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Sustainable Agricultural System in Asia

Strengthening Human Resource Development Program in Universities

Edited by

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Proceedings

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The Nagoya University Graduate School of Bioagricultural Sciences offers a five-year curriculum, divided into two periods: a two-year master's program (first period) and a three-year Ph.D. program (second period). Incoming graduate students can join one of four graduate programs: Biosphere Resources Science, Biological Mechanisms and Functions, Applied Molecular Biosciences and Biosignal Regulation.

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The Nagoya University Bioscience Biotechnology Center (NUBBC) is mandated to study at biochemical and molecular biological levels the biological function in higher plants and animals. Bioresource of rice mutant lines and freshwater fish stocks are another important subjects. Further, biotechnological approach is used for the application of fundamental research of bioscience. NUBBC cooperates with the Graduate School of Bioagricultural Sciences and the Graduate School of Sciences in research and educational activities, especially in Division of Development Signaling Biology and Division of Bioscience under a joint program.

PROCEEDINGS

These proceedings contain refereed papers presented during the Satellite Forum 2002 held at Nagoya University, Japan.

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Foreword

The development of a sustainable society is one of the major concerns in the 21st century. With this is the fact that current concerns on food production and its support systems have to be addressed so that agriculture would continually be capable of supporting the food requirements of the ever-increasing global population. Agricultural science, which is the pivotal gear of food production, has to be re-examined as to its strength and weaknesses in light of the present demand for more food and sources of human energy. Furthermore, it is essential to review the role of universities in the development and strengthening of human resources towards the achievement of the goals for sustainable agriculture development, as well as in promoting international cooperation to face the challenges of globalization.

It is on the aforementioned premise that the Nagoya University system Graduate School of Bioagricultural Sciences held a Satellite Forum on Sustainable Agriculture Systems in Asia: Strengthening of Human Development Program in Universities on 20-21 June 2002 at Nagoya University, Japan. The forum is the first in a series of forums organized under the general focal theme of "The University-Architect of the 21st Century." It focused on the present state of agricultural development that should serve as basis for activating, strengthening and expanding existing academic programs.

These proceedings include papers presented, highlights of discussions and recommendations put forward by the forum participants and resource persons. It is hoped that these proceedings will stimulate further discussions and result to more collaborative activities among institutions and individuals concerned with sustainable agriculture development in Asia.

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Message from the Editors

The Satellite Forum on Sustainable Agriculture System in Asia: Strengthening of Human Development Program in Universities was held to discuss sustainable agricultural production systems and biotechnology in Asia with special emphases on research and resource development; and to document the contribution of the university in general, and the Nagoya University Graduate School of Bioagricultural Sciences in particular.

Approximately 180 participants from nine countries attended the Forum. Twenty resource persons presented papers on topics focusing on sustainable bioproduction systems, biotechnology for sustainable bioproduction, and international collaboration for sustainable bioproduction. The general discussion at the end of the presentations provided a venue for exchange of ideas and experiences among experts, as well as elicited suggestions and recommendations from the participants and the resource persons. It also gave the students the opportunity to express their opinions especially focusing on student development towards global standard. Poster presentations and exhibits by students also highlighted the Forum.

Aside from the papers that were critically reviewed by us, these proceedings include a summary of the highlights of discussion and recommendations of the Forum. It is with much optimism that the results of the Forum as recorded in these proceedings will serve as bases for follow-up activities that would encourage the implementation of more international collaborative activities in support of sustainable agriculture and human resource development in Asia.

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Sustainable Agricultural System in Asia: Strengthening Human Resource Development Program in Universities

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Chapter 1

Sustainable Bioproduction Systems

Cultivar Requirement for Sustainable Production of Rainfed Lowland Rice in SE Asia

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Abstract

Rice is the main staple crop in many Asian countries and contributes greatly to the national economy. In some SE Asian countries, including Thailand, Cambodia and Laos, rainfed lowland rice occupies more than 60 % of the total rice growing areas, but grain yield is low due to drought and low inputs in general. An ACIAR (the Australian Centre for International Agricultural Research) project in 1992-2005 has examined cultivar requirement for rainfed lowland rice under different conditions. The project contributed to the development of plant breeding strategies such as, identification of plant characteristics associated with drought resistance, cultivar requirement for direct seeding, development of a new breeding program in Thailand, characterization of rice growing environments and the development of low temperature tolerant cultivars. This paper describes achievements of the ACIAR project, with particular emphasis on cultivar characteristics contributing to drought resistance and cultivar requirement for direct seeding in relation to sustainable agricultural development in SE Asia.

There has been a change in the socio-economic condition of rice cultivation in the region. A general shortage of labour has resulted in a recent shift in some regions from traditional transplanting to direct seeding. Major problems of direct seeded rice are poor crop establishment and presence of weeds. Cultivars required for direct seeding have high seedling vigour, competitive ability against weeds, lodging resistance and photoperiod insensitivity.

Drought is a major problem in rainfed lowland rice. Our recent work indicates that genotypes that can maintain higher leaf water potential produce higher yield than other genotypes under late season drought conditions, which are common in the region. In order to screen large numbers, the delay in flowering in response to water stress may be used. However, grain yield of a genotype under rainfed lowland rice is strongly affected by the potential yield of the genotype and the phenology, particularly flowering time in relation to drought timing. Therefore, cultivars widely adapted to the rainfed lowland environments should have high potential yield and the appropriate flowering time as well as drought resistance.

The importance of rice in SE Asia is such that improvement in rice production through development of adapted cultivars will have a large effect on the national economy. Another important area associated with sustainable agricultural production in SE Asia is human capacity development. Agricultural scientists in the region need to be well trained to ensure that the technologies they will develop are a component of sustainable agricultural production. The ACIAR project contributed to the training, particularly the postgraduate training of national scientists in Australia.

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1. Rice production in SE Asia

In many SE Asian countries agriculture contributes greatly to the national economy. For example in 1998, agriculture's share of the total labour force was around 60-80 % in Thailand, Laos and Cambodia (the three countries in the Mekong region considered most in this paper), while that of gross domestic product (GDP) was around 10 % in Thailand and 50 % in Laos and Cambodia.

Rice is the main staple crop and is the backbone of the agriculture industry in many Asian countries. Rice consumption is still high in most SE Asian countries; per-capita consumption in 1999 exceeded 150 kg in Laos and Cambodia and 100 kg in Thailand. Rice is mostly consumed in the area of production and the proportion that enters into the market is rather small.

In some SE Asian countries, including Thailand, Cambodia and Laos, rainfed lowland rice ecosystem is the most common among the different rice ecosystems, occupying more than 60 % of total rice growing areas. In this ecosystem, irrigation water is not available for rice production. However, farmers grow rice in bunded lowland fields so that standing water can be maintained during crop growth in seasons of good rainfall. Most rainfed lowland areas practice subsistence agriculture with rather low input and low productivity. The farmers have limited resources and hence, the use of fertilisers and other chemicals are generally low, limiting rice production particularly in Laos and Cambodia. Therefore, grain yield is often limited by the lack of availability of water and soil nutrients. Drought is a common problem particularly in seasons of low rainfall. More than 50 % of the total rainfed lowlands in Asia are considered to be drought-prone according to Garrity et al. (1986). In some countries such as Laos, farmers consider drought as the most important constraint for high yield in rainfed lowland rice. Currently, yield is low in rainfed lowland rice; for example, 1.3 t/ha in Cambodia, but this can be increased with development and adoption of suitable technologies, including new cultivars that are widely adapted to the rainfed lowland area.

Human population density in the rainfed lowland areas in these countries is low compared with most other countries in Asia. This general lack of labour in the Mekong region for rice production means that labour saving technology is required for rainfed lowland rice (Pandey 1997). Thus for example, direct seeding technology, which requires much less labour inputs than transplanted rice, may be more appropriate in the Mekong region than other highly populated areas in Asia. However, current cultivars are developed for transplanted rice and the development of cultivars adapted to direct seeding will help increase the yield and stabilize rice production.

The development of cultivars adapted to rainfed lowlands, particularly drought resistant cultivars and those suitable for direct seeding, is required for sustainable agricultural development in the region.

2. The ACIAR rice improvement project

The Australian Centre for International Agricultural Research (ACIAR) provides funds for international agricultural research partnerships for the benefit of developing countries and Australia. There are more than 25 partner countries and more than 40 Australian R&D providers involved in ACIAR operations. Most projects are conducted in Asia, particularly in SE Asian countries. A larger proportion of ACIAR funds are spent on bilateral projects such as the rice improvement project described below, but there is also a multilateral program, which contributes to individual international agricultural research centres.

In a bilateral project, the common mode of operation is that Australian scientists visit the partner country often, and inspect research and discuss strategies with national scientists. After the research program is set up, national scientists conduct most experiments in their own countries. The national scientists may visit Australia to attend a short-term training course. For long-term training, postgraduate scholarships are available to participating scientists in most countries.

An ACIAR project in 1992-2005 (Plant breeding strategies for rainfed lowland rice in Thailand, Laos and Cambodia) has predominantly examined cultivar requirement for rainfed lowland rice under different conditions. The project aims to develop plant- breeding strategies for rainfed lowland rice in the Mekong region. This may be achieved by identifying plant characteristics associated with drought resistance and cultivar requirement for direct seeding, examining different genotype selection methods suitable for rainfed lowlands and characterizing rice-growing environment.

Major achievements of the project are as follows: 1) Identification of environmental constraints; 2) Identification of large genotype by environment interaction for grain yield; 3) Modification of the Thai rice breeding program; 4) Identification of drought resistant characteristics; 5) Identification of characters of cultivars widely adapted to rainfed lowlands; 6) Development of direct seeding technology; and 7) Identification of mechanisms of low temperature tolerance in rice.

Early work is described in Fukai et al. (1998) whereas some of the more recent achievements are described in our recent ACIAR proceedings (Fukai and Basnayake 2001). The issues of drought resistance characteristics and cultivars adapted to direct seeding (part of 6. Development of direct seeding technology) are detailed later in the paper under separate headings while the topic of identification of mechanisms of low temperature tolerance is done in Australia, and will not be discussed. Here the remaining issues are described briefly, particularly in relation to drought problems in the Mekong region.

1) Identification of environmental constraints

The major limitation for rainfed lowland rice is drought, and we have identified two major drought patterns, i.e. early season drought and late season drought. The early season drought is common in all three countries examined. Frequent problems are transplanting failure and the use of old seedlings for transplanting and subsequent reduction in yield, as a result of no standing water at the appropriate time of transplanting. Late season drought is also common particularly in Northeast Thailand, which, on average, causes yield loss of around 10-35 % each year (Jongdee et al 1997, Khunthasuvon et al 1998).

Soil fertility is also low in the rainfed lowland areas and the use of fertilizer is rather limited. Without severe drought, rice growth and yield can respond strongly to N and sometimes P fertilizer (Khunthasuvon et al 1998, Suriya-arunroj et al 2000). Drought reduces nutrient availability to rice, and this causes further yield reduction when standing water disappears before flowering. Detailed characterization of growing environments, particularly water environments, which are variable in space and time (Wade et al. 1999), is essential for the development of efficient rice breeding programs. To assist in the characterization of rice growing environments in Laos, we have developed GIS temperature and rainfall maps.

2) Large genotype by environment interaction for yield

A large genotype by environment (G x E) interaction component of variance for yield has been found consistently in our rainfed lowland rice experiments in Thailand, Laos and Cambodia. The interaction variance component could be as much as six times greater than the genotype variance. The G x E interaction for yield is often associated with genotypic variation in flowering, as drought affects genotypes differently when they are in different phenological development stages. The large G x E interaction for yield was due mostly to large genotype by location (L) by year (Y) interaction. This is partly associated with the irregular pattern of drought development in rainfed lowlands. The involvement of large G x L x Y interaction is also associated with variation in times of seeding and transplanting and occurrence of flash flood as well as drought and biotic stresses. Commencement of the wet season varies greatly from year to year, resulting in variation in time of sowing. Cultivars differ in their photoperiod sensitivity, and hence their flowering times vary greatly, depending on the time of sowing. This also contributes to the large G x E interaction for yield.

3) Modification of rice breeding program in Thailand

The current breeding program conducts mostly intra-station trials with early generation materials, and inter-station yield trials are conducted only later with advanced generation materials. This approach is not effective in the rainfed lowland conditions where G x E interaction for yield is large. Here a large number of yield trials across locations and years are required for identifying widely adapted lines that produce high yield in the region.

The emphasis in the suggested new breeding program is on increased early yield testing at a large number of sites in the selection program, use of a drought resistance screening technique, use of a rapid generation advance technique, and increased on-farm testing. Some of these points have already been incorporated into the breeding program, and it is gradually evolving into a new system in Thailand. The outcome would be the development of new cultivars in a shorter period of time and hence, the breeding program is more efficient in terms of financial return (Pandey and Rajatasereekul 1999).

4) Characterization of cultivars widely adapted to rainfed lowlands

Using the drought tolerance screening method that we have developed recently in Thailand, we hope to produce cultivars that are drought resistant. Grain yield of a genotype under rainfed lowland rice is, however, also affected strongly by the potential yield of the genotype and the phenology, particularly flowering time in relation to drought timing.

Our experience indicates the importance of high potential yield (that is obtained under well fertilized and irrigated conditions) in determining yield under many conditions in rainfed lowlands, particularly under conditions where yield reduction is not large. Where yield reduction was less than about 50 % of the potential yield, genotypes with high potential yield produced higher yield. Examination of performances of cultivars in Thailand indicates increase in potential yield by about 1 t/ha from traditional cultivar to advanced elite line (Fukai and Basnayake 2002). The genotypes suitable for drought conditions in rainfed lowland rice depend on drought severity, and also whether the timing of drought is predictable. In cases where the timing of drought is predictable, phenology is important in escaping the drought, whereas for unpredictable and severe drought conditions, genotypes that possess appropriate drought resistant traits would produce higher yield than genotypes without them.

5) Cultivars for direct seeding

Direct seeded area increased rapidly with shortage of labour for transplanting in the late 1980s in Northeast Thailand. By 1992, rice areas established from transplanted and dry-seed broadcast were 73.6 % and 25.5 %, respectively (Naklang 1997). Direct seeding is a common practice in Northwest Cambodia; however, it is rarely practiced in Laos. This situation may change with the decline in labour availability for transplanting.

For the whole area of Northeast Thailand, mean yield in 1989-92 was 1.80 and 1.37 t/ha respectively, for transplanted and dry-seeded, broadcast rice (Naklang 1997). Thus, one of the reasons for the lack of yield improvement in recent years in Northeast Thailand was the expansion of areas under direct seeding, which produced lower yields compared with transplanting. Existing cultivars were developed under transplanted conditions and may not be most suitable for direct seeding.

The effects of the change from transplanting to direct seeding on agronomy of rice are as follows:

- *Early seeding*. With direct seeding, wetland cultivation operation is reduced compared with transplanting, and this makes early seeding possible. Early seeding will allow the direct seeded crop to often escape from late season drought, if photoperiod insensitive or mildly sensitive cultivars are used.
- *Crop establishment difficulty*. Compared with the growing environment of a seedling nursery, which is generally located at a favourable and protected position within the farm, direct seeding of a crop in the main fields takes place under more difficult crop establishment conditions. Direct seeding in rainfed lowlands often requires more precise soil moisture conditions for good crop establishment. Thus, there is a higher risk of poor establishment under direct seeding.
- *High plant density*. Compared with transplanting, direct seeding particularly broadcasting, will result in a higher established plant density under favourable growing conditions. This is related to the larger amount of seeds used for direct seeding, and the high plant density may result in a larger number of panicles and hence higher grain yield.
- *Weed problems*. The problem of weeds in direct seeded rice paddies is greater than in transplanted paddies. This is associated with poor land preparation often due to seeding early in the wet season. Poor rice establishment due to direct seeding results in poor competition against weeds. Lack of standing water during early stages of growth causes difficulty in controlling weeds.

A review of the cultivar requirement for direct seeding in rainfed lowland rice by Fukai (2002) is summarized here. Characters required for direct seeded rice are associated with the agronomy of direct seeding mentioned above, and they include photoperiod insensitivity, good competitive ability against weeds, seedling vigour including submergence tolerance and lodging resistance.

- *Photoperiod insensitivity*

The requirement for photoperiod sensitive cultivars for drought-prone areas may not be strong under the direct seeding system, because with early seeding, photoperiod insensitive cultivars would mature early and escape the late season drought. Compared with photoperiod sensitive genotypes, the use of photoperiod insensitive genotypes would provide a better opportunity to develop high yielding cultivars (Mackill et al. 1996).

