Report

Plant Breeding and related Biotechnology Capacity

Lao People's Democratic Republic

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Acronyms

ACIAR	Australian Centre for International Agricultural Research
ARC	Agricultural Research Center
DED	German Development Service
DNA	Deoxyribonucleic Acid
HHRC	Haddokeo Horticulture Research Center
FAO	Food and Agriculture Organization of the United Nations
FTE	Full Time Equivalent
FNPP	FAO-Netherlands Partnership Programme
GDP	Gross Domestic Product
IRRI	International Rice Research Institute
PCR	Polymerase Chain Reaction
PGRFA	Plant genetic resources for food and agriculture
PNG	Phonngam Rice Variety
PRES	Phonngam Rice Experiment Station
LRC	Livestock Research Center
Lao PDR	The Lao People's Democratic Republic
NAFRI	National Agriculture and Forestry Research Institute
NEM	New Economic Mechanism
NRRP	National Rice Research Program
MAF	Ministry of Agriculture and Forestry
MSG	Monosodium glutamate
RIL	Recombinant inbred lines
SDC	Swiss Agency for Development and Cooperation
SSD	Single Seed Descent
STEA	Sciences Technology and Environment Agency
TDK	Tadokkham Rice Variety
TRSS	Thasano Research and Seed Multiplication Station
TSN	Thasano Rice Variety

1. Introduction

Lao People's Democratic Republic (Lao PDR) is a landlocked country located in Southeast Asia, bordered by China and Burma to the North, Cambodia to the South, Vietnam to the East, and Thailand to the West. The total land area is 236 800 km^2 and nearly 70% of the total land area is occupied by mountains and forests. The total population is 5,800,0000 inhabitants, consisting of three main ethnics: Laosung, Laotheung, and Laoloum. More than 85% of total population is engaged in agriculture and live in the rural area.

Lao PDR has tropical and sub tropical climates distinctly divided into wet and dry seasons. The average annual rainfall is 1 400 mm in the Northern areas and 1 950 mm in the South. It is over 3 000 mm in the Champasack (Boliven plateau) and the Bolikhamsay provinces. Agriculture is one of the most important economic sectors of Lao PDR. Rice is the most important staple food of Laos' people and its cultivation practice is done under irrigated and rainfed lowland, and upland conditions. In 2004, 78% of the production came from lowland area planted during the wet season; 14% from the lowland area planted in the dry season and 8% from the upland. The upland system is more important in the Northern part of the country. The largest wet season lowland area is planted in the Central part of the country.

Agriculture in Laos has played an important role in helping rehabilitating and stabilizing the national economy. It was achieved through production increase. Lao PDR is one of the countries with a large proportion of land located between 14° and 22° latitude North and 100° and 108° longitude East. It stretches more than 1 700 km from North to South. The topography is largely mountainous, with elevations between 800-1 500 m. The Central and the South regions of the country consist of flat to gently undulating lowland, alluvial plains, at an elevation of 100-300 m. A mountainous border with China and Vietnam bound most of the Northern part of the country.

Environmental Conditions for Agriculture

The variability in rainfall, temperature, and soil types makes it extremely difficult to farm effectively and to produce optimal and high quality yields. The monsoon season brings severe rains and last from September to October. The wet months vary according to the location from May to September and the rainfall varies with altitude. Annual rainfall distribution varies across the Northern, Central and Southern agricultural regions of Laos. Provinces in the Northern region generally receive less rainfall than the Central and Southern regions with small variations across provinces. Temperatures are as low as 13°C at high altitudes in the coldest period of the wet season and as high as 35°C in the hottest period, between March and May, of the dry season. In the wet-season temperatures are relatively stable and within the range of 20 to 30°C. The crops are grown in different agro-ecosystems ranging from rainfed upland to rainfed lowland.

In general, the annual upland cropping consists of rotation systems of food crop such as cassava, maize, soybean and intensive vegetable farming systems, which usually coincide with steep slopes. The land under annual upland systems is very prone to erosion because of minimum soil protection by upland crop.

Rice is grown throughout the country under diverse climatic conditions; it is difficult to define the most suitable for its development. Rice is grown under rainfed and irrigated lowland, and rainfed upland conditions throughout the whole country. During the dry season lowland rice maybe fully irrigated or supplementary irrigated. Upland rice is grown in unbundled fields and water comes from rainfall. Terraces for paddy cultivation on mountainside may be seen in the Northern region in Laos.

Apart from rice cultivation, vegetables are also important food crops. In general, farmers grow them in their home gardens. These vegetables are the main sources of nutrients for the rural farmers. They cultivated many kinds of cash crop such as cassava, vegetables, corn, and tuber crops in upland areas in the wet and dry seasons. The land under vegetables cultivation is relatively small and often farmers use their paddy fields for vegetables cultivation during dry season; during the wet season it is limited due to high rainfall. At present, the emerging smallholders (small-scale contract farmers) and concession based commercial farming systems (contract and land allocation for large farms) are influencing changes in the subsistence agriculture system in some areas. In general, farmers are still nurturing their traditional varieties because of their valuable consumers' characteristics, better adaptation to different farming conditions, low input requirement and resistance to pests and diseases.

The most important local vegetables for food security are: Chinese mustard, pakchoi, yard long bean, cucumber, eggplant, tomato and chilies. They include crop varieties selected by farmers which have evolved in farmed fields known as "Farmer's Vegetables" and those varieties that are primitive, mostly non-cultivated and have adapted to different local environmental conditions are known as "landraces".

Typically grown on sloping fields and associated with 'slash-and-burn' systems, cassava, vegetables, corn and tuber crops cultivation are mostly found in dry season in upland areas. Wet season vegetables cultivation is limited mainly due to high rainfall, resource limitations, and limited work force. However, the land under vegetables cultivation is relatively small.

Economy Based on Agricultural Products

The country is, in comparison to many other countries, still relatively rich in natural vegetation. The biodiversity is tremendous where the natural habitat has been undisturbed. Agriculture is the principal economic sector in Lao PDR accounting for about 52% of total Gross Domestic Product (GDP) and employing 80% of the labor force. 60.5% of average household production is from agriculture. In the poor rural areas with no access to road and electricity, 83% of total income comes from agriculture. The predominantly agricultural nature of the economy means that any growth must be based on productivity gain in the rural sector. Accordingly, the government of Laos has sought to improve the productivity of the agricultural sector through a range of initiatives including the market-oriented New Economic Mechanism (NEM). Plant genetic resources for food and agriculture (PGRFA) have contributed significantly to economic development during the last decade. There are many crops that can be introduced in the market for economic advantages.

In reality, the agriculture based on annual cropping system has been carried mainly by family management and has been producing food and income for the families. There are a few farmers managing large areas but the majority is small farmers that rely on seasonable crops for living.

Among the agricultural sub-sectors, rice production is considered as the single most important activity in Lao PDR economy. In order to meet the requirements of the national economy the agricultural sector is expected to: contribute to an ample supply of products to consumers, utilize efficiently the human and natural resources, expand the local market, and be stable.

Part of the success of the agriculture in the country is because of the contribution of the plant breeding programmes of the Agricultural Research Center (ARC) in Laos. During the past decade the crop improvement programmes evolved by adapting new breeding methods to the regular programme activities and by introducing materials from other Southeastern Asian countries. The offer of varieties has been expanded with the release of new varieties.

However, the numbers of improved varieties are still very limited and they are not available for all important crops in Lao PDR. There is an increasing demand for new varieties for different crops. The challenge Lao PDR breeders are facing today is to improve rice grain quality, mainly cooking and eating quality (softness and aroma). The country has a large number of glutinous rice cultivars with different fragrances. The distribution of different rice cultivars across Lao PDR is related to the distribution of ethnic communities.

As such, Lao PDR is giving high priority to the national rice improvement programme. There have been efforts to develop varieties for specific agro-ecosystems. The contribution of the breeding programme to the national economy has been significant. Recognizing that rice is the most important crop for Lao PDR, this report discusses how the plant breeding programme at ARC under the National Agriculture and Forestry Research Institute (NAFRI) has contributed to the reduction of poverty in the country.

At present, Lao PDR government, including the National Rice Research Program (NRRP) and ARC, under NAFRI, understands the major importance of the benefits produced by the rice crop regarding profitability. However, this report also calls the attention towards other crops farmed by the local small farmers.

In Lao PDR, vegetables are grown on about 31 000 ha, making up about 3.9 percent of the total cropped area. The Ministry of Agriculture and Forestry (MAF) estimates that 236 000 tons of vegetables were produced in 1999 and 636 000 tons in 2000. A wide range of vegetables are grown and species differ between agro-ecological zones and between wet and dry seasons. Common vegetables grown and consumed include: chili, coriander, leaf onion, yard long bean, eggplant, cucumber, tomato, water spinach, cabbage, and pumpkin. “Wild” vegetables also make up a significant proportion of the vegetable intake of many rural people.

Other important crops and fruits include: maize, cassava, taro, sesame, sweet potato, mung bean, soybean, peanut, tobacco, cotton, coffee, tea, sugar cane, mango, citrus, sweet tamarind, watermelon, peaches, bananas, pineapple, durian, and jack fruit.

Data on the economic value of non-rice indigenous crop varieties are not available for Laos. However, they have been grown for food and some of them have been grown for income generation. These crops play an important role as a supplementary food to rice or in other words food security and hunger relief, mainly during the period of rice shortage.

Demand for food in Lao PDR is increasing due to the annual population growth. Recently there has been a trend towards quality food and food diversity, mainly because of the growing economy and the open market systems. With these recent economic developments and government policy for a market economy, changes are taking place in the farming sector.

Germplasm Collection and Conservation

National institutions in collaboration with international organizations have taken measures to identify and conserve the biodiversity to preserve valuable genetic material for future use. With the aid of international funding organizations, ARC under NAFRI has initiated several biodiversity programmes for several crops including rice. For some crops there were special biodiversity projects such as the “Rice biodiversity project for rice germplasm collection” (ARC, NAFRI) funded by the Lao-IRRI project. Another example is the “Agro-biodiversity project for vegetables” (HRC, NAFRI) funded by the German Development Service (DED). These two projects collected useful information on diversity of plant genetic resources of rice and vegetables from different accessions.

Collection expedition activities have been a joint effort between the germplasm unit at ARC, under NAFRI, and IRRI germplasm collector from the Philippines based in Lao PDR. Collection of local germplasm started in 1995 and lasted till 2000 with funds from the Swiss Agency for Development and Cooperation (SDC) through the Lao-IRRI project. The programme has collected more than 13 193 samples of traditional cultivars from all provinces in Lao PDR. Recognizing the diversity and importance of the traditional rice varieties in the country a number of rice germplasm collecting missions were undertaken in Lao PDR.

Therefore, the systemic collections were part of a project to conserve the biodiversity of the rice gene pool. These varieties are been evaluated based on the main traits described in descriptors for rice. The collected accessions are preserved in ARC cold room in Vientiane Municipality. Many of the collected varieties have been used directly in various levels of testing and some have been used as donors or recipient for specific traits to develop new rice varieties.

Currently the information on how the collected accessions have been used by the breeding programmes is available in the existing crop breeding programmes of ARC. The rice accessions are evaluated for aromatic, glutinous and non-glutinous characteristics, and physiological traits such as biotic and abiotic stresses. This material has been used as donor parents in many crossing programmes. Utilization of rice genetic resources in the improvement programme can be considered satisfactory.

As mentioned, vegetables are another important group of crops for food security in Lao PDR. The Laotians consume mostly the local farm grown vegetables. There is a wide range of local traditional vegetables that are grown in upland conditions in dry season. The demand for vegetables is higher during wet season than the dry season. The majority of the vegetables was collected by the agro-biodiversity project at Haddokeo Horticulture Research Center (HHRC), which identified a small number of useful genetic resources. At present, these vegetables have been introduced to farmers. They are from families of *Gramineae* (lemon grass), *Amaranteceae* (wild amaranth) and *Solanaceae* (wild eggplant).

The vegetable seedbank was established at HHRC in 2002 with the assistance from DED. The genetic conservation and utilization project for vegetables of HHRC has collected and conserved seeds from all the available indigenous vegetable varieties under medium-term storage. The collections also include those of landrace materials that are contributing to food security. The project also aimed at developing research programmes to identify most suitable vegetables for different regions.

Up to date, more than 2 140 accessions are conserved in the *ex situ* collection. Conservation facilities are equipped with two air conditioning units (one back-up), four fridges, and equipment for seed drying, processing and packing, computers and glasshouse space. Seed accessions from 13 vegetables species are stored in these seed banks and the number of accessions varies from 15 to 320 for different vegetables species. More than 200 accessions are available from legumes, chili, and mustard.

ARC maintains field genebanks for maize, cassava, sweet potato, cotton and sugarcane. A total of 280 accessions, namely 94 maize (*Zea mays*), 99 cassava (*Manihot esculenta*)*, 27* sweet potato (*Ipomea batatas*), 36 sugarcane (*Saccharum officinarum*), and 21 cotton (*Gossypium* spp) are conserved in the field genebank at ARC in Vientiane. The institute maintains this genetic material by propagation of seeds or clones every year.

Field genebanks for pasture and fodder grasses is located at Livestock Research Centre (LRC) in Naxaythong district. Evaluation and seed production of *Brachiaria* spp and

S*tylosanthes* spp are carried out in these field genebanks. In addition there is a multiplication programme for cassava at LRC.

2. Description and interpretation of the data from each organization

The objective of this survey is to provide decision makers with means to strengthen national programme capacity to respond to needs and priorities on the sustainable use of plant genetic resources.

This survey focuses on plant breeding and associated biotechnology activities in Lao PDR. The methodology used to gather the information was a questionnaire provided by FAO. The work was carried out in two Research Stations and three Research Centers, which have plant breeding and associated biotechnology activities, namely:

- Phongnam Rice Experiment Station (PNGS) in Champasak province is the central part of Lao PDR;
- Thasano Research and Seed Multiplication Station (TSNS) in Savanaket province is the southern part of the country;
- Agriculture Research Centre (ARC) in Vientiane capital;
- Haddokeo Horticulture Research Centre (HHRC) in Vientiane capital;
- Livestock Research Centre (LRC) in Vientiane capital.

These five organizations represent the public research sector institutions involved in plant breeding and associated biotechnology. There is no private sector breeding programme in Lao PDR. In the sequence we present the analysis of the results of the survey carried out in each of these five institutions.

Phonngam Rice Experiment Station (PRES)

The Phonngam Rice Experiment Station was established in 1985 and located in the Champasak province. This station plays an important role in the evaluation of segregating populations (F_3 to F_5) developed by the rice improvement programme of ARC and introduced from neighboring countries. After the selection, the most suitable materials to the objectives of the programme are distributed to farmers in the province.

The main mandate of the Station is to multiply and distribute rice seeds in the whole province. The Station started the rice breeding activities in 1995 and at the time had only one scientist with BSc degree and background in plant breeding. However, there have been staff movements and in 2007 there are two breeders (one BSc and one MSc).

The current financial support to the research station work is 54 000 000 kips of which 35 000000 kips go to plant breeding (in September 2007 the exchange rate was around 1US$ to 9950 kips). Some varieties have been developed in the station such as: PGN1, PGN2, PGN3, PGN5, and PGN6. The most limiting factor to strengthen the local capacity to carry out breeding programmes is the very limited availability of financial resources.

Thasano Research and Seed Multiplication Station (TRSS)

The Thasano Research and Seed Multiplication Station is the main station in the Central region of Lao PDR. It was established in 1998 and is located in the Savannakhet province. Similarly to PRES this station plays an important role in the evaluation of segregating populations (F_3 to F_5) developed by the rice improvement programme of ARC and introduced from neighboring countries. Selection is applied to these materials and seeds of the improved lines are distributed to farmers in the province.

Currently in this Station there is one breeder with PhD. The current total research budget for the TRSS is of 30 000 000 kips of which 20 000 000 kips are for plant breeding activities. There have been varieties developed by the station: TSN1, TSN2, TSN3, and TSN4. The most limiting factor to strengthen the local capacity to carry out breeding programmes is the inadequate number of plant breeders.

Agriculture Research Centre (ARC)

ARC was established in 1986 and is located at Saithany District of Vientiane capital. It is the principal research center under NAFRI. In the past decades ARC has mainly focused on rice research. ARC has also provided support to the regional research stations such as the TRSS in Savannakhet (rainfed and irrigated lowland rice), PRES in Champasack province (rainfed and irrigated lowland rice), Houay khot Upland Research station in Luang Prabang province (national center for upland rice research), and Agricultural Research in Northern region at LuangNamtha province. The last two research stations are just beginning to work on plant breeding and because of that they were not surveyed.

Rice research disciplines are developed within the national rice research programme including varietal improvement, germplasm conservation, and integrated production systems. The main research activity has been to breed rice for high grain yield and good grain quality aiming at developing varieties suitable for the Laotians consumption. NAFRI recognizes the necessity to upgrade plant breeding activities at ARC. Due to NAFRI's policy besides rice, ARC is played an important role for collection of other crops including soybean, maize, and cassava, among others.

The country has a very limited capacity in the area of plant biotechnology. At ARC a biotechnology laboratory was established in 2002 and its main activity is related to tissue culture of crops such as banana.

Currently ARC has 11 plant breeders, three BSc, seven MSc and one PhD. The current total research budget is 180 000 000 kips of which 150 000 000 kips go to plant breeding. There have been varieties developed by ARC center: TDK1, TDK2, TDK3, TDK4, TDK5, TDK6, and TDK7. The most limiting factor to strengthen the local capacity to carry out breeding programmes is the inadequate number of plant breeders.

Haddokeo Horticulture Research Centre (HHRC)

There are not well structured plant breeding programmes for crops other than the ones mentioned before. The staff at HHRC have been collecting indigenous genetic resources of vegetables from farmers' field in different regions of the country and evaluating them. There are no plant breeders working in this center. The financial resources allocated to plant breeding are only for farmers' field collection and multiplication of the conserved materials.

Livestock Research Centre (LRC)

The plant breeding activities at LRC are restricted to the introduction of pasture genetic resources from other countries. There are no plant breeders working in this center and no allocation of financial resources.

3. Assessment of the National Plant Breeding and Associated Biotechnology Programmes

As part of FAO's global plant breeding and associated biotechnology assessment, Lao PDR made an effort to gather information on its capacity to be part of the group of more than 50 countries where this survey has been carried out. In the previous sections we reported on the country's agriculture situation and priority crops, as well as on the individual plant breeding capacity of the institutions. In the next sections we will report on breeding activities for different crops and present the results of a workshop carried out in the country to discuss the national assessment and to make recommendations on strategies to strengthen national capacity.

General Information on National Capacity to Use Plant Genetic Resources

There have not been any significant changes in the number of plant breeders in the last 10 years (Table 1). Currently there are 14 breeders in these five institutions and in 1995 there were 8. Similar to the number of plant breeders, the education level of the staff is very limited, in 2006 there were only 2 scientists with PhD degree. The others had MSc (8) and BSc (4). HHRC and LRC did not have any plant breeders. Regarding the number of biotechnologists, these are much lower, only 4 in 2004 (Table 2).

The current financial allocation for total research budget of ARC is the highest fund 180 000 000 kips of which 150 000 000 kips go to plant breeding. The budget for the PRES is 54 000 000 kips for total research budget of which 35 000 000 kips are for plant breeding. The lowest budget is the one of the TRSS (total budget of 30 000 000 kips with 20 000 000 kips for plant breeding). There is an additional 30 000 000 kips, which was allocated to HHRC (Table 3). Therefore, the total plant breeding and associated biotechnology budget in 2006 was 235 000 000 kips or around US$24 000.

The allocation of resources presented in table 4 indicates that rice has by far the largest allocation. However, there are some investments made in crops such as maize, roots and tubers, grain legumes and soybean. HHRC has 100 percent of its allocation to vegetables, but there are no breeding activities going on at HHRC.

So far most of the work on plant breeding has been on rice. Breeding activities for other crops are still very limited in the country. As mentioned before LRC and HHRC only have been introducing plant genetic resources from abroad. The former has introduced 72 varieties of forage.

Table 5 shows the products of the rice breeding activities been carried out and by PRES, TRSS and ARC. The three institutions released 16 rice varieties to farmers: 5 by PRES (PGN1, PGN2. PGN3, PGN5 and PGN6); 4 by TRSS (TSN1, TSN2, TSN3 and TSN4) and 7 by ARC (TDK1, TDK2, TDK3, TDK4, TDK5, TDK6 and TDK7). The table also indicates the main limiting factors to strengthen their capacity to better utilize plant genetic resources.

Rice Breeding Activities

The rice improvement program introduced some good varieties from Thailand, Vietnam and Philippines. The Tadokham (TDK) variety was released by ARC before 1997. The crosses were made as part of the IRRI-Thai project at Ubon Rice Research Center in Thailand with selections made by the plant breeders from Lao PDR. The records indicate that the crossing activities at ARC commenced in 1997. The breeding programme has developed F_1 populations and lines were selected from them. In the later stage of selection (F_2-F_5) some

improved materials were sent to other provinces for further selection. The national rice breeding programme produced good results based on the varieties released to farmers.

There were many single crosses and two-way crosses made by the programme between 1996 and 2003. The male parents for the crosses were selected based on their yield performance in replicated experiments conducted at ARC and in the rice research stations in other provinces. The selection criteria used to choose the female parents were based on glutinous endosperm type. Some of those single crosses were introduced from the Thai-breeding program. Most single crosses used in two-way crosses were derived from TDK1 as the recipient parent. Some of the single crosses were backcrossed with TDK1. TDK1 has been extensively used as a parent mainly because of its wide adaptability and superior cooking quality (aromatic). This character has been successfully expressed in the subsequent progenies. Other varieties that have been used mainly as the female parent are local varieties or improved varieties in relation to the objective. A large number of crosses were made with IRRI lines as donors to these recipient parents, with the aim of combining the high yield potential of the IRRI lines with the adaptation and quality of the local materials. Most of the early-generation (F_2-F_7) selections were done at ARC.

Other than collection and evaluation of local landraces there were not breeding activities carried out for crops other than rice. This is why the emphasis on the previous paragraph was on rice. In addition, as mentioned before rice is by far the most important crop for Lao PDR people.

At present, rice breeding work has been practiced for several years but is still not established firmly yet. The first objective for the breeding programme is to breed rice varieties characterized by their superior quality, medium or late maturing and high yielding. Rice breeding methods are the mainstay of the main self-fertilized crop. Rice is the only crop in Lao PDR with well defined breeding objectives. Farmers are adopting modern rice varieties due to their high yield potential over local landrace material. In addition to the improved varieties there are also locally improved and imported varieties of rice. In the rainfed lowland rice ecosystems of Lao PDR farmers have been cultivating traditional varieties for many years. These genetic resources are sources for farmers and breeders. These traditional varieties often have superior quality to modern varieties and they can be well adapted to local growing conditions. Varieties combining this trait with high yield potential, tolerance to diseases characteristic of intensified rice production systems, and lodging resistance are likely to be retained and use by farmers, either directly or in the form of improved varieties derived from crosses with traditional varieties. Nevertheless, development of rice varieties for different regions by the national breeding programme has progressed slowly. This is due to limited opportunity to evaluate breeding lines/varieties.

Crossing and Selection

ARC has successfully developed several segregating populations carrying traits for aromatic rice, drought and cold tolerance, seed color, and glutinous and cooking quality (softness). In the past 10-15 years, Lao PDR rice breeding programme has been heavily depended on the IRRI-Thai breeding programs. Crosses were made at IRRI or Thailand and progenies were planted in Thailand nurseries. Lao PDR breeders selected material from the segregating populations (F_3 or F_4) and further selection and testing was undertaken at ARC.

The parents used in the crossing programme are from local varieties, IRRI lines, Thai-IRRI lines, and traditional and improved Thai lines. More than 100 crosses were made in Lao PDR breeding programme. These crosses mainly derived from parental lines from Lao PDR local varieties (MakYom, Muang-Nga, TaKhet, MakHing,Ikhao, DoYuan, and KhaoKham), Lao PDR improved varieties (TDK1, TDK2, TDK3, TDK4, NTN1, and SK12), Thai varieties (RD10, RD23, RD6, NSG19, HomPooPhan, and KDML105), IRRI lines (IR43506-UBN-520-

2-1-1, IR253-100, IR68, IR36, and IR8), Vietnam lines (CR 203 and B1014), and Philippine lines (PSBRC1 and PSBRC 10). The methods used for these crosses were single and three-way cross. Usually, bulk and modified bulk selection methods are used in the F_2-F_4 generations. Pedigree breeding methods are occasionally used in F_2-F_4 generations for particular crosses. However, pedigree method is widely used for late generation selection (F_5-F_6).

Linking Rice Breeding and Biotechnology in Lao PDR

In the past, the Rockefeller Foundation (RF) provided funds to screen local rice landrace materials for drought tolerance. Out of 130 accessions screened by ARC two accessions (Chao Deng and Chao America) showed better adaptation to water stress. These varieties were included in the farmers participatory selection programme conducted by ARC in 2003-07. In recent years, the breeding programme funded by ACIAR (Australia Cooperation for International Agriculture Research) project and the RF aimed at screening for drought tolerance of rainfed lowland rice to identify and select rice drought resistance in drought prone areas in rainfed lowland conditions in Lao PDR. The previous work of ACIAR and RF projects allowed to identified and develop plants that are tolerant to drought, well-adapted and high yielding. This work needs to be continued for further development and the advanced lines need to be further tested widely in different locations in the country before their release as varieties.

The crossing programme started in 2003 in Lao PDR. Several lines were identified from the first two years and were crossed with the most popular cultivars in the region. The RF support to the Thai Department of Agriculture allowed the development of superior donors and the populations development were continued in Lao PDR. Those populations were used to develop recombinant inbred lined (RIL) by single seed descent. DNA samples from a number of donors and recipient lines were analysed at National Center for Genetic Engineering and Biotechnology, in Thailand, for polymorphism. The breeders and their assistants were trained to use the dark room facilities at ARC and they successfully made crosses during the dry season. The populations were advanced both in wet and dry seasons.

The detail programme of the population development is presented in Table 6. In total 19 F_1 hybrids were successfully made at ARC in 2003 and 2004. Those F_1 seeds were grown in pots and F_2 seeds were developed during the dry season under photoperiod room facilities. In 2004, 100-150 F_2 seeds were taken from each cross and F_3 and F_4 SSD populations were developed. In 2005, the most proven five crosses were identified based on the final selections of donors and advanced to F_5 stage. The remaining populations are used in the national breeding program and the field trials are conducting for pedigree selection. The seeds from the lines produced from the project are being stored for future marker assisted selection program in Lao PDR.

Maize Breeding Activities

In 2004, maize planting area was 67 500 ha, with total production of 203 500 tons; increased by 74% compared to year 2000. About 54.3% of growing area is in the northern part. It is grown in monocrop or with upland rice. In the middle and Southern parts maize is grown for domestic consumption; often the farmers plant the local cultivars, which are mainly waxy. In recent years, the Lao PDR Government has paid attention to maize production for animal feed by introducing hybrid variety, as result there was a substantial production increase. However, the country does not have a full maize breeding programme with improvement phases. There are only limited activities been carried out at ARC.

Maize is the nation's second most important crop after rice. It was grown throughout the country under household level to meet demand and as source household income. In Lao PDR maize cultivation practices also have been recently introduced from different countries in Southeast Asia. At the district level production targets are set every year.

Maize is grown in the dry season in Vientiane Capital and Vientiane province to meet animal feeding demands. There are two main cultivated maize one an open pollinated variety (Haddokkeo 4) and the other a hybrid from Vietnam (LVN 10). By the end of 2005 there were in ARC genebank 17 accessions of cultivated maize from Vientiane Capital and Vientiane province, 41 from Luang Prabang province and 3 from Xiengkhouang province. Today, in the cold room of ARC there are 94 local maize accessions. The scientists will use these accessions in their breeding programmes in the near future.

Soybean Breeding Activities

Soybean (*Glycine max* L) is normally planted at the family level and scattered throughout the country for domestic consumption, processed as sweets and alternate source of income. In the area near by market and\or adjacent to the neighboring countries, soybean is grown as an important source of income. At present, the total area planted to soybean is about 22 824 ha and the production is 21 000 tons. Soybean is the one supplied as raw material for animal feed processing factories. Similar to maize the breeding activities are very insipient without an operational breeding programme in place in the country.

Soybean crop is considered as one of the main cash crop after rice and maize for the national economy in Lao PDR. The culture can be found through out the country from the North to the South cultivated by small farmers. The varieties used are some "local varieties" and others introduced. This crop is considered as complementary cash crop and used for self-consumption. However, because of the high local and external demand it is becoming gradually important. It is mainly used as source of protein, but it is also used for edible oil extraction. It is important source of superior yet inexpensive protein and oil for human consumption. A by-product from oil production called soybean cake or soybean oil meal is been used as high protein animal feed ingredient.

Research on grain legumes has been emphasizing soybean since 1997-1998. There were many varieties of soybeans introduced in the country and most of them were recorded at HHRC and received further selection for dissemination to farmers. ARC started research on grain legumes in 2006 with emphasis on soybean.

At the end of 2006 there were 20 accessions maintained at ARC cold room facility, which are the accessions the scientists are conserving for future use. After collection the soybean materials are planted and evaluated for the major agronomic characters.

Cassava Breeding Activities

Cassava or tapioca (*Manihot esculenta*, Crantz) is an annual tuber crop grown widely in the tropics and sub-tropics. It can easily thrive in sandy-loam soil with low organic matter, receiving low rainfall and high temperature. It is therefore a cash crop cultivated by small-holder farmers within the existing farming systems in many countries. Cassava roots are utilized for making dry chips, pellets, native starch, modified starch, MSG (monosodium glutamate), glucose, fructose, sorbitol, sago, citric acid which are used in the food, beverage, feed, paper, textile, and plywood industries. In addition, they are used as the major raw materials for the production of bioethanol, an alternative biofuel to be blended with petroleum gasoline. In spite of all these beneficial characteristics the country does not carry yet breeding activities aiming at developing new cassava varieties.

Sweet potato Breeding Activities

Sweet potato (*Ipomoea batatas* Lam) is a common crop in Laos after rice and maize. Traditionally sweet potato is used as human food when rice is not sufficient, although at present it is commonly used as feed for farm livestock, especially pigs. The tubers have high carbohydrate content while the leaves are rich in protein, and both tubers and vines can be used as animal feed. Thus, if the leaves could be separated from the stems a considerable improvement with respect to the dietary protein and amino acid supply would be expected.

Vegetables Breeding Activities

Vegetables are important for food security in Laos. Laotians mostly consume local, farm-grown vegetables. There is a wide range of local traditional vegetables that are grown in upland conditions in dry season. The demand for vegetables is higher during the wet season than the dry season. They are also important for their nutrition value (balanced diet), both in rural and urban areas and for providing income to the female farmers who sell them in the market. In Lao PDR both cultivated and wild vegetables are used mainly grown in permanent home garden and in dry season riverbank garden.

At present Laos farmers lack access to good quality planting material and the technological inputs required to grow high quality vegetables. Lao cities currently import many vegetables, particularly during the rainy season, while most Laos people currently eat much less than the internationally recommended figure of 70 kg per capita per year. This suggests that there is a good market opportunity for vegetables if farmers are able to produce sufficient quantities at the right price.

There are several vegetable species grown in the various agro ecological conditions of Lao PDR and some are suitable for both lowland and uplands. Many are mainly grown in the dry season because of the higher incidence of pest and diseases than in the wet season. Some vegetable species have been recommended for trial and breeding activities but no systematic testing has yet been done to identify suitable species for upland conditions. Before introducing and testing vegetable species at HHRC, researcher should collect and promote to grow vegetable seeds from household and look carefully at the local agro ecological and socio-economic conditions. In general much of the seed comes from neighboring country such as Thailand. HHRC should provide valuable varieties to local vegetable producer such as cabbage, tomatoes, carrot, onion, cucumber and so on. However, most of the local vegetables were collected by the agrobiodiversity project at HHRC, which addressed this issue and identified a small number of genetic resources. The vegetables introduced at HHRC are from families such as: *Graminaceae* (lemon grass), *Amaranteceae* (wild amaranth), *Solanaceae* (wild eggplant). The seeds are collected and stored from all the available indigenous vegetable varieties in medium storage at HHRC.

Other crop breeding activities

There are no breeding programmes yet for crops other than the ones mentioned above. There have been isolated activities to evaluate, for example pigeon pea and yard long bean. Cotton is grown in areas where there is guaranteed market (from 1995 to 2004 the annual planted area decrease gradually from 9 624 to 2 420 ha).

Even though coffee is a top most export product there are no breeding activities with the crop. In 2004, the total planted area was 37 576 ha with a production of 23 100 tons and yields ranging from 400 to 800 kg/ha. The main coffee planted area is the Boliven Plateau, which is an ancient volcanic soil area covering four provinces of the Southern Lao PDR.

In recent years, NAFRI has imported a large quantity of fruits from neighboring countries. This strategy is causing losses of landraces because the cropped area of the introduced varieties is increasing and occupying space that previously belonged to the local varieties. A number of local landraces including papaya (*Carica papaya* L.), banana (*Musa sapientum* L.), mango (*Mangifera indica*), orange (*Citrus sinensis*), pine apple (*Annas comosus*), water melon (*Citrullus lanatus*) and passion fruits (*Passiflora edulis* L.) have been grown in urban areas. These indigenous fruit species have high value for the country and urgently requires collection and conservation to ensue that biodiversity in Lao PDR will not be lost.

The diversity of local fruit species has not changed significantly in the last 10 years. However, the imported fruits are becoming more popular among urban communities. This change could influence the market of local fruits and nuts in the future and may cause genetic erosion of the local genetic resources.

In recent years, new plantations have been established in Lao PDR with these crops. The genetic diversity has changed when looking at modern and farmers' varieties. High yielding varieties and popular landrace materials were developed for yield, food quality and biotic and a biotic stress conditions. Vegetables were selected from germplasm and distributed to different regions. These new materials are popular in urban commercial farms while traditional varieties are still grown in rural farms. There is limited information available on vegetable genetic resources and breeding before 2002. Between 2002 and 2006, with the financial assistance of the DED, NAFRI and HHRC scientists conducted a comprehensive survey in 14 provinces on vegetable genetic resources.

Biotechnology activities

Biotechnology is an important tool for germplasm evaluation, utilization and improvement. The recently developed technique known as the polymerase chain reaction (PCR) has been widely used in the detection of plant polymorphism, which is analyzed for individual identification and isolation of genetic makers in the developed country in Southeast Asia.

Lao PDR has initiated two biotechnology laboratories on tissue culture located at ARC and the Sciences Technology and Environment Agency (STEA), established in 1998 and 1999, respectively. They concentrate their activities on tissue culture to produce banana, potato, and some flowers.

The potential areas for these laboratories to work in association with the plant breeding programmes are:

- Tissue culture to growth pure plants from the improved varieties
- Rapid propagation to produce a large number of plants is a short period of time
- Conservation of endangered species by reproducing many plants in safe laboratory conditions, from limited original samples
- Improvement in quality by selecting strains that have particular characteristics.

Externally these institutes have been works with the Asian subcommittee on biotechnology and the Lao/China Committee on Science, Technology and Development Cooperation.

4. Conclusions and Recommendations

The main reasons for this weakness are: staff limitations, financial restrictions, poor knowledge and lack of training for staff and insufficient knowledge on plant genetic resources use. A major limitation in the utilization of plan genetic resources for crop improvement programmes is the lack of well educated and trained staff. Currently there are

only very few plant breeders and agronomists working on a few crops and relying on external projects for financial assistance to evaluate the genetic resources.

Lao PDR plant breeding activities focuses on rice because it has the high priority for the food security of the country and it has support from the Lao-IRRI, Biodiversity Project and Aciar Project. There are no structured breeding programmes for other important crops, such maize and vegetables. Research stations such as TRSS and PRES are trying to have some breeding activities by introducing F_5 and F_6 segregating populations from elsewhere for selection.

Any approach to strengthen the national plant breeding and associated biotechnology capacity must emphasize the development of human resources to counter most of the future challenges on biodiversity use and conservation. Given the magnitude of the challenges that Lao PDR faces today it has to be more resourceful and find balanced solutions for conservation while moving towards a market-oriented economy for effective engagement of economic affairs with regional and international communities.

5. Strategies to strengthen plant breeding capacity in Lao PDR

Agriculture remains one of the most important economic sectors in Lao PDR. The government's 6th Economic Development Plan from 2006 to 2010 relates very much to agricultural development, especially on food security, slash and burn shifting cultivation reduction; conservation, protection and sustainable use of the environment; biodiversity conservation; and poverty alleviation. Indeed, many aspects of the development plan are about multifunctional of agriculture. In line with the 6th Economic Development Plan we have to clearly understand the role and contribution of plant breeding to food security, environmental, and economic development.

The reduction of the slash and burn systems for rice cultivation and change to the rice terraces will significantly stabilize rice production in mountainous areas. In the Northern provinces of the Mekong River basin, the presence of rice terraces is important for food mitigation in the Central and Southern provinces of Lao PDR.

Lao PDR farmers, mainly some ethnic groups in the Northern provinces, use traditional agriculture practices characterized by mono cropping in the rainfed rice season. The use of local rice varieties with low yield for family consumption is still very popular.

The Government of Lao PDR has expressed through different policy documents that conservation and utilization of genetic diversity is highly important to improve food security, alleviate poverty, and promote rural development. In 2007 FAO, with support from the FAO-Netherlands Partnership Programme (FNPP) and in collaboration with NAFRI, carried out a plant breeding and associated biotechnology survey in the country. The results of this assessment were analyzed and presented to a group of 15 technical people representing different Laotian research institutions. The following recommendations were made by the group to the local authorities aiming at promoting utilization and conservation of plant genetic resources (PGR):

- The number and the educational level of plant breeders in Lao PDR are very limited. In order to strengthen national capacity to use PGR it is necessary to urgently develop a national strategy for short- and medium-term human capacity building. This may be attained through:
    - Developing a national strategy for short- and medium-term investments to educate scientists from the different research institutions in the country

- Promoting short training courses on specific priority subjects related to use and conservation of PGR
- Linking short-term training courses with previous breeding experience of the trainees and with hand-on opportunities
- Providing training opportunities also for technicians and farmers involved in plant breeding activities
- Using the local human capacity to train others in the country
- Giving support when scientists come back from studies to ensure the use of acquired knowledge
- Demanding from the international centers support in the area of human capacity building
- Calling the international community's attention to the needs of the country in relation to human capacity building, including the donor's community
- Looking for international loans to allow planning and investing in human and structure capacity building
- Preparing project proposals to raise funds to facilitate the implementation of the above mentioned recommendations

- The utilization of PGR is key for food security and poverty alleviation in developing countries. Allocation of resources to plant breeding activities is essential for breeders to carry out varietal development programmes. In general, developing countries prioritize plant genetic diversity conservation and utilization however they limit the resources allocated to activities related to PGR, this is also true for Lao PDR. Therefore, the group recommended that efforts should be made to increase allocation of resources to utilization of PGR and suggested the following:
  - Improve the current national PGR policy emphasizing utilization of local genetic diversity and consequently strengthening the allocation of resources to use of PGR
  - Increase the share of the government's budget to organizations that are working with PGR conservation and utilization
  - Dialogue with international donors' agencies interested in PGR to request including and prioritizing Lao PDR in their portfolio of resources allocation
  - Prepare and submit to international donors project proposals to raise funds for PGR utilization in the country

- Currently the country has been collecting and introducing a limited number of plant genetic materials from different crops to use them as potential new varieties or as parental sources for the local breeding programmes. To promote crop diversification and intensification there is need to revise the breeding strategies focusing on increasing the number of materials available to breeders as well as centering attention to local demands. This may be achieved through:
  - Supporting collections of PGR in regions known to have high genetic diversity for the chosen crop or crops
  - Establishing a strategy to regularly introduce breeding lines from international centers and neighboring countries

  - Participating in the existing PGR networks coordinated by the international centers
  - Requesting PGR of the annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) to countries members of the ITPGRFA

- One of the first steps to use PGR is to have knowledge on their characteristics and potential. Thus to promote utilization there is need to significantly increase the number of local materials characterized. Some alternatives to accomplish this are:
  - Revise the breeding programmes activities to ensure that resources are allocated to this activity
  - Collect information on a minimal number of characteristics on the priority crop or crops to start with and increase the number as additional resources are made available
  - Request international centers to send information on Lao PDR material that have already been characterized elsewhere; this may be particularly true for rice
  - Prepare project proposals to raise funds to facilitate the implementation of the above mentioned recommendation

- Improved varieties need to meet producers and consumers' demands for quality and other important traits. To speed up plant breeding programmes it is important to prioritize utilization and improvement of local varieties. In order to attain this the following options are proposed:
  - Revise the breeding programmes activities to ensure that introductions of PGR and crosses are made emphasizing this requirement
  - Increase farmers' participation in the breeding programmes
  - Request intellectual property rights (IPRs) on the developed products

- Lao PDR is a country that has a rich plant genetic diversity. Only three Research Centers (ARC, TRSS, and HHRC) have some facilities and equipment for short- and medium-term conservation. In addition, the country does not have a long-term storage facility to conserve PGR from all crops, including wild relatives. This lack of investments related to conservation jeopardizes the future of the country's food security, therefore it is recommended to provide facilities for long-term conservation at national level. The choices for meeting this demand are:
  - Allocate resources for the required equipment and facilities
  - Consult with the Nordic Genebank staff to introduce their concept of PGR conservation, which is simple and inexpensive
  - Prepare project proposals to raise funds to facilitate the implementation of the above mentioned recommendation

- Biotechnology tools can only contribute to food production through enhancing plant breeding activities, therefore it is mandatory to have strong plant breeding programmes in place and clear goals to be achieved through the application of biotechnologies before start considering the different tools. The role biotechnology can play will depend upon the crop, thus it is recommended to have an in-depth analysis before deciding on investments in this area. Some alternatives to achieve this are:

- Ensure that any investment made in biotechnology is done in the context of an existing breeding programme and targeting at solving specific problems
- Consult other countries in the region to learn about their experience in this area and transfer them to Lao PDR as appropriated
- Request international support to clearly understand the role biotechnology can play to enhance the local breeding programmes
- Up-grade the facilities of the current biotechnology laboratories, which are only doing tissue culture work for multiplication, to have them supporting breeding activities

- There is a general feeling among policy makers that variety development is a simple task and everybody can do it. Farmers have been doing it successfully for ages without breeders' intervention. Therefore, there is no value for the activity or the breeders, which is reflected in the poor allocation of resources to the activity. Thus, it is recommended that awareness should be raised, mainly among policy-makers, to educate them on the relevant role of the plant breeders. To meet this objective the following is suggested:
  - Preparing and distributing to policy makers educational materials in layman language with information on the plant breeding activities
  - Preparing and distributing to policy makers educational materials in layman language with information on how plant breeding contributes to food security, rural development and income generation
  - Organizing short events with policy makers explaining what plant breeding is and how varieties are developed
  - Organizing field days to show how difficult is the job and the work conditions of plant breeders

6. Tables

Table 1. Number and educational level of scientists involved in plant breeding activity in each institution in the period 1995 to 2004.

Institution	Education level	1995	2000	2004
Phonngam Rice Experiment Station	B.Sc	**1**	**1**	**1**
	M.Sc	0	1	1
	Ph.D	0	0	0
Thasano Research and Seed Multiplication Station	B.Sc	0	**1**	0
	M.Sc	0	0	0
	Ph.D	0	**1**	**1**
Agricultural Research Center	B.Sc	**2**	**2**	**3**
	M.Sc	**5**	**6**	**7**
	Ph.D	0	0	0
Haddokeo Horticulture Research Center	B.Sc	0	0	0
	M.Sc	0	0	0
	Ph.D	0	0	1
Livestock Research Center	B.Sc	0	0	0
	M.Sc	0	0	0
	Ph.D	0	0	0
Total		**8**	**12**	**14**

Table 2. Number and educational level of biotechnologists involved in plant breeding activities

Institution	**Education level**	**1995**	**2000**	**2004**
Agricultural Research Center	BSc	0	0	3
	MSc	0	0	1
	PhD	0	0	0

Table 3. Research budgets for Laotian institutes engaging in agricultural research between 1995 and 2007 expressed in million kips (1US$ = 9950 kips).

Institution	Financial resources	1995	2000	2006
Phonngam Rice Experiment Station	Total research	17	30	54
	Plant breeding	10	20	35
	%	58.8	66.7	64.8
Thasano Research and Seed Multiplication Station	Total research	0	20	30
	Plant breeding	0	10	20
	%	0	50.0	66.7
Agricultural Research Center	Total research	190	210	180
	Plant breeding	130	150	150
	%	68.4	71.4	83.3
Haddokeo Horticulture Research Center	Total research	20	30	50
	Plant breeding	10	20	30
	%	50.0	66.7	60.0
Livestock Research Center	Total research	0	0	0
	Plant breeding	0	0	0
	%	0	0	0

Table 4. Considering the total organization's resource allocation (human and financial) for plant breeding activities, percentage distribution by crops and/or crop-group.

Institution	Crops	1995	2000	2007
Phonngam Rice Experiment Station	Rice	100	100	98
	Oilseeds (Soybeans)	0	0	2
Thasano Research and Seed Multiplication Station	Rice	100	100	100
Agricultural Research Center	Rice	85	80	60
	Maize	5	10	20
	Fiber crops(cotton)	3	3	0
	Roots and Tubers	2	2	10
	Other legume	5	5	10
Haddokeo Horticulture Research Center	Maize	20	0	0
	Vegetable & Fruit	80	100	100
Livestock Research Center	Forage	0	0	0

Table 5. Number of approved varieties and main limiting factor per institution for 2006.

Institution	Approved Varieties[1]	Main limiting factor
Phonngam Rice Experiment Station	PNG 1,2,3,5,6	Lack of financial resources
Thasano Research and Seed Multiplication Station	TSN 1,2,3,4	Inadequate number of breeders
Agricultural Research Center	TDK 1,2,3,4,5,6,7	Inadequate number of breeders
Haddokeo Horticulture Research Cente	0	N/A
Livestock Research Center	0	N/A

[1] PNG = Phongnam Rice Variety; TSN = Thasano Rice Variety; TDK = Tadokkham Rice Variety

Table 6. Achievement of Rice Breeding Program at Agricultural Research Center

Year	Local varieties (Recipient/donor)	Improved varieties (Recipient/donor	Lao improved varieties
Before 1975	Do-Nang-Naun, sanpatong	IR20 and C4-63.	
During 1975-1990	DoNouan, MakYom, DengHom& Do Deng	IR8,IR36, IR2823-103, B1014,TR24,IR42,RD8, IR253-100, IR848-120, IR789-98, RD10, CR203& KDMl 105	Salakham1-7-2, and Salakham 2-69.
From1991up to 2000	MuanNga,Dok-Mai, Dok-Tiow, Makhing, Takhiat, Nang-Nuan,	RD6,Hanyi71,RD23 and NSG 19.	TDK1,TDK2, TDK3, TDK4, PNG1, PNG2, TSN1
From 2000up to 2007	Kainoy Leuang Homphouphan Homsagniem Homkhenchanh Meuang Nga Phea Kao Hang YI 71 EtiaKondam Homdamdouane	B6144F- MR – 6-0-0 IR 71525-19-1-1 IR 55423-01 IR 62443-2B-7-2-1-2 IR 62445-2B-12-12	TDK5,TDK6,TDK7, TDK8,TDK9,TDK10 TSN2,TSN3,TSN4, TSN5,TSN6,TSN7, TSN8,PNG3,PNG4 , PNG5,PNG6.

Remark: Thadokkham (TDK) The location of the main research center responsible for coordinating the activity of the National rice research program.

Phonngam (PNG) The name of the Southermost lowland rice research and seed multiplication center in Pakse District of Champassack.

Thasano (TSN) the name of the lowland rice research and seed multiplication center in Savannakhet province.