fund: Ayut Kongpan and Ekkasit Phongphitak)

1 PhD student (Netnapha Insalud) won best paper award and 3 (Dang Huu Thang, Adirek Punyalue, Utumporn Chaiwong) best posters at the 4th Annual Meeting of Crop Science Meso Groups, 26-27 October 2005, Rayong.

PhD student (Prateep Oupkaew) won best paper award at AgBiotech Graduate Conference II, May 16-17, 2005, Chulabhorn Research Institute, Bangkok.

5. Impacts
The project’s impacts were recorded directly on collaborating farmers, focus villages and their neighbours in the form of new promising rice varieties and strategies identified to increase return from crop production and effective control of weedy rice. We have contributed to increased national awareness of the value of local rice germplasm and how best they might be conserved. Our findings provide technical inputs for initiatives to make use of genetically diverse local rice germplasm and to control weedy rice in various public and private, initiatives in the national system for agricultural and environmental research and development.

Research progress

1. Characterization of genetic diversity and its ecological and agroecological context

i. Extent and nature of diversity in the germplasm
The extent and nature of diversity in the local rice germplasm was confirmed with detailed characterization of genetic variation in specific traits and microsatellite markers of cultivated, wild and weedy rice, with more populations and number of markers used in this 4th year. We have so far identified 20 microsatellite markers (RM1, RM22, RM212, RM103, RM55, RM44, RM219, RM295, RM335, RM270, RM171, RM164, RM167, RM253, RM6, RM149, RM122, RM118, OSR28, RM211, RM241) for use in rice diversity studies, and are now in the process of evaluating more in order to cover all 12 chromosomes of rice.

a. Structure of genetic variation in cultivated rice
Detailed diversity analysis of local varieties has now been expanded to include more than 200 accessions of named varieties. The hypothesis that genetic distance (with microsatellite markers: RM1, RM6, RM164, RM241, RM253, OSR28) in Bue Chomee is closely related to geographical distance of the seed source has been confirmed with additional seed samples to cover its entire geographical range (total 26 accessions). Bue Chomee is basically quite uniform in its habitat, being a popular variety for mid altitude highland paddy (about 600 m, generally with good water control).

Diversity analyses have been conducted with other named varieties adapted to more diverse agroecological conditions. These included a variety adapted to varying altitudes up to 1,200 (Bue Polo, 23 accessions); a gall midge resistant variety, but of which different accessions have shown variation in responses to gall midge in different locations (Moey Nong, 148 accessions); deep water rice (Khao Banna, Leuang Yai) variation in grain iron (Bue Bang, Bue Gua, Bue Kee, Ja Nae Nae, Ja Fu Fu); and tolerance to soil acidity (Bue Bang, Bue Gua).
b. Wild rice

Diversity analysis of “wild rice” populations (from outside the rice field, those from inside the rice field are classified as “weedy rice”) from the north, northeast and central regions, with pure line KDML105, CNT1 and SPR1 for comparison, is almost complete. From one set of the populations, 443 individuals have been grouped, based on 17 morphological characteristics, into three groups: wild (similar to large, naturalized populations), like cultivated (similar to KDML105 and SPR1) and hybrids (those falling in between wild and cultivated). With DNA analysis (still in progress) we have found wild rice from naturalized habitats to be genetically more diverse than those that occur near rice fields (irrigation channels, farm ditches etc). Genetic background of these basically on-farm wild rice populations are much closer to cultivated rice than those from naturalized habitats.

ii. Dynamics in the gene pool

We have identified and described two major processes that influence genetic diversity in the rice gene pool (1) seed flow and (2) gene flow. While biologically distinct, the first involving the transfer of seeds and the second transfer of pollen, their effects can be closely interconnected.

a. Seed flow

The management of rice seed has been found to be highly dynamic and diverse among farmers, even when keeping to one named variety. Illustrated with gall midge resistant Moey Nong (Figure 1) the networks for seed transfer within the village of Mae Moot are influenced by several practices: (1) the diverse frequencies in which farmers renew their seed lots, (2) the different methods of seed selection by individual farmers and (3) the different clusters of farmers sharing seed source, dominated by certain individuals who are well known for the quality of their rice seed. We have followed the trail of some seed lots and found similar networks for seed flow to extend beyond the village, and in other varieties as well. Diversity analysis is underway to determine how these ‘distances’ in seed management (method of seed management X length of time a seed lot is grown by one farmer) influence genetic variation. The transfer and exchange of rice seed among farmers have also been found to contribute to the spread of weedy rice in a major way, as do two other practices: (1) introduction of combined harvesters, (2) ‘Lai Toong’ duck raising, in which rice fields after harvest are gleaned by flocks of ducks.

In response to increasing labour cost and synchronous ripening of very few single varieties in each location, requiring timely harvest all at the same time, the rice area reaped by combined harvesters is expanding rapidly. Evidence of seed flow from field to field can be found everywhere in areas with weedy rice problem. At heading time, the first passes of the harvester after it had been harvesting a heavily infested field stand out clearly as weedy rice infestation in a previously clean field. As the army of combined harvesters follows the ripening rice from the central region to the north and northeast, major dispersal and mixing of rice genes are to be expected. Weedy rice that has been found in jasmine rice (KDML105) in the northeast is being examined if it had come from the Central Plain or originated locally from hybridization between KDML105 and local wild rice as a response to major agronomic changes from transplanting and hand harvesting to direct seeding and combined harvesting.

The practice of Lai Toong duck raising, in which flocks of ducks follow the harvesters as the crop is reaped is common throughout the Central Plain. During the day the flock is allowed to feed on the grain that had fallen on the ground and sheltered
in one place at night where they are fed a rice supplement. This supplement rice, usually the lowest grade, is genetically diverse (full of weedy rice) and still largely viable. Some farmers have remarked that weedy rice has become serious after the ducks had been housed in their fields. However, on account of the bird flu risk, the government has announced that the practice must stop by the end of 2005, which means its contribution to seed and gene dispersal will be terminated.

b. Gene flow

Further evidence supporting gene exchanges between wild and cultivated rice were obtained from 3 sets of studies. The first set involved crossing experiments between wild and cultivated rice. There were three wild rice populations from the central region: PCB (in situ conservation population at Prachin Buri Rice Research Center; LP, KC and NY), KC (Kanchanaburi) and NY (Nakhon Nayok) and one from the north LP (Lampoon). Cultivated rice included 7 modern bred (SPR 1, SKN, CNT 1, PCB 1, PCB 2, PTT 60, RD10) plus 9 local (LMN111, KDML105, RD 6, Plai Ngarm, Khao Banna, Leuang Yai, Pahn Tawng, Kum Doisaket, Niaw Sanpatong) varieties. With PCB as the male parent, seed set ranged from 5% to 62%, of which 31% to 87% germinated and developed normally, producing panicles with spikelets that were 38% to 80% fertile. Crosses with exceptionally fertile progenies included those with semi-dwarf, high yielding varieties such as SPR 1, CNT 1 and RD10 as well as crosses with local varieties such as Plai Ngarm and Leuang Yai. By the time the hybrids reached F2, they were almost as fertile as the cultivated parents, although their seed shattering habit was still very close to the wild parent, i.e. virtually 100% of the spikelets were shed before maturity.

The second set of studies of “wild rice” (1.i.b above) found populations of wild rice that were close to cultivated rice fields to be (1) less genetically diverse, and (2) genetically closer to cultivated rice, than those that were in naturalized habitats. The presence of cultivated rice alleles of microsatellite marker RM1 found in “wild rice” in natural habitat has now been confirmed with 3 more markers, RM 211, RM 164 and RM 44.

The third set of studies focused on the mixing of wild and cultivated rice genes in weedy rice. This has now been confirmed in detailed diversity analysis of 3 popular varieties for the Central Plain, where weedy rice problem is widespread: PTT1 (semi-dwarf, photoperiod insensitive, aromatic) and Phothong (very short duration, “3 month rice”, photoperiod insensitive, enabling three successive crops to be grown in one year), SPR 1 (an HYV). Seed lots of these from farmers’ fields have been found to be highly diverse genetically, with both wild and cultivated traits in the same plants. Analysis of 11 seed lots of PTT1 from farmers’ fields in Supanburi province found both cultivated and wild alleles (hybrid) of two microsatellite markers, RM1 and RM 164, in all plants from 8 of the seed lots, and 90% of the plants in another seed lot. Of the remaining 2 seed lots, one was 100% wild and the other was 50% hybrid, 40% crop and 10% wild, by these two markers.

iii. Relationship between genetic diversity and ecological and agroecological variation

Variation in the ecological and agroecological conditions associated with some of the genetic diversity has been further defined. Adaptation and other traits found in local varieties in some difficult environments included resistance to the insect pest gall midge, tolerance to soil acidity, adaptation to deep water, high altitudes and aerobic condition and grain iron.
We have found the variety *Moey Nong* in 16 villages in the foothill of the Mae Chaem Valley, southwest of Chiang Mai. Some farmers say that they prefer *Moey Nong* for its better adaptation to exceptional cold weather as well as for gall midge resistance. Among the 21 seed lots of *Moey Nong* tested at Mae Moot, one was found to be as susceptible to gall midge as SPT1 (susceptible check), 4 moderately susceptible, 9 resistant (same as RD4, susceptible check), and 7 highly resistant (completely free of silver shoot, symptom of gall midge damage). Variation in susceptibility to gall midge and yield was also found in a trial involving 7 accessions at 4 locations. Adult and pupae samples of the insect collected from 10 locations in 5 provinces have shown significant variation within and between populations, measured in wing length and width and length:width ratio, and also preliminary DNA analysis (AFLP). For the quality of the cooked grain of *Moey Nong*, a glutinous or waxy grain type, we have confirmed that there are two sources of deterioration in grain quality: (1) contamination of non-waxy grains, and (2) presence of these non-waxy grains with high alkali spreading values (6 or higher). What is not clear is why some seed samples are more prone to this deterioration in grain quality than others.

Tolerance to soil acidity is important in upland rice on very acidic soils and also in deep water rice on acid sulphate soils. *Khao Banna* has been identified as well adapted to extreme acid sulphate soils. Assessment of variation among different deepwater varieties and accessions is ongoing. From the uplands, variations in tolerance to aluminium (Al) toxicity have been found between named varieties, between accessions with the same name and within seed lots. For example, we have found 80% of plants in one seed lot of *Bue Bang* to be more tolerant to Al than Koshihikari (Al tolerant check) while all plants in one seed lot had about the same level of Al tolerance as Koshihikari. Ability to keep growing roots in high Al is one strategy for adaptation to soil acidity. Other varieties avoid the acidity by increasing root growth in the surface soil with pH elevated by the ash, into which rice in slash and burn system is sown. (This is a risky strategy when/where the surface soil moisture becomes depleted). *Pa Ai Kupe* was one of the varieties found to be least tolerant to Al, yet it is a very popular variety, grown by almost everyone in the village. This popularity may be partly explained by the fact that it is highly valued for brewing purpose, but it also does not yield so much poorer in farmers’ field than more Al tolerant varieties such as *Bue Bang*. Although the percentage of yield depression due to soil acidity is greater, *Pa Ai Kupe* still gives comparable yield in acid soil, because of the variety’s higher growth potential in non-acidic condition.

With single genotype advanced breeding lines from Phitsanulok Rice Research Centre we have established that grain Fe varies much more by genotype and only slightly by environment (3 locations X 2 years). Among these was CNT 89098-281-2-1-2-1 with Fe concentration in the same range as the high Fe check, IR68144. Grain iron is another trait that has been found to have structure of genetic diversity similar to acid tolerance, i.e. variation within seed lot, between seed lots with same name and among different varieties. Within seed lot variation is being investigated in two local varieties, Chao Khaw and Nam Roo, to identify individual genotypes with exceptionally high Fe, if any. Genetic control suggested by the pattern of variation in grain Fe found within seed lots is being investigated. Some crosses between low and high Fe genotypes produced progenies with similar levels of grain Fe as the high parent, but other crosses produce grain with Fe midway between the parents from the F1 plants.
After establishing that there is genotypic variation in adaptation to aerobic/anaerobic condition of rainfed rice, we have examined responses of the rice plant in order to identify parameters that may be used in quick assessment for better adaptation among genotypes. Two key factors that influence rice growth and yield in this situation are \( \text{O}_2 \) and P supply to roots. With sufficient P and water supply, rice actually grows better with external supply of \( \text{O}_2 \) to its roots than without. Rice roots in aerated solution also take up P much more efficiently than in \( \text{O}_2 \) depleted nutrient solution. Without external supply, \( \text{O}_2 \) is transported to the roots through the aerenchyma, but at some cost. Rice roots growing in \( \text{O}_2 \) depleted nutrient solution quickly develops a barrier to radial oxygen loss in order to deliver \( \text{O}_2 \) to the root tips more efficiently, but nutrient uptake is also hindered. Experiments are underway to evaluate how rice genotypes may differ in their P uptake efficiency under aerobic condition and how efficiently they acclimate to alternate aeration and anaeration of the roots.

Arbuscular mycorrhizal (AM) fungi have been found to increase nutrient uptake by upland rice from acidic low P soil, although in general, because of its very fine roots, rice has a much lower AM dependency than other cereals (e.g. corn, sorghum). We have also found that AM fungi enhanced nitrogen concentration in the grain of upland rice in acidic soil by 9% and phosphorus concentration by 22%.

iv. Databases
We now have two sets of databases of cultivated and wild rice and some of the associated cropping systems: (1) broad survey and (2) detail information.

a. Broad survey
The broad survey databases contain
1) Cultivated rice databases germplasm
   - The uplands (upland and wetland rice): by location (province, district, village, farmer and ethnic group), variety name and accession.
   - Lowlands (wetland and deepwater rice).
2) Georeferenced wild and weedy rice populations located in the country’s main rice growing regions: northern, northeastern and central provinces.

b. Detailed information
Detailed databases include selected in depth information on specific aspects of specific populations, sets of germplasm and cropping systems.
1) Named varieties with special characteristics and their variation
   - Gall midge resistant Moey Nong (reaction to gall midge populations)
   - Bue Chomee (polymorphism in relatively uniform habitat: mid elevation, irrigated wetland)
   - Bue Polo (adaptation to varied elevation, upland rice)
   - Early maturing upland rice
   - Grain iron (range found in local germplasm; structure of genetic diversity in local varieties: within seed lots, between seed lots with same name, among varieties; popular and modern varieties; advance breeding lines; GxE)
   - Acid tolerance (upland rice and deep water rice)
   - Grain quality (milling, eating)
   - Adaptation and acclimation to aerated/anoxic condition.
2) Wild rice
- Structure of variation in populations from northern, northeastern and central provinces, and genetic relationship to cultivated rice (includes cross-fertility)

3) Weedy rice, associated with
- HYVs and modern bred varieties (SPR1, PTT1 and 3-month rice)

4) Cropping systems
- Weedy rice infestation in irrigated rice-rice (HYVs) in two villages (Kok Trabong and Kao Sam Sib Harb) in Kanchanaburi (history of infestation by individual plots since 2001, economics and population genetics).
- Rotational shifting cultivation with upland rice and associated crops on acidic, infertile soil, with rice diversity, and species diversity, fallow enriching tree (Macaranga denticulata) and arbuscular mycorrhizal fungi.
- Grain yield data from crop cut survey, 2002 to 2005
- Database of yield of upland and wetland rice by crop cutting in Lao PDR initiated.

5) Farmers’ seed management and networks for seed exchange
- Variety turnover in 3 focus villages: Huai Tee Cha, Mae Rid Pagae, Mae Moot
  - Moey Nong
    - among farmers’ within a village
    - family and social networks, across villages and districts
- Farmers’ networks for ‘clean seed’ of SPR1 (weedy rice free)
- Local varieties of deep water rice

2. Mechanisms, economic and other incentives and reasons for local rice germplasm management and conservation

Several factors and processes that contribute to the maintenance of genetic diversity in local rice germplasm have been identified. They are associated with (1) the key roles that local varieties play in some cropping systems and (2) the way in which farmers manage their rice seed. Our assessment that invasive weedy rice constitutes a serious economic loss has been confirmed in consultative meetings with farmers individually and in groups.

i. Mechanisms, economic incentives and non-economic reasons that are instrumental in persuading farmers to conserve and use genetically diverse traditional varieties instead of “improved” modern varieties

By the end of this fourth year of the project, we have met still very few farmers who are growing local rice varieties because they “do not know any better”. The primary reasons for growing local varieties may be economic, social or both.

a. Economic incentives

Two aspects of ‘economic incentives’ for farmers’ to continue to use local varieties have been identified: (1) better adaptation of local varieties in areas not reached by national breeding program; (2) quality of genetically diverse local varieties for crop management and meeting grain quality requirement of consumers.

Preference for local varieties are articulated by farmers in terms of higher yield, superior grain quality and better adaptation to specific stresses and cropping systems. Crop cutting survey in 2005 provided yield data to support this for selected varieties in selected cropping systems for one more year in Thailand and initiated yield database for wetland and upland rice in Lao PDR. In areas not reached by national breeding program rice yield is limited by ecological constraints such as soil acidity and infertility, water stress and pests and diseases. In the highlands with limited conditions for wetland rice, upland varieties outnumbered wetland varieties two to one. There
are, however, considerable variation among ethnic groups and villages within each group in access to the combination of land and water essential for growing wetland rice. Adapted varieties have been verified to possess traits including acid tolerance, adaptation to specific water and flood regimes and resistance to gall midge. Others meet the need of specific cropping systems with earliness and responsiveness to residual soil fertility. Evidence has begun to build up, suggesting that local varieties can be highly sensitive to small variation in the environment (e.g. different varieties or seed lots for a few days in flood duration and different local populations of gall midge); and may have more than one strategies to cope with constraints such as soil acidity.

Genetically diverse local varieties can be outwardly very uniform, especially for those seed lots belonging to farmers who take pains with seed selection. This has now been verified from the appearance of plants in standing crop (height, colour), their phenology (timing of developmental stages such as heading and maturity) to the appearance of panicles (branching, size, grain load), spikelets (size, shape, pigmentation of the husk and apiculus) and grain quality. These local varieties have generally proved to be quite satisfactory for the purpose of crop management and in quality of the grain to home use and the market, including for export. Specific named varieties are also recognized by farmers from their similar external appearances, in spite of genetic differentiation that exists among seed lots with the same name.

b. Social rules and conditions

The many different cultural rules and tastes that exist among different ethnic groups in the country contribute significantly to diversity of local rice germplasm. The highlands account for some 300 names of local rice varieties, distributed among the 10 highland ethnic groups: Karen 43%; Hmong 16%; Mian 12%; Kon Muang 8%; Akha 6%; Lua 5%; Lahu 4%; Lisu 3%; Chin Haw 2%; Tai Yai 2%. Most of these are heirloom varieties typical to each group. Two thirds of the varieties are non-glutinous types, which is staple for all highland people except Kon Muang, who have migrated from the lowlands where glutinous rice is staple. We found about 10 named varieties that had been transferred from other ethnic groups, including from the lowlands and across the border from Myanmar. Among the Karen, the largest ethnic group in the highlands, the degree to which seed management is governed by traditional rules varies from village to village. Of our two focus villages, the strict rules about how the family rice must be preserved and inherited among the siblings found in Tee Cha were not encountered in Mae Rid Pagae.

ii. Farmers’ seed management and conservation characteristics of the farming systems

Unlike corn farmers, who can rely on a highly developed commercial seed system, rice farmers depend largely on the seed grown by themselves or other farmers. In connection to this, we have identified two processes associated with genetic diversity: (1) seed selection and turnover practiced by individual farmers (2) the social networks through which rice seeds are exchanged and transferred.

The level of selection practiced differs among farmers, and for individual farmers can vary from year to year, or with each of the rice varieties grown. Sometimes a portion of the bulk harvest from the previous season furnishes as seed for the next crop. Seed from other farmers also ranges from any seed that happens to be available to those that had been carefully inspected in the field and bespoken before harvest. Even when keeping to one named variety, the management of rice seed has
been found to be highly dynamic and diverse among farmers. In gall midge resistant Moey Nong we have identified 3 variables within farmers’ networks for seed transfer: (1) the frequencies in which farmers renew their seed lots, (2) the different methods of seed selection by individual farmers and (3) the different clusters of farmers sharing seed source, sometimes across great distances. The method of seed selection by some farmers is very similar to that described in plant breeding textbook as ‘mass selection’, in which thousands of panicles may be selected by each farmer in one season.

A common pattern in all this is the rapid turnover of seeds, in which farmers may change seed lots every 2-3 years but keep to varieties with the same name, trying out new varieties, or returning to the varieties they had earlier dropped. This rapid turnover in seed creates complex patterns of gene flow through the landscape as farmers acquire and distribute seed within dynamic networks of exchange. All this contributes to genetic diversity of local rice germplasm, enhanced by genetic variation within seedlots and between seedlots with the same name, and gene flow between varieties and between crop rice and wild rice.

iii. Impact of weedy rice

Participation in several national and local (district and provincial) consultative meetings with farmers and other stakeholders throughout 2005 has confirmed that invasive weedy rice is a serious and growing threat in the country’s main irrigated rice growing region. In addition to obvious economic impact of yield loss and price mark down already reported, we have found that the problem is exacerbated by contamination of weedy rice in the rice seed. In response to our recommendation to use clean seed, farmers invariably respond, “But where do we get this clean seed?” Apart from farmers’ own seed crop, weedy rice contamination has been reported in seed multiplication fields of the Department of Agricultural Extension in several provinces. Purity of the 2005 seed crop planted from breeder’s seed of PTT1 and SPR1, the two most popular HYVs that suffer from weedy rice invasion, is now being verified by microsatellite marker analysis.

3. Participatory procedures for crop research and management that will contribute towards an improvement of local community’s capacity for increasing crop productivity and germplasm conservation.

The above findings and understanding have been used to develop participatory procedures to improve productivity of rice-based cropping systems while conserving local rice germplasm (Figure 2). Actual participatory activities focused at two levels: (1) farmers and local community (2) national rice research and extension system.

i. Identification and verification of problems and evaluation of local varieties as on-farm solutions

Specific constraints identified from consultation with farmers have been verified with strategic measurements. Local varieties with special adaptation were identified as solution by farmers from areas with similar constraint, and verified. Seed lots were assembled and evaluated. Local rice varieties continued to be evaluated in farmers’ fields as solution to gall midge, soil acidity, low temperature stress and early maturity to fit into the cropping system (includes to furnish an early harvest when the household’s rice supply from last year runs out). We have also begun work on two deep water rice varieties for adaptation of specific flood regime and tolerance to extreme acidity of acid sulphate soils. The general approach for verification and evaluation of local varieties has to be sufficiently adaptive to deal with the different
nature of some of the constraints and plant responses and to utilize better understanding of the situation that have been gained.

The high degree of genetic variation we found in accessions of *Moey Nong* is recognized by farmers as variants of the gall midge resistant variety sharing common characteristics of round grain with glutinous endosperm of uniform grain size with straw colour husk. On-farm evaluation confirmed adaptation to its natural range as well as resistance to the gall midge that were always better than “improved” varieties from the national breeding program, as well as frequently better than the single genotype, pure-lined *Moey Nong 62 M*, which proved to be sensitive to gall midge in two of the three sites (Figure 3). The evaluation of *Moey Nong* accessions was repeated in 2005 and expanded to cover two more areas: (1) commercial jasmine rice area in Maesot, with severe gall midge problem and heavy pesticide use; (2) area in Chiang Dao growing supposedly resistant *Moey Nong* that sustained serious damage by the pest in 2004. This year’s crop has just been harvested, data processing and analysis are in progress.

We now have 4 years of actual yield data to confirm farmers’ assertion that their own rice varieties can respond very well to improved fertility of acidic upland soil. In fallow patches enriched with *Pada* (local technology for fallow enrichment, identified as *Macaranga denticulata*), farmers’ rice yield, averaged $2.63 \pm 0.21$ t/ha, compared with only half that and much more variable yields ($1.31 \pm 0.55$ t/ha) where *Pada* was only one quarter as dense during the fallow period. Early rice varieties obtained from other villages to meet farmers’ need for earlier harvest, to tie them over before the main crop comes in, were evaluated. *Bue Polo* (u), *Jakudi* and *Bue Kae*, although about 2 weeks earlier, yielded in the same range as full season varieties. *Bue Cho* and *Ble Chao* were one more week earlier, but suffered severe damage by rats and birds. [*Bue* and *Ble* both mean rice in Karen and Hmong, respectively].

In the case of rice varieties adapted to low temperature, we found that *Bue Polo* from elevations 700 to 1,200 m in two provinces all yielded about the same at around 2.5 t/ha, compared with non-adapted varieties with a lot of empty glumes yielding 0.9 t/ha or less. We have gone back to the lab to measure genetic diversity in all of the 23 accessions of *Bue Polo*, include an early maturing one (see above). For many rice varieties we have found that production of reliable clean, good quality seed to be the bottleneck that can affect rice yield and quality, as well as maintenance of particular seed lots. Although we have met many exceptional farmers who would take the extra trouble to do mass selection with tens of thousand panicles with each seed lot, but the majority of farmers do not. We have also identified several local rice varieties with good yield potential and quality that are not uniform or consistent. A streamlined procedure for mass selection of rice seed for general farmers is now under development and will be evaluated with help from farmers in 2006.

ii. Evaluating mixed row planting to control gall midge

The method of mixed row planting of different rice varieties for disease and pest control was evaluated in 3 locations with gall midge and blast problem, including the focus village of *Mae Moot*. Half-replacement series design was used to measure the intercrop effect and at the same time satisfy farmers’ requirement for the different rice varieties. In addition, there was another planting in a gall midge free location to separate out the pest and disease protection component from the competition component. Unfortunately, this year is a good year for gall midge and disease (from farmers’ point of view, i.e. not so much problem; or a “bad year” from researcher’s
Records were also made of the ‘whitehead’ symptom (stemborer) that affected some of the sites. The data and harvest are now being analyzed, some definitive answers are expected. Next we consult with farmers about their reaction and interest.

iii. Integrated control of weedy rice

The integrated control of weedy rice we have developed has been further refined to engage the whole community as well as to match the variation in farmers’ circumstances. At the focus village of Kao Sam Sib Harb the last remaining infested fields in the dry season crop 2005 (Figure 4) were cleaned by the wet season crop 2005 that followed. Two factors contributed to this: (1) civic pride when the village was chosen as the site for a “Weedy Rice Free Village” field day, organized by the Department of Agricultural Extension for some 1,200 farmers from 4 neighbouring provinces on 25 September 2005, and (2) an awareness of the risk of re-invasion of the weedy rice from remaining infested fields from the combined harvester. Another village in near by province has made commitment to keep their village weedy rice free.

Along with a suite of control measures developed by our weed scientists, major constraints to effectiveness of each measure were identified, which then formed the basis for identification and recruitment of collaborating farmers. Trials of post emergence herbicides that began in 2004 crop were continued in dry season 2005 crops with pretilachlor, butachlor, thioencarb and oxadiargyl. The trials with oxadiargyl which previously proved to be effective were expanded into large scale farmers’ crop (1-3 ha fields) in areas with really heavy infestation (212 to 716 weedy rice panicles per m²) in 4 provinces. This proved to be highly effective, with weedy rice panicles brought down to 23 to 116 weedy rice panicles per m² and rice yield increased from 1.32±0.61 t/ha to 5.10±0.69 t/ha, representing yield increases of 61% to 85%. The farmers reported satisfaction with their following wet season 2005 crop, which received treatment of the post emergence herbicide, and was very clean.

iv. Scaling up the twin objectives of increasing return from rice farming and conservation of genetic diversity in local rice germplasm.

We have identified and collaborated at various levels with different actors in the national rice research and extension system in order to: (1) verify our findings and understanding of the role of local varieties and genetic diversity in rice farming in its many different variation and condition; (2) enhance solutions to problems being developed; and (3) identify opportunities to disseminate findings and solutions more broadly.

a. Local rice varieties

For the use of local rice germplasm we have found allies in both the Thai Rice Research Institute and Department of Agricultural Extension. From the convention that improvement meant single genotype ‘improved’ varieties, including pure-lined local varieties, we have found a beginning in the shift of idea towards mass selection of local varieties among rice breeders. They have been convinced by evidence in the field of situations in which local varieties were judged by buyers as well as farmers to be superior than results from varieties or advanced breeding lines from the national breeding program. That ‘mass selection’ is a method taught in plant breeding textbooks is a great comfort to some. Others found re-inforcement in their interpretation that local rice varieties embody local knowledge and wisdom, recognized as an important ingredient for development by the of the 8th National Economic and Social Development Plan. We continued to work with Community Rice Centres
(CRC) which have found local varieties to be more appropriate to their seed production scheme, since the area they serve grow local varieties instead of ‘improved’ varieties. Some popular varieties that are still uneven in appearance have been identified. The evaluation of genetic structure of popular local varieties (see above) begins to tell us how best the diversity might be maintained. Making available as widely as possible a simple, streamlined method for seed selection looks more promising in maintaining genetic diversity but providing ‘foundation seed’ of local varieties from rice research centers would be logistically advantageous. A study has been initiated in collaboration with the a rice research centre to assess trade-offs, if any.

To appeal to the special place that rice has in Thai society and exploit the growing recognition of the value of local rice germplasm as a national heritage, we have initiated a network for appreciating local rice varieties among different research, extension and development groups in the country with the aim to raise public awareness in the value of local rice varieties and to share research findings about them. Chiang Mai University is providing the start up fund of 200,000 baht for the first “Goodness in local thai rice varieties that we can eat, sell and explain” (this sounds a lot better in Thai!) in June 2006. Details are still being worked out, but probably include features (1) an expo of rices with special quality, (2) sharing results on understanding of local rice, (3) discussion on how to promote use and conservation. First announcement is expected to go out early January.

b. Controlling weedy rice
In order that project findings are used more effectively to control weedy rice on the national scale we have developed alliance with the Plant Protection Research and Development Office, Extension Department, local governments and national and local agricultural suppliers.

4. Workshops, meetings, training, publications and honours

a) Workshops and meetings
1) Project annual meeting involving all partners was held in Chiang Mai on July 30-31, 2005.

2) A regional symposium on “Diversity, Management, Protection and Utilization of Local Rice Germplasm” was held in Chiang Mai on August 1-2, 2005, with about 100 participants, with 26 participants from outside Thailand (China, Taiwan, Japan, Cambodia, India, Lao PDR, Vietnam, USA, UK and Australia).

3) A workshop was held at Agronomy Department, Chiang Mai University, on August 3 2005 to discuss “Partnership and Collaboration on Local Rice Germplasm in the Centre of Diversity” with project partners and colleagues from Japan, India, China and IPGRI.

4) Field workshop in Cambodia, December 19-24, 2004, involved potential trainers from Thailand and scientists from Cambodian Agricultural Research and Development Institute (CARDI), potential partners identified

5) A meeting with potential new partners from CARDI (Ouk Makara) and Lao (Phoumi Inthavong and Chay Bounphanousay) Agricultural Research Centre was held in Chiang Mai on May 9-10, 2005.

7) CMU team attended the 4th Annual Meeting of Crop Science Meso Groups, 26-27 October 2005, Rayong.

11) Six graduate students attended 3rd Graduate Seminar, Faculty of Agriculture, Chiang Mai University, 18 November 2005.

8) Researchers and students from project attended and presented their results at national (70 papers) and international (39 papers) conferences and meetings (Attachment 1).

b) Training

1) Graduate studies
   - 1 PhD completed (ML)
   - 2 M.Sc students (PO, NP) converted to PhD program
   - 2 Graduate students from the region commenced studies in association with project: one from Lao PDR (VP), one from Vietnam (DHT)

2) Short term training and transfer from overseas:
   - 1 researcher (AP1) in now being trained with CU and NYBG partners in New York on analysis of social processes and networks
   - 3 PhD students completed training in Australia: one on restoration ecology (NY), one on methods for studying rice adaptation to aerobic/anaerobic condition (NI), one in molecular studies of nutrient efficiency trait (SP)
   - 1 PhD student (NP) is now at Queensland University, to train in biochemical methods for studying acid tolerance in rice

3) Project results provided materials and case studies for a training course on “Conservation of Rice Genetic Diversity and Sustainable Rural Livelihood”. The training course was conducted in collaboration with United Nations University and the Office of Agricultural Development and Extension for Northern Region, with 60 participants, 3 from from Lao PDR, one from Vietnam and the rest from Thailand. UNISERV, Chiang Mai University, 30 March to 1 April 2005.

4) Local training
   - 1 graduate student (PO) was trained in gall midge lab of the Department of Agriculture in Bangkok.
   - Two researchers (TS2, TA) from project were trained in GIS for biodiversity conservation as part of FAO’s international training workshop on in situ conservation in Bangkok on October 29 – November 2, 2005.

c) Publications and papers (See attachment 1)

1) Papers in Thai 20
2) Papers in English 68

d) Awards and honours

3 MSc students (Suwanee Laenoi, Pennapa Jaksomsak, Amena Promin) have been awarded research scholarships from Thailand Research Fund

3 PhD students have been awarded scholarships (Burapa University Faculty Development Fund: Prateep Oupkeaw; Royal Golden Jubilee Scholarships from Thailand Research Fund: Ayut Kongpan and Ekkasit Phongphitak)

1 PhD student (Netnapha Insalud) won best paper award and 3 (Dang Huu Thang, Adirek Punyalue, Utumporn Chaiwong) best posters at the 4th Annual Meeting of Crop Science Meso Groups, 26-27 October 2005, Rayong.

PhD student (Prateep Oupkaew) won best paper award at AgBiotech Graduate Conference II, May 16-17, 2005, Chulabhorn Research Institute, Bangkok.
5. Impacts

The project’s impacts were recorded (1) directly on collaborating farmers, focus villages and their neighbours, (2) on various parts of the national system for agricultural and environmental research and development, and (3) internationally. Our students have also learned to work more closely with farmers.

i. Direct effects on collaborating farmers, the focus villages and their neighbours

In Tee Cha, our intervention coupled with farmers’ felt pressure on the land, has resulted in renewed interest in the village’s wetland rice area and experimentation with “new” rice varieties. Although only six families own wetland paddy others in the village also benefit from the more labour intensive growing of wetland rice in terms of employment. Several promising early upland rice varieties have been identified and are now evaluated by more farmers. Bue Kae, first evaluated in 2003, planted on production scale yielded 48 tang from 1 tang of seed sown, (local measure of rice yield, equivalent to about 3 t/ha) was among the highest in the village. We are discussing with farmers the possibility of more rapid expansion of some of these by obtaining extra seed from the original source. The number of farmers who are participating in additional income and food producing activities including growing maize for pigs, planting coffee, evaluating new chili varieties, etc have also increased.

Effective control of weedy rice has been documented in the focus village of Kao Sam Sib Harb (Figure 4) and in neighbouring provinces. This constituted a restoration of up to 6 t/ha of rice yield per crop in individual fields.

ii. National system for agricultural and environmental research and development

Our research outputs have had impact on the national system of agricultural and environmental research and development in 2 areas: (1) conservation of local rice germplasm, and (2) weedy rice control.

a. Conservation of local rice germplasm

Project findings contributed to increased awareness in the value of local rice germplasm and understanding towards its management and conservation. The project was instrumental for an undertaking to evaluate economic value of local rice varieties to ethnic minority groups of northern Thailand by Social Research Institute of Chiang Mai University with funding from the National Research Council of Thailand. Our findings support Community Rice Centers that wish to produce seed of local varieties instead of improved varieties.

b. Weedy rice control

The project is responsible for weedy rice being recognized as a national problem, and our contribution in biological and ecological understanding provide basis for control measures. We continue to be the main source of technical inputs for various weedy rice control initiatives:

- National meetings on weedy rice (both attended by about 200 people):
  - National Consultation to find solutions to the weedy rice problem, organized by Department of Agricultural Extension, September 19, 2005
  - Technical Symposium on Weedy Rice, organized by the Plant Protection Research and Development Office of the Department of Agriculture, Hotel Rama Gardens October 21, 2005
• Publication by Plant Protection Research and Development Office, Department of Agriculture, Ministry of Agriculture and Cooperatives of 200 copies of a volume of technical papers on weedy rice (Jamjod S. and Maneechote C. eds.), with financial support from a consortium of public offices and agricultural chemical companies.
• Publication by Plant Protection Research and Development Office, Department of Agriculture, Ministry of Agriculture and Cooperatives, a booklet “Weedy Rice” by Maneechote C. (2005) in 3 printings, with financial support from a consortium of agricultural chemical companies.
• Recognition of weedy rice problem by public seed multiplication centers.
• Research by some agricultural chemical companies (e.g. Bayer Thailand, TJC Chemical) on chemical control of weedy rice.

Note: With BASF’s herbicide resistant Clearfield Rice and transgenic rice: our findings so far would recommend (letter to relevant regulatory offices in preparation) that before they are introduced into open field test there must be exhaustive evaluation of
  (1) their possible interbreeding with locally grown rice, weedy rice and wild rice;
  (2) population ecology of the hybrids in cultivated rice field and natural habitats including abandoned rice fields.

iii. International interest
United Nations University funded a pilot training on biodiversity and livelihoods at Chiang Mai University, attended by local rice workers and 3 from Laos plus 1 from Vietnam.
PI (BR) was invited by the Science Council of the CGIAR to review the Upland Rice Program of the International Rice Research Institute.

List of figures
1. Seed flow among farmers and seed management at Mae Moot village (rice variety: gall midge resistant Moey Nong)
2. Roadmap
3. Gall midge responses in % damaged tillers or silver shoots (A) and grain yield (B) of 7 Moey Nong accessions ( ) at 3 locations in comparison with improved varieties SPT1 ( ) and RD6 ( ); and pure-lined, single genotype Moey Nong 62 M ( ), with error bar for each location. Grain yield is inversely related with % silver shoots (Mae Moot, r = -0.84; Na Ruen, r = -0.75; Mae Mink, r = -0.89; 3 sites combined, r = -0.83)
4. Changes in weedy rice infestation in individual fields over time, Kao Sam Sib Harb village, Kanchanaburi.

Attachments
1. Figures
2. List of publications
3. List of Biodiversity and Livelihoods training PowerPoints
4. Posters
Farmer’s field, identified by number, size of circle indicates length of time the seed lot has been grown: smallest 1 year, biggest 38 years, with colour coding for seed selection method: (solid arrows point to seed sources).

- Select panicles from harvested sheaves
- Select panicles in the field
- Select small area, bulk harvest
- No data
- Dead ancestor
- No selection

Figure 1. Seed flow among farmers and seed management at Mae Moot village (rice variety: gall midge resistant Moey Nong)
AGRODIVERSITY FOR IN SITU CONSERVATION OF LOCAL RICE GERMPLASM IN AND NEAR ITS CENTER OF DIVERSITY

Figure 2. Roadmap
The process is iterative, but continuation of research in specific areas has to be weighed against other activities
Figure 3. Gall midge responses in % damaged tillers or silver shoots (A) and grain yield (B) of 7 Moey Nong accessions ( ) at 3 locations in comparison with improved varieties SPT1 ( ) and RD6 ( ); and pure-lined, single genotype Moey Nong 62 M ( ), with error bar for each location. Grain yield is inversely related with % silver shoots (Mae Moot, $r = -0.84$; Na Ruen, $r = -0.75$; Mae Mink, $r = -0.89$; 3 sites combined, $r = -0.83$)
Figure 4. Changes in weedy rice infestation in individual fields over time, Kao Sam Sib Harb village, Kanchanaburi.
POSTERS

1. Characterization of wild rice populations in the 3 regions of Thailand  Adirek Punyalue, Benjavan Rerkasem and Sansanee Jamjod
2. Farmers’ seed selection and improvement for cooking quality in local Moei Nong populations  Utumporn Chaiwong, Sansanee Jamjod, Kanok Rerkasem and Benjavan Rerkasem
3. Seed turnover and germplasm exchange of local rice in three villages of Northern Thailand Anothai Sirabanchongkran, Kevin Coffey, Utumporn Chaiwong, Warapong Boonma, Narit Yimym, Miguel Pinedo-Vasquez, Christine Padoch and Kanok Rerkasem
4. Grain iron in Thai rice Saicome pintasen, Pennapa Jaksomsak, Chorpet Sanchai, Sansanee Jamjod and Benjavan Rerkasem
5. Social Network and Distribution of Muey Nawng Rice in Mae Chaem Valley of Chiangmai Province Pojjanee Supamongkol, Ariya Phaokrueng, Benjavan Rerkasem and Kanok Rerkasem
6. Collaborative demonstration initiatives to control gall midge in heavy infested area Therdak Anakad, Nikon Tipauksorn, Sansanee Jamjod, Benjavan Rerkasem and Kanok Rerkasem
7. Characterization of rice gall midge (Orseolia oryzae Wood-Mason) populations in Northern Thailand Rattiya Charapok, Jiraporn Tayutivultikul, Sansanee Jamjod and Weerathap Pongprasert
8. Genetic Diversity within Farmer’s Seedlots of Supanburi 1 Rice. Ronnachit Jindalouang, Chanya Maneechote, Benjavan Rerkasem and Sansanee Jamjod
9. Farmers’ approaches to the development of highland paddy Warapong Boonma, Anothai Sirabanchongkran, Narit Yimym and Kanok Rerkasem
10. Interspecific hybridization between cultivated rice (Oryza sativa L.) and wild relative (O. rufipogon Griff.) Theerasak Sinthukhiew, Sansanee Jamjod, Benjavan Rerkasem
12. Responses to phosphorus in waterlogged and non-waterlogged soil condition of Thai rice genotypes Suwannee Laenoi, Sansanee Jamjod and Benjavan Rerkasem
13. Local Rice Database Tinnakorn Srivichai, Sansanee Jamjod, Benjavan Rerkasem
15. Fallow regeneration and soil fertility restoration for upland rice production in shifting cultivation of Northern Thailand Narit Yimym, Benjavan Rerkasem and Kanok Rerkasem
16. Genetic diversity of weedy rice populations found in Pathumtani 1 and Phoethong rice fields Anupong Wongtamee, Chanya Maneechote and Sansanee Jamjod
17. Yield and yield component of F1 hybrids between crop x wild rice and crop x weedy rice Napat Somkual, Sansanee Jamjod and Benjavan Rerkasem
18. Weedy rice contamination in farmer’s seed after application of clean seed and topping off weedy rice panicle methods Panomwan Boonchuay, Chanya Maneechote, Benjavan Rerkasem, and Sansanee Jamjod
IN THAI (With English Abstract)


IN ENGLISH


43. Rerkasem B. 2005. Traits in the context of cropping systems: introduction to variation in characteristics for adaptation and usage. Presented at the international symposium on Diversity, Management, Protection and Utilization of Local Rice


International Workshop on ‘Shifting Agriculture, Environmental Conservation and Sustainable Livelihoods of Marginal Mountain Societies’, October 6-10, 2005, National Institute of Rural Development, North-Eastern Regional Centre, Guwahati, India


BIODIVERSITY AND LIVELIHOODS TRAINING POWERPOINTS

1. Diversity of wild rice population in natural habitat, by Adirek Punyalue
2. Lao rice biodiversity, by Viengphone Bounphanousay
3. Biodiversity and sustainable rural livelihood, by Kanok Rerkasem
4. Biodiversity in rotational shifting cultivation of Tee Cha village, by Narit Yimyam
5. Conservation and utilization of Thailand’s native rice germplasm, by Benjavan Rerkasem
6. Genetic diversity of local rice varieties, by Saikaew Meesin
7. Morphological and physiological characteristics of local rice varieties from the highlands, by Pojjane Supamongkol
8. Local Rice Cultivation in Deepwater Rice Areas of Thailand, by Wilailak Sommut
9. Crop diversity, by Christine Padoch
10. Crop genetic diversity, by Sansanee Jamjod
11. How to measure diversity, by Kevin Coffey
12. Economics’ Loss from Weedy Rice Invasion in Kanchanaburi Province, by Ariya Phaokrueng
13. Participatory research with expert farmers to control weedy rice, by Chanya Maneechote
14. When hybrid progeny of cultivated and wild rice becomes a noxious weed, by Chanya Maneechote
15. Expert farmers, by Kanok Rerkasem
16. How can network analysis increase our understanding of agrodiversity?, by Kevin Coffey
17. Genetic diversity in farmer’s seed of Supanburi 1, a high yielding variety rice, by Ronnachit Jindaluang
18. Naturally occurring gene flow between wild and cultivated rice, by Sunisa Niruntrayakul
19. Interspecific Hybridization between cultivated rice (Oryza sativa L.) and wild Rice (O. rufipogon Griff.), by Teerasak Sinthukiew
20. How to study genetic diversity directly, by Tonapha Pusadee
21. Working with expert farmers, by Warapong Boonma