- *Competitive ability against weeds*

With rather limited resources available for hand weeding or purchase of herbicides, rainfed lowland rice farmers in the Mekong region need competitive cultivars to suppress weed growth. Several plant characters have been identified for strong competitiveness. They are tall plants with good tillering ability and canopy development. Since tall plants are often low yielding and tend to lodge, shorter intermediate height (eg, between tall traditional plants and semi dwarf plants) would be desirable. Rapid tillering in the seedling stage will contribute to rapid canopy development. The ideal plant type for strong competition against weeds will have shoots that spread and cover the ground rapidly during the vegetative stage but with the onset of panicle initiation they will not dominate over reproductive organ development. Another character associated with competitiveness is the long growth duration of rice genotypes. Long duration genotypes have more time to recover from weed competition that may have taken place during early growth stages.

- *Seedling vigour*

Seedling vigour is required for direct seeded rice, particularly for rainfed lowlands where water control is limited and crop establishment conditions are not favourable. Semi dwarf cultivars have shorter mesocotyl and total seedling length, and this is disadvantageous for good crop establishment particularly when seeded deep in the soil or in standing water. Submergence of young seedlings is a common problem with direct seeded rice, and hence submergence tolerance is required.

• *Lodging resistance*

Lodging is another common problem in rainfed lowland rice, particularly under direct seeding in high soil fertility areas. This is associated with the use of high plant density and resultant tall plants with thin stems, and shallow planting in direct seeding. Tall traditional cultivars tend to lodge, and intermediate height cultivars are generally more suitable to direct seeding. Large stem diameter, thick stem walls and higher lignin content would also reduce lodging (Mackill et al. 1996).

6) Drought resistant cultivars

Environment characterization has been made to identify drought types. While early season drought is a common problem in Thailand, Laos and Cambodia, development of cultivars adapted to this type of drought is considered more difficult than for cultivars resistant to late season drought. Thus, we have concentrated on identifying plant characteristics that convey resistance to late season drought, which is often severe particularly in Northeast Thailand.

Our research results have shown that rainfed lowland rice may be considered as conservative drought avoider. Rice is very sensitive to water stress, and leaf elongation stops, stomata close and leaves roll under mild soil water deficit. The root system is always shallow, and extraction of water from deep soils is limited. Late season drought develops earlier if plant size is large and hence, soil water extraction is fast and water demand is high. Thus, ideal rice plants will use the limited amount of available water slowly so that soil water will last till well beyond flowering stage. Once standing water disappears from the field before flowering, and no substantial rain falls during the flowering to grain filling stage, yield is reduced severely. The pattern of water use and subsequent development of water stress is schematically shown in Figure 1 (from Pantuwan et al. 2002a).

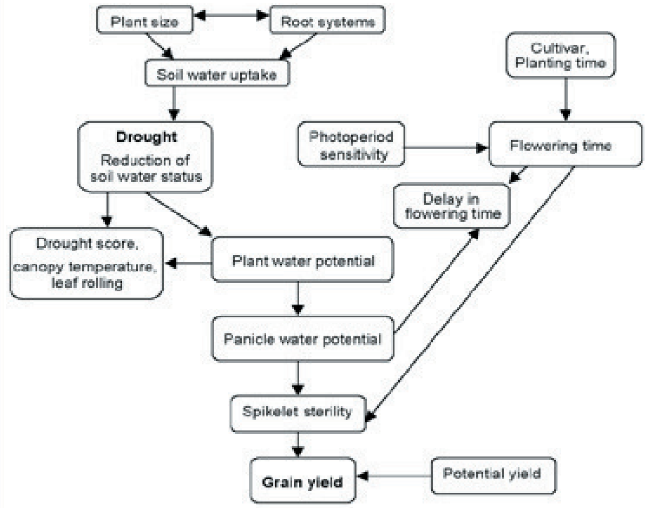

Fig 1. Schematic diagram illustrating the effects of drought stress on grain yield when drought develops at around flowering time.

The plant breeding process for drought adaptation can be made more efficient when traits other than yield are added to the selection process. In rice, various workers have identified putative traits for drought resistance. Our recent work (Jongdee, 1998; Pantuwan et al. 2002b) indicates that genotypes that can maintain higher leaf water potential (LWP) produce higher yield than other genotypes under late season drought conditions, which are common in the region. Leaf water potential integrates a number of mechanisms that contribute to the water status of the plant, but it appears stable under different environmental conditions. The mechanisms of maintaining high LWP under water stress appear to be related to water transport systems within the plant, and large xylem size was found to be associated with high LWP among six genotypes examined (Sibournheung et al. 2001). In order to screen a large number of genotypes, the delay in flowering in response to water stress may be used. One of the consequences of the loss of plant water potential is a delay in flowering of the stressed plants relative to those that are well watered (Pantuwan et al. 2002b). Other characters that have been examined as putative drought resistant traits include deep root system and osmotic adjustment, but they were not found to be effective in minimizing the adverse effect of late season drought.

A new project has just commenced with funding from the Rockefeller Foundation. The objective of the project is to select drought resistant lines in rainfed lowland rice for the Mekong region. Table 1 lists selection criteria for development of adapted cultivars for rainfed lowland rice in the Mekong region.

Table 1. Suggested selection criteria within a maturity group for developmentof adapted cultivars for rainfed lowland rice (Irrigated and rainfed conditions with drained water) in the Mekong region.

Irrigated conditions	Rainfed conditions with drained water prior to anthesis
• High potential yield with • High harvest index • Intermediate height • Small dry matter at anthesis	• High potential grain yield • Minimal delay in flowering • Maintenance of favourable plant water status

For this project we will be utilising the screening method we developed in Thailand, whereby we select a site with low rainfall and where drainage of standing water is possible. We screen genotypes mostly in the wet season, as rice growth in the dry season is quite different from that in the wet season. In these screens, the planting will be 2-3 weeks later than the commercial crops to increase the chance of late season drought, particularly with photoperiod insensitive materials. In addition, standing water from 10 days before flowering onward will be drained from the field, to increase the likelihood of drought stress. There will be a well-watered control trial. Grain yield under the drought trial will be adjusted for flowering date and yield potentials using the concept of drought response index (DRI) (Bidinger et al., 1987). The DRI will be used for identification of drought resistant genotypes.

3. Sustainable agricultural production

Sustainable agricultural production is discussed here in relation to increased rice production as a result of development of improved rice cultivars, international research projects and human resource development.

1. Increased rice production

Once improved cultivars are found to be well adapted to a rainfed lowland region, they are generally well adopted by farmers. An example of this is shown in Laos, where recently released improved cultivars such as TDK1 have been widely adopted in different parts of the Mekong river plains. The improved cultivars are high yielding, and often are photoperiod insensitive with shorter growth duration than traditional cultivars. Thus, they can be more flexible in terms of planting windows. Unlike most other technologies where cultural practices are altered or additional resources are required, farmers can use new cultivars without any modification in their cultural practices. However, it should be stated that the advantage of new improved cultivars is often increased with addition of appropriate inputs, such as fertiliser application.

Another point to note is that adapted cultivars such as those with drought resistance should reduce yield losses, and this contributes to reduced fluctuation of rice production; reduced crop failure and yield loss contribute directly to sustainable agricultural production.

Introduction of cultivars may contribute to the development of a new cropping system. This may be the case with the introduction of IR66 to rainfed lowlands in Cambodia. This cultivar is quick maturing and photoperiod insensitive, and could be planted early in the wet season, followed by traditional photoperiod sensitive cultivars late in the season. This has contributed to increased rice production in the country.

The improvement in rice production through development of adapted cultivars that will eventually have a large effect on the national economy highlights the importance of rice in agricultural production in SE Asian countries. With the higher yield of rice, as a result of adoption of new cultivars, the area required for rice production may be reduced particularly in areas where marketing of rice is limited. This allows other crops to be grown, and this contributes to diversification of cropping, and may result in reduced fluctuation of food production. The area, which is not suitable for rice production but may be suitable for other crops, such as that of sandy soils with high percolation rate, may be converted to production of other crops, contributing to the development of sustainable production systems. Alternatively if a rice market is available, then excess rice can be sold, contributing to the development of a cash economy. Once self-sufficiency in rice is achieved, rice production may be aimed at quality.

Rice cultivar development research is required for changing socio-economic environments to maintain and further develop sustainable agricultural systems.

2. International research projects

International projects in rainfed lowland rice are an important component of the rainfed lowland research in these countries. In most cases international projects work together with national scientists to improve rice production and/or develop sustainable agricultural production system. It is thus, important to understand the current problems of rice production and develop research projects addressing such problems together with national scientists. In the case of our ACIAR rice improvement project, we have worked on development of strategies for improvement of rainfed lowland rice. This has required the continual modification of objectives within the project framework as identification of limitations evolved. International projects need to be dynamic, and as the results are produced, research emphasis needs to be redirected to maximise the benefit to the project and more importantly, the region. Often, it is not until the project is well under way that the true limitations (to production) can be identified. This identification of the problem and modification of project activities cannot be achieved by conducting isolated short-term experiments. Results and their interpretation rely heavily on the establishment of good communication and understanding between national and international scientists and the development of this report alone requires a long-term project approach. New ideas and areas of research can then be incorporated relatively easily into existing projects. An example of a shift in emphasis in our ACIAR project was the identification of the need for characterization of the environment from a minor component to a major sub-project of Agro-ecological characterization in Laos.

International cooperation may be further promoted by conducting research in more than one country in SE Asia. For example, in our ACIAR project, there were always two neighbouring countries working together. Often the problem is similar; for example, drought and flood problems in rainfed lowland rice in Thailand, Laos and Cambodia. Technology transfer may be possible among areas of similar growth and social environments. For example, rice genotypes found to be high yielding in Thailand did well in Laos and Cambodia. Thus, adapted cultivars can be readily transferred from one country to another.

3. Human resource development

Another important area associated with sustainable agricultural production in SE Asia is human capacity development. The ACIAR project, like many other overseas projects from Australia contributed to the training of national scientists in Australia. This appears particularly successful in postgraduate training. A large number of scientists have successfully completed higher degrees at the University of Queensland in association with our ACIAR rice improvement project. The staff members who are associated with the ACIAR rice improvement project have supervised (including those currently enrolled) seven PhD students (including 3 from Thailand, 1 from Cambodia) and ten Masters degree students (including 2 from Laos and 1 each from Thailand and Cambodia). Four of these postgraduate students have conducted their research in the Mekong region. These former students have strong impact on research and development in the national breeding program of their home countries. For example, postgraduate students from Thailand contributed greatly to the development of the new rice-breeding program in the country.

In the medium to long term this improved research and human resource capability would flow on to the development of new rice cultivars and cropping systems in the region, again contributing to sustainable agricultural production.

Universities in Australia, as in Japan, have taken in a number of undergraduate and postgraduate students from SE Asia. One possibility for the further development of international cooperation would be to enable postgraduate research to be conducted in the student's home country. The advantages of this are that the 1) research topic is more relevant to the student; 2) research findings are often directly applicable to the country of concern; 3) the supervising University staff will have the opportunity to gain greater awareness and understanding of research needs in the student's home country; and; 4) the exposure of University staff to the country where the research is conducted would help in identifying future overseas research projects.

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Rootcrops as Food, Feed and Industrial Materials: The Challenge to Address Their Production and Post-harvest Needs

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Abstract

The objective of this paper is twofold: first, to introduce the group of starchy underground storage organ-producing crops known as root and tuber crops or simply rootcrops, whose importance and prospects are not yet fully understood; and second, to pose a challenge to all concerned in the global agricultural science community, particularly those from the Graduate School of Bioagricultural Sciences of Nagoya University, to give attention to research on these crops in order to contribute fully in securing food supply for scores of millions of people the world over. Suggestions are, likewise presented on how the concerned scientists and experts could respond to the call for action, as well as, the essential changes that need to be in place in order for them to have relevant contributions in increasing regional and global food supply. Generally, the world food situation is abating and the picture for Asia is not different. Agricultural science education failed to bolster sustainable agriculture and food security measures because it could not respond well to the needs and expectations of the farmers since it either lagged behind in the developing countries or it advanced too much in the developed ones. A number of physical factors, however, contribute to this food supply shortfall. One of these is the continuing reduction in the supply of water in many areas of the world. Rootcrops grow and produce economic yield where other crops may fail; hence these crops are expected to play a key role in reducing hunger and poverty. The task to increase and sustain rootcrop production is rather a tall order. There are simply a lot of things to consider and many main and sub research avenues to be attended to. Involvement of as many players as possible is therefore required, and participatory research or collaborative undertaking is seen as the best possible approach at the moment. Scientists and researchers in the developed countries like Japan are looked up to engage in this concerted activity. However, certain adjustments have to be instituted so that relevant interventions could be extended from their end. Foremost of this is a paradigm shift to be followed by changes in outlook and approaches in the way research is conceptualized and undertaken, giving way for some freedom and flexibility.

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Introduction

The significance of rootcrops

Rootcrops, in layman's terms, mean the group of crops, otherwise known as root and tuber crops, which produce underground tubers or corms. Common among these crops are cassava (*Manihot esculenta*); sweetpotato (*Ipomoea batatas*); potato (*Solanum tuberusum*); and yams (*Dioscorea esculenta*), which constitute the so-called major rootcrops. Others, which are classified as minor rootcrops are the edible aroids (taro, *Colocasia esculenta*; yautia, *Xanthosoma sagittifolium*; giant taro, *Alocasia macrorrhiza*; swamp taro, *Cyrtosperma chamissonis*; elephant foot yam, *Amophophallus campanulatus*) and the lesser yams (*Dioscorea alata, D. bulbifera, D. hispida*).

While the major rootcrops are cultivated in a large extent globally, occupying around 50 million hectares (Scott et al., 2000), the edible aroids and the lesser yams are considered minor rootcrops chiefly because they are of lesser importance in terms of total production and commercial demand. However, some of these crops may have a special function in the food system in certain countries or regions so that they are produced in greater extent than those identified as major rootcrops. A good example of this is taro, which is planted in large scale in many South Pacific countries, being a staple food and an export item (Iosefa and Rogers, 1999).

In 1995-97 farmers produce 639 million tons of cassava, potato, sweet potato and yams annually which was valued more than US$41 billion or about one-fourth that of the value of the major cereals (Scott et al., 2000). The production of these crops is mostly in Asia, Africa and Latin America where the greater demand is for food. It is a fact that where poverty is prevalent, rootcrops are widely planted though production efficiency in these areas may be low. In the Philippines alone, rootcrops, which are grown in a broad range of agro-ecological condition, have a significant function in providing food security and livelihood among the resource poor people living in fragile upland environment, which comprise about 65% of the total agricultural land in the country (Pardales and Roa, 2001). In the global scene, the picture is not different at all, in that rootcrops are typically a small farmer crops and are the basic sources of their food and cash resource (Alexandratos, 1995); the crops being tolerant to adverse growing condition and low input-farming practice compared to other food crops. In relation to this, Scott et al. (2000) had this to say…

"*Root and tubers deserve particular attention because many of the developing world's poorest and most food insecure households look to these crops as a contributing, if not the principal, source of food, nutrition and cash income. Among other things, farm households see the value of roots and tubers in their ability to produce more edible energy per hectare per day than other commodities and in their capacity to generate yields under conditions where other crops may fail.*"

The prospects of rootcrops

The paper containing the above-quoted statements and other information cited earlier, entitled " Roots and tubers in the global food system: A vision statement to the year 2020," provide a very comprehensive picture of the present and the future of root and tuber crops. Ordinarily, however, these crops are grown for household or village-level use where they are utilized as food, feed or processed into starch for domestic needs (Wheatley et al., 1995; Horton, 1988). However, current trends show that what has been a traditional use of root crops, particularly cassava and sweet potato, in the household such as feed for backyard-raised livestock, is expanding and being practiced in a wider scale at present. In China and Vietnam and other parts of the world sweet potato is becoming a popular crop that is used as pig and other livestock feed, which provides high returns (CIP, 2000; Scott, 1992). In a developed country like Japan sweet potato has been identified to offer an array of utilization possibilities such as source of starch, flour, food colorants, and protein and enzyme which have high potential as ingredient for medicine (Yamakawa, 1998) while research on processing the crop into novel products is ongoing in some research centers (Tamaru, 1998).

Cassava, on the other hand, had become a vital export commodity of Thailand to the European Union (EU) as animal feed besides being processed into the global market, the starch in many other parts of the world. In demand for cassava chips (*tapioca*) in 1999 was about 6 million tons (ASEAN, 2000).

However, with food shortages common in many parts of the world, the future of cassava lies on the fact that it is identified by the Food and Agriculture Organization (FAO) and the International Fund for Agricultural Development (IFAD) as a crop that can help reduce hunger and poverty in many parts of the developing world. The crop is a basic staple to 500 million people in the tropics and sub-tropics besides being a source of livelihood to millions of farmers, processors and traders around the world (FAO, 2000a).

Of the potential of root and tubers in the years to come, Scott et al. (2000) said the following:

"Root and tuber crops have myriad and complex roles to play in feeding the world in the coming decades. Far from being one sort of crop that serves one specific purpose, they will be many things to many – very many people. By 2020, roots and tubers will be integrated into emerging markets through the efficient and environmentally sound production of a diversified range of high-quality, competitive products for food, feed and industry. These crops' adaptation to marginal environments, their contribution to household food security, and their great flexibility in mixed farming systems make them an important component of a targeted strategy that seeks to improve the welfare of the rural poor and to link smallholder farmers with these emerging growth markets. We estimate that by 2020 well over two billion people in Asia, Africa and Latin America will use root and tubers for food, feed and income. Many of these people will be among the poorest of the poor."

Rootcrops Production System

Being generally associated with poverty, rootcrops are therefore customarily planted as subsistent crops in many parts of the world. The subsistent rootcrops growers are smallholder and resource-poor farmers who grow the crops principally for food. They utilize degraded upland areas that are usually not their own, and normally of less than 0.25 hectare. Subsistent rootcrop production system is devoid of technological applications utilizing only traditional varieties of rootcrops and simple crop care and management practices (Pardales et al. 2001). On one hand, this is primarily because they do not have the resources to comply with what is required for intensive rootcrop cultivation. On the other hand, to some extent, they are being taken for granted, including their indigenous knowledge system, by scientists and extension workers (Pardales et al., 2001). For many years, institutional scientists thought that the small, economically deprived farmers readily embrace whatever production technology is introduced to them. This high-minded attitude had resulted in the introduction of crop production technologies that were not suitable to the environmental and biophysical condition of a certain area, as well as to the socio-cultural mind set of the local people (Pardales and Yamauchi, 1999; Pardales et al., 2001). In one way or another, this also solidified the farmers' hesitation against subsequent external intervention.

The other production systems in which rootcrops are grown are semi-commercial and commercial. In the former, rootcrops are planted in larger tracts of land, usually ranging from 0.25-0.50 hectare, which are commonly situated in sloping to hilly areas (Pardales and Roa, 2001). Semi-commercial rootcrop production is established principally with two intentions, that is, for food and income. Much importance is given to the food requirement of the household while the desire for income is only subsidiary and realized only if crop yield is more than what the household could consume. The farmers engaged in semi-commercial rootcrop farming are normally a bit sophisticated than the subsistent ones, in that, they experiment on the use of some technological innovations like growing recommended varieties and using certain crop care and management practices but almost always in comparison with their customary varieties and cultivation procedures (Pardales and de Guzman, 2001). In relation with the subsistent farmers, the semi-commercial rootcrop growers have likewise a system of knowledge, which may not differ at all from that of their subsistent counterparts. Their production systems have a lot of things in common like the location and characteristics of their farms (terrain and ecological condition), cropping system involving the use of other crops, use of their proceeds, etc. Their social interaction is frequent considering the fact that they both go to the same local market where they sell their products and derive their household needs.

The commercial rootcrop production, on the other hand, is almost 100% for the industry although in the Philippines this may also be 100% for the fresh market in metropolitan areas (Data et al., 1997). The farmers attending to this production system are usually resource-rich and are profit oriented. They are highly dependent on technological innovations and interventions for increased field output (Pardales et al., 2001), hence, their need for technical backstopping from research institutions. Pardales and Roa (2001) mentioned that commercial rootcrop production system is high on application of new technological innovations and interventions where the complete package of recommended cultural management practices for the crops are keenly followed.

World Food Situation and the Role of Rootcrops in Meeting Food Demand

The current condition

Pinstrup-Andersen and co-workers (1997) in their food policy report presented their assessment of the prospects for global food security in the next quarter century. Among the important things they emphasized was the following…

"Between 1993 and 2020, global demand for cereals is projected to increase by 41% and for meat by 63%. Most of the increase in demand is expected to occur in the developing countries. In many of these countries, however, food production is unlikely to keep the pace with the jumps in demand. The "food gap" – the difference between production and demand for food – could more than double in the developing world in the next 25 years. This food gap will have to be filled through increased imports. This should not be case for alarm for the higher-income developing countries, but the poorer countries might not be able to import food in needed quantities. Likewise, even when the low-priced food is available in the marketplace, many poor people might not be able to afford the food they need."

FAO (2000b) estimated that 826 million people around the world still do not have enough food to eat even at the present time when there is said to be an abundance. This FAO report also cites that 792 million in developing nations and another 34 million in industrialized countries were undernourished during the period 1996-98. Singh (2000) reported that the Asia-Pacific region alone is home to two-thirds of the world's undernourished people and in terms of real number this is a staggering 515.2 million. In a separate communiqué, FAO (FAO, 2002a) reported that the food production in Asia is indeed declining. In January 2002 the estimated drop in cereal production (rice, wheat and coarse grains) was 989.3 million tons based on what had been realized during the preceding year. This shortfall in food production was attributed to adverse weather conditions and economic decline in many developing countries.

Drought is probably the most serious factor affecting crop production among the stresses related to weather condition. FAO (2000b) had in fact launched several initiatives to help the Near East countries (e.g. Iran, Iraq, Jordan, Syria, Pakistan, etc.) fight drought and desertification. FAO (2000c) had therefore cautioned all concerned that the great global challenge for the coming years will be on how to produce more food with less water. In recent years many parts of the world have experienced long-term dry spells, the most popular of which is the one being brought about by the El Niño phenomenon, which takes place in almost regular occurrence. Probably because of the crops' known ability to tolerate adverse growing condition (Cock, 1985) IFAD and FAO (FAO, 2000a) organized a forum on tropical rootcrops, which approved a global action plan and a cassava development strategy, basically to position the crop as a key commodity in reducing hunger and poverty. Kim et al., (2002) pointed out that cassava has many advantages over cereal crops in that it is tolerant to drought, pests and degraded soils. On a broader context, however, Scott et al (2000b) had these to say:

"Future prospects for the role of roots and tubers in the global food system will be greatly influenced by various demographic, economic, political and environmental trends." "Our analysis suggests that many of these trends will stimulate growers and consumers to produce and consume more root and tubers in new ways, for new uses, and using new technology."

"The largest absolute increase in root and tuber production will take place in Sub-Saharan Africa (cassava and yam, primarily) under both scenarios. China will account for the bulk of additional sweet potato output, and both China and India are projected to harvest two-thirds or more of the additional potatoes produced. Furthermore, increases in root and tuber production will be driven by demand for food in the case of potato (both fresh and processed) and yam. Processed food products such as noodles made from starch and non-food uses such as feed will be much more important for cassava and sweet potato."

Food security and sustainable agriculture: What now?

The decade of the 1980s ushered hopes to the millions of food hungry people in the world through unprecedented initiatives of many institutions, which were indications then that great things were forthcoming. One of the ideas that surfaced and was well received by people of different walks of life, i.e., farmers, policy makers, experts, consumers, and others was sustainable agriculture. This concept rested on the principle that the needs of the present generation must be met without compromising the ability of future generations to meet their own needs (Feenstra et al., 1997). Hence, the matter of cooperation of all people concerned including those in the academe is a prime imperative. Simply put, sustainable agriculture is the responsibility of all participants in the whole agriculture system. While this concept or practice may have brought dividends in economically commercial crops, in rootcrops and other crops of less economic value for that matter, this concept until now is still a much talked about issue but seemed unrealizable. More often than not, each player is to his own and the focus is diffused. In the developing world sustainable agriculture is far from reach. In the developed one it rests in the theoretical minds.

In the middle of the 1980s, the food security idea sprung up and lots of definition were coined. The implication was that all people should have access to food at all times not just for survival but also for continued active participation in the society. In a commissioned paper, Hall (non-dated) mentioned that:

"A country and people are food secure when their food system operates in such a way as to remove the fear that there will not be enough to eat. In particular, food security will be achieved when the poor and vulnerable, particularly the women and children and those living in marginal areas, have access to the food they want."

What happened? FAO (2000b) clearly stated that the food insecurity in the world shows no progress towards world food summit target. Taking away physical reasons aside like changing climatic patterns, it is believed that one of the reasons for the failure of sustainable agriculture and food security measures in much of the developing world is that agricultural science education could not fully respond to the current needs and expectations of the agricultural producers. Either it lagged behind in the developing countries or it advanced rigidly too far in the developed ones that researchers became inconsiderate of anything less challenging and non-popular. In addition, Atchoarena and Gasperini (2002) had the opinion that the contents and delivery process of agricultural education have been generally isolated from other ongoing processes of education and training within the rural environment.

Elements and Process of Mitigation On the Food Production and Utilization Problems

Pardales and Yamauchi (1999) presented a so called "domain interaction approach" in developing technologies or finding solution to nagging agricultural production problems in the field. Basically, this idea came about as experiences of technology failures of PhilRootcrops, a government research institution in the Philippines, came one after another with the farmers, the so-called "end users of technology," passively complaining of the non-practicability and non-usefulness of the technologies introduced to them. Pardales et al. (2001) pointed out that the basic reason why recommended technologies did not work out well with the farmers was that they were not involved in the development of the technologies. In the case of the sweet potato varieties developed through conventional breeding by PhilRootcrops scientists and introduced into a certain locality, these varieties did not last long in the farmers field because they were too sweet and watery, bushy in growth stature so that they were prone to weed competition, and not tolerant to limited water supply, pest infestation and degraded soil condition. Pardales et al. (2001) had this observation:

"Experiences with rootcrop production technology failures across practically all classes of rootcrop farmers brought up the following points which necessarily call for alternative ways of developing technologies and introducing them to end users:

- *Researchers/scientists have no monopoly on technological ideas and innovative practices. They cannot impose something on farmers because in the end it is the farmers themselves that determine what is best for them.*
- *Merely letting the farmers view and make judgment on introduced technologies or innovations is not sufficient and does not guarantee adoption of technologies.*
- *Unless the farmers clearly understand the principles behind a certain technology they cannot appreciate the need for its methodological application."*

Having the ways and means of producing crops as the focus of attention in increasing food availability, it becomes imperative that all involved players of the agricultural activity (i.e., the scientists, extension workers farmers) have to consider the element of participation or collaboration as pivotal point in the technology development – technology transfer – technology adoption cycle. Nevertheless, it should be taken into account that the whole process has to be viewed by all players from the same vantage point to cultivate a sense of sensibility towards interdependence and cooperation.

Participatory research is one area where the traditional players in the technology continuum could come together for a more meaningful and shared undertakings in looking for a solution of a certain field crop production problem. As a research approach, participatory research is a methodological strategy, which recognizes the critical contributions (i.e., practices, attitudes, skills, knowledge, motivations) of the different stakeholders of an undertaking (Pardales et al., 2001). Furthermore, it is a process that is highly dependent on skills of facilitation and an open mind-set of those involved. Out of their experiences in piloting a farmer field school on sweet potato integrated crop management, the same workers (Pardales et al., 2000) presented the beneficial outcomes of participatory research with farmers as follows:

- *Saving on resources. Whether participation is among technical researchers or between researchers and farmers or processors, financial, material or physical resources can be shared.*
- *Enriched knowledge system. The blend or integration of indigenous or local knowledge and the technical or scientific knowledge brings about sustainability in the application of a certain technology. This is because the farmers develop a sense of co-ownership of the ideas or technology.*
- *Immediate application of developed or improved technology. Because the farmers are partners in technology development or improvement they need no further convincing as to the appropriateness, practicality or efficiency of a certain agricultural practice. Being key players in the innovation process, others in the locality look up to them as authoritative example of*

development, thus, adopting any agricultural intervention easily.

- *Capacity building. In participatory research the farmers gain skill and knowledge in comparing and evaluating different ideas or practices themselves. This process of judging out ideas or practices which include seeing, discovering and reasoning develops the farmers capacity to analyze, thereby making them capacitated to solve field problems effectively. On the part of the researchers, working in partnership with farmers introduces them to action research, which give them broader perspective of the real condition in the field and the need to consider various issues in working out technological interventions and innovative systems. Furthermore, participatory research or extension enriches the technical or academic preparations of a researcher for formal instruction and training.*
- *Scaling up. That participatory research is one good approach to solve local field problems with local people being part of the problem-solving process has the potential of becoming a participatory community development. The practice could be adopted through an experienced and capacitated local farmer who can lead others to be engaged in participatory diagnosis and analysis of certain problems.*

While scientist-farmer participatory activity may be considered a vital relationship to bring a change in the way agriculture related field problems are studied, scientist-scientist technical collaboration also brings positive dividends. The paper of Pardales and Yamauchi (1999) also cites the fact that collaborative undertaking on certain area of research, no matter how small the fund or short the duration is, could lead to the discovery of many things – simple scientific explanations they may be. These facts could then pave the way for broader scientific understanding and technology development. Basic research information could lead to the formulation of recommended practices or development of novel technologies. To alleviate the abating food production elsewhere in the world, it is suggested that an elemental framework of intervention by all concerned be followed, taking into account the domain interaction approach of technology development brought up by Pardales and Yamauchi (1999) (Fig. 1).

In other words, the critical strategic element in attempting to alleviate an alarming declining world food situation is establishing an atmosphere of participative or collaborative undertakings among the concerned. For rootcrops whose versatility, significance and potential in many aspects is well recognized (Scott et al. 2000a; Scott et al., 2000b), there is a need for greater interest and attention from various sectors in the scientific and agriculture community to critically study their production, storage, processing, utilization, status and problem

(Wheatley et al., 1995). Rice is one crop whose production capacity had been pushed up because of scientific breakthroughs as a result of heightened collaborative interest of many international, national and local institutions and researchers (Pardales and Yamauchi, 1999).

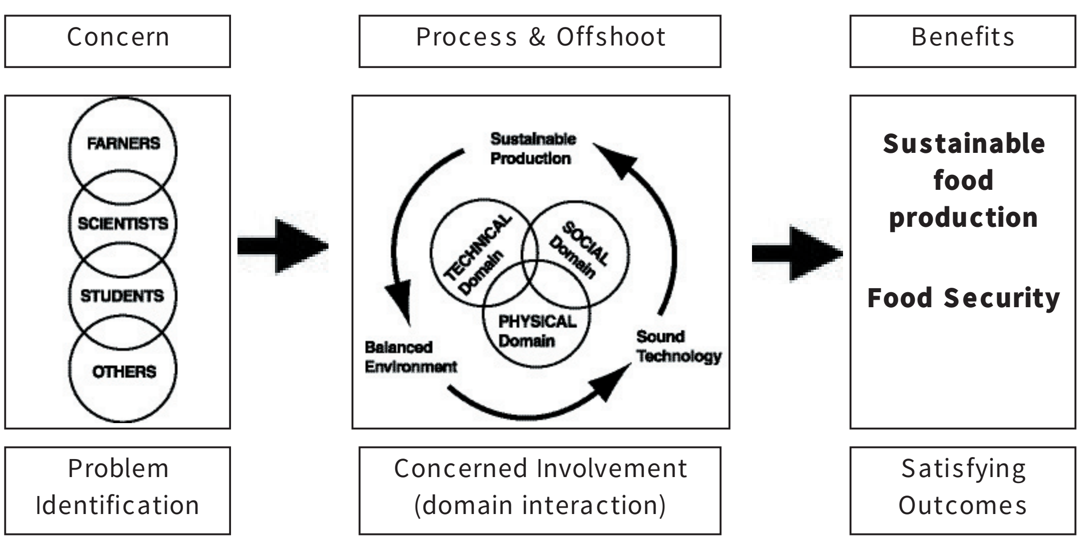

Fig 1. Elemental framework of intervention in mitigating the problem of declining regional and global food production adopting the domain interaction approach of technology development as the process.

Academic Adjustments to Meet Challenges in Securing Regional and Global Food Supply

The case of Nagoya University: Previous observation

Observation and experience had it that many, if not all, academic laboratories in the former School of Agriculture in Nagoya University (presently the School of Agricultural Sciences) undertake research on certain crops or animals based on either of the two considerations: interest of the professors-scientists, or interest of the agency giving funds for the research. The crop of interest by the professors-scientists is studied in the laboratory by the scientists themselves and their students if the source of research fund gives freedom to the researchers in terms of the crop that they could work on. On the other hand, the latter is pursued if the agency giving research funds has the say on the crop that the laboratory has to particularly deal with. At present the way the object (plant or animal) of the study is selected in the different laboratories of the School of Agricultural Sciences may not actually deviate much from the old custom since the long established system of research funding remains practically the same.

Basically, there is nothing wrong with the system, which has been the tradition for scores of years now, but the practice portrays a strictly limited or restricted view of looking at underlying problems or issues having to do with food supply problem mitigation. This is duly because the conduct of research by academic laboratories hinges solely on either the personal academic interest of scientists or the corporate concern of the funding institutions rather than giving some degree of attention to the interest of farmers and other agricultural players. More often than not, research results and concomitant information are especially packaged to fill pages of technical journals to satisfy high-end consumers who themselves are scientists and academicians who may have very limited contact likewise with farmers, food processors, etc. The present situation of declining food production right in Asia (FAO, 2000a) should be a cause for alarm so that research attention and efforts should be directed towards the prevailing factors that constrain sufficient and sustainable food production (Pardales and Yamauchi, 1999).

The need for a paradigm shift: A suggestion

Significant contribution to improve the world food situation warrants that resources, interest and outlook be shared among agricultural stakeholders wherever they may come from. This could mean that the well-funded, laboratory-entrenched agricultural scientists in developed countries like Japan have to reconsider their way (objective and method) of pursuing research - from being personally motivated, academically driven, passive and single-minded into problem-based, broadminded, proactive and forward looking kind of researcher. The paradigm shift that is advocated in this paper is the change from the long established tradition of carrying out experiments based on one's personal desire for enlightenment on certain scientific riddles to engaging in collaborative or participative research with partners from outside his normal domain, be they from other countries or regions. This could only be done if scientists reach out to others (scientists, extension workers, farmers, etc) to engage in discussion and exchange of ideas on certain pervading issues affecting regional or global agriculture, if only to alleviate the economic condition, improve the production system, and secure the food supply base of the greater majority of the people in the long run, who are resource poor, vulnerable, and food insecure. Furthermore, the paradigm shift here could also mean adjustments in ones interest, say from rice to rootcrops, from soil fertility to natural resources, etc. The whole thing calls for flexibility and openness of everyone involved.

A paper by Nabangchang (2001) classified agricultural research into *supply-driven* and *demand-driven*. The former kind of research, which is the conventional approach, identifies the research agenda based on pre-conceived notions of scientists as to what is needed by farmers or technology users. Pardales and Yamauchi (1999) considered this as a "know it all" attitude of scientists. In contrast, the latter kind of research, necessitates that research agenda be identified by the end users of the technology themselves (the farmers commonly) since they are the ones who know what they need to understand or have. In his attempt to present the merits of the demand-driven research, Nabangchang (2001) stated the following in furtherance:

"The desirability of the shift from supply-driven to demand-driven research is based on observed shortcomings of the former in four main aspects, namely: (i) the tendency to extract the research

activities from social, physical and environmental context into a more laboratory-controlled environment, (ii) the monopoly of research by scientists, specialists, academics at the expense of the exclusion of the farmers who, in many respects, are the most experienced field experts and are therefore prime resource persons, (iii) the probability of the incompatibility of research results and the physical environment, (iv) the tendency of treat of adoption of technology as given through failure to recognize the farmers' economic perspectives as he weighs and balances the costs and benefits and all risk factors involved in adoption of new technology."

Other adjustments to be done: A view from outside

The intrinsic system in typical Japanese academic laboratories is the seeming lack of flexibility of the students to work something out on their own. It is a common practice that professors decide on what research problem their students would pursue. By and large, this kind of arrangement is not a problem with the students. Besides the fact that this is customary, students enjoy the privilege of having their laboratory and related needs covered by the research fund of their professors. This system may be ideal in developed countries where the applied technological needs of its agricultural producers are taken care of by the governmental research institutions and the academe covers the basic aspects of scientific investigations. In a way, however, this is being centrist and without regard for what is happening around, and what the needs of the people are in the region or other parts of the globe. This may be viewed as *self preservation* or *academic survivalist* on the part of the resource-rich scientist by their counterparts in the developing countries who are vulnerable to food insecurities simply because they cannot do so much for reason of lack of necessary resources and technical capabilities to some extent (Pardales and Yamauchi, 1999).

The staggering situation of the world food supply (FAO, 2000b; 2002a) and the opportunities and prospects that other crops like rootcrops could offer (FAO, 2000a; Scott et al, 2000a; 2000b) therefore calls for the agricultural scientists and students in developed countries to be *sensitive* to explicitly consider the problems of food production especially in countries having poor and erratic food production performance. Academics and students must be keen of what is happening in the global or regional agriculture arena. They must both be observant of the issues and concerns of agriculture for the rest of the world. They must be flexible and bold to venture into different realms of research. They must be ready to leave their laboratories occasionally to work with partners (not as subordinates, not as mere recipient of technical aids, but as equals) in foreign lands where the greater food production problems are usually realized.

Academics must also be more vocal in rationalizing the necessity that research-funding agencies give funds for studies on crops other than what are considered economic priority crops of Japan. It is a great relief though that the way of thinking of some funding agencies is slowly changing towards the positive side of this.

For instance, the Japanese Ministry of Education, Science and Culture (Monbusho), has started a few years ago in approving research grants to the Laboratory of Crops Science, and presently the Bioresources Cycling Laboratory (BCL) of the Graduate School of Bioagricultural Sciences for studies centered on rootcrops. These grants paved the way for certain Japanese scientists to engage in collaborative work with some foreign researchers. The case in focus could be the latter laboratory's (BCL) collaboration with the Philippine Root Crop Research and Training Center (PhilRootcrops) in studying the drought resistant mechanisms of rootcrops, which is in accordance with FAO's challenge to combat drought and produce more food with less water (FAO, 2002b; 2002c).

Research Avenues on Rootcrops to Bolster its Role as Food, Feed and Industrial Materials

While limiting their viewpoint on participatory research with farmers in developing agricultural technology, Pardales et al., (2001) included some activities where participatory research may have greater application. Considering the greater challenge of the present in the light of food security apprehensions, the same activities could be considered as the avenues over which participatory research or collaborative works on rootcrops could be made to strengthen their position in meeting the demand for food, feed and industrial raw materials. These research avenues are as follows:

- *Development of new rootcrop varieties.*

While the farmers as producers and consumers at the same time have their specific requirements in a variety of certain rootcrops, the needs of the greater majority of the people and the industry on a global context may be entirely different. In view of this, breeding strategies may need to be an issue for participative discussion by as many stakeholders as possible especially if the breeding process requires techniques beyond conventional methods or support activities that are not within the means of one laboratory or institution. An example of this could be the breeding for high anthocyanin content in sweet potato for the food coloring industry (Odake, 1998) or for the emerging health food business (Kays and Kays, 1998), or simply to improve the nourishment of the greater majority of the people who are resource poor and depend on sweetpotato as primary food item for their households (Scott et al., 2000a).

The fact that rootcrops is eaten by scores of millions of people around the world and the greater number of this are from Asia, the bigger challenge in tailoring new rootcrop varieties is in improving their nutritive content since rootcrops are normally low in basic nutritional composition (Bradbury, 1988; Wheatley et al., 1995). Basically, this is a research area that necessitates the use of advance tools in biotechnology so as to shorten the breeding process and to win the race against time to avert undernourishment of some 515.2 million people in Asia-Pacific alone (Singh, 2000).

The other areas whereby specific participatory or collaborative research may be done along this main research avenue are as follows:

- o Genetic resources evaluation.
- o High starch content.
- o Resistance to pests and disease organisms.
- o Resistance to environmental stress factors.
- o Early maturation.
- o Resistance to post-harvest deterioration.
- o Non-conventional breeding approaches.

- *Improvement and/or development of production and post-harvest practices.*

Rootcrops are generally known as hardy crops that grow in adverse condition, yet they are found to be sensitive in many extents to unfavorable environmental factors (Pardales et al., 1999; Pardales et al., 2000; Pardales, et al., 2001; Pardales and Esquibel, 1996; Agili and Pardales, 1997, etc) which ultimately reduce their economic yield. The underlying reasons for environmental stress sensitivity and yield reduction in rootcrops is not thoroughly understood yet, so that, there is a great need for in depth studies on the eco-physiology of these crops right in the place where they are commonly grown so as to increase, stabilize, and sustain if possible, their production levels on a unit area basis. Traits that confer resistance or tolerance to certain adverse factors are still to be clearly identified so as to feedback plant breeders with the appropriate characters for inclusion in their design for an improved variety.

Furthermore, rootcrops tubers or corms are highly perishable (Scott et al., 2000a; Scott et al., 2000b; NAS, 1978) so that losses are great if they are not handled well after harvest. Hirose and Data (1983) and Uritani and Data (1983) have elucidated the physiology and biochemistry of deterioration in cassava, but there could be more new insights that could be discovered in the light of today's novel technological tools, which may help prevent rapid deterioration of fresh rootcrops produce.

Along this line, the following are some examples of the areas that need focused research attention:

- o New production practices and techniques.
- o Non-chemical based weed control.
- o Non-chemical based production and postharvest pest control.
- o Physiological response to various environmental stress factors such as limited water supply, high soil temperature, soil acidity, shade, etc. to develop mitigating interventions.
- o Novel handling and storage techniques to check physical, physiological and biochemical deteriorations.

- *Improvement and/or development of production and processing tools and equipment.*

Rootcrops production may be the least automated venture among the economic crops grown for whatever purpose. This is because most of its production areas are in marginal locations and the common systems of production are mostly subsistent and semi-commercial. To some extent even those considered commercial farms in developing countries mostly resort to draft animals for land preparation and other cultivation activities. Because of this, the efficiency of rootcrop production is very low. In terms of processing, starch mills, for example, in many countries employ the antiquated machines that are inefficient and cost ineffective. Village level processing are mostly manual. The following should be the subjects of attention by concerned researches with advanced know-how and fundamentals:

- o Low cost draft animal-drawn tillage and cultivation implements.
- o Functionally designed lightweight and low cost production and processing tools and simple machines for women and children.
- o Novel commercial production, post-harvest and processing machines.

• *Development of new products*.

Wheatley et al. (1995) mentioned that the sizable potential of rootcrops for contributing to socioeconomic development in rural areas requires a combination of efficient, sustainable crop production with new or improved products and markets. Because the products have to be competitive, product development has to consider identification of product ideas, research, piloting and commercialization. This line of activities seemingly appears simple but is actually intricate for ordinary players since a number of considerations like local market situation, constraints and opportunities have to be viewed with clear focus. Again, concerted efforts from various players have to take center stage if rootcrop production is to be boosted by strong value adding up through processed product development. Basically, the studies that may need to be conducted in this area should be as follows:

- o Market survey techniques to identify new products with high market potential.
- o Product development
- o Piloting techniques
- o Market sensitivity
- o Commercialization
- o Management techniques.

Conclusion

Rootcrops are an acknowledged bunch of crops the world over with great potentials, foremost of which is its promise to offer food security to scores of millions of vulnerable resource limited people. Although these crops are generally associated with poverty, their prospects do not end with the poor. The developed world receive benefits from these crops, unknowingly probably to most policy experts, and scientific people because of the different forms by which they may be traded, e.g., starch, chips, frozen items, etc. Yet, in spite of this, rootcrops are not being given much research attention to fully exploit their uses, which have been proven to some extent to even go beyond the traditional like as source of medical remedies, etc.

Critical evaluations of the potential of root and tuber crops have been published. World bodies like CGIAR and FAO have acknowledged these crops to provide food security in the light of an increasing world population, getting adverse climatic condition, depleting natural resources and worsening livelihoods among the disadvantaged sectors of society. The scientific community is therefore challenged to respond, and the act of doing so is not that difficult. This is because the nature and background of the crops are known, the system of their production is understood, their uses are made clear, the element of mitigation is suggested and the necessary adjustments to react to the challenge is given, and so as the main and tributary avenues of research. If there is a need for more understanding to affect a more thorough intervention along these areas, it is just a matter of reaching out to the farmers, researchers and other players in the agricultural arena of the less developed world. Sensitivity is key.

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Status and Prospects of Asian Forests and Forest Products

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Abstract

Forest is a very important natural resource not only because of its various functions, but also because of the great challenge and opportunity it offers to mankind. Although it is a renewable resource, its sustainability and functions require wise and sound management. Forest goods in Asia range from wood to non-wood forest products (NWFPs). Forest services and utilization range from soil and water conservation, to employment, tourism and recreation, mitigation of climate change, conservation of biological diversity, and expression of cultural and spiritual values. The different living standards of the people in a particular country, make various stakeholders place different values on the forest. Universities have a role to play in the conservation and management of the forests, as well as in helping find solutions to problems concerning the sustainability of the forests.

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The role of forests is becoming more and more important while their existence is subjected to increasing pressure brought about by the increase in population, which cause the conversion of forest lands into residential areas and food crop lands, as well as the increased demand for forest products, among others. In the Asian region, forests (natural and plantation) occupy a vast 548 million ha of land out of the total land area of 3,085 million ha. It is not the smallest one as compared with the forestland in Oceania region, which only occupied an area of 198 million ha, and more or less equal to the forest area in North and Central America region, but it only occupied 18% of its area, as compared with 23% for Oceania, 26% for North and Central America, or 22% for Africa.

Asia, with a population density of 117.8 per km^2 in 1999, is much denser than the world average of 45.8 per km^2 and is the densest region compared to Oceania of 3.5 per km^2, South America of 19.4 per km^2, North and Central America of 22.3 per km^2, Africa of 25.7 per km^2, or even Europe of 32.2 per km^2.

To reduce the pressure on natural forest as a source of raw material (wood) for the industry, plantation forests have been established in large areas in some Asian countries. Trees in such plantation have been mainly utilized recently for pulp and paper industries. There have been objections on the monoculture system of the plantation forest as having negative environmental and social impacts, but so far there have been no solution. Harvesting in forest plantation also left many residues such as leaves, branches and barks that can still be utilized instead of being burned. The barks of some trees contain substances such as tannin that can be used for wood-based industry.

Among the available products that can be obtained from the forest, the share of wood is only five percent of the total economic value, as in the case of Indonesia's natural forest despite the fact that people in the country rely mostly on such commodity for a living. Leaves of many trees actually contain an essential oil; however, promotion on the utilization, and the added value from such products are still being neglected. Various alternative food crops can be obtained from the forest especially during times when the country faces shortage of staple foods. The problem is that there is a lack of knowledge and ability to utilize such alternative economically including the processing and storage of crops for longer periods of time. A better use of NWFPs will assure the existence of tree plantation and hopefully leads to sustainable forest management.

Deforestation in the Asian forests has recently increased dramatically. The causes of forest degradation are varied. In order to avoid overexploitation of forest products a sound forest planning and management should be implemented.

Attention should also be focused on the deforestation caused by forest fire. Establishment of monoculture forest plantations has been identified as one of the main causes of forest fire. To cope with the limited available space, the people in some parts of this region have to implement a more efficient and intensive use of the land. Agroforestry is one of the alternatives to address such limitation. Efforts to introduce agroforestry has increased recently, but related information and studies on the implementation of agroforestry are still limited.

A timber-oriented exploitation in the management of the forest has to be shifted to sound forest ecosystem management--a condition that could conserve our rich biological diversity. Efforts in reducing CO_2 emission need a deeper and comprehensive study on their effects to the existing natural and plantation forests. The potential social, economic and biological diversity benefits arising from investment in high-quality conservation, agroforestry and sustainable forest management initiatives, however, should be clarified.

Almost all countries in Asia still encounter many problems in implementing and assuring sound sustainable forest management. Universities, as one of the key players in human resources development, have to come up with ideas and solutions to challenge the problem related to sustainable forest management. Unfortunately, most of the universities in Asia only put little attention to it. The introduction of a university networking among the countries in Asia, and a stronger cooperation among them will probably lessen the problems.

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Nutritional Management to Control Environmental Impact in the Sustainable Animal Production

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Abstract

The animal industry must be environmentally sound to insure its long-term sustainable growth. In order to prevent pollution from animal waste, P, N, and pharmacological level minerals should be properly managed. Microbial phytase has been used successfully to control P excretion. Activity of natural phytase in certain plant feedstuffs is high enough to be considered in feed formulation. Nitrogen control can be achieved through amino acid supplementation and protein restriction in the diet. Supplementation with carbohydrases reduces output of excreta as well as N. Ammonia release from the manure can be reduced by using a low crude protein diet along with the supplementation of probiotics products. Excretion of minerals, which are used at pharmacological level can be reduced by using chelated forms. Cu and Zn in the form of methionine chelate have been successfully used in the diets of broilers, layers and/or pigs.

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Introduction

The animal industry must be environmentally sound to ensure its long-term sustainable growth. Livestock wastes, mostly manure, can be a valuable resource as a fertilizer or soil conditioner. But it can be a potential hazard to environment as well. Environmental concerns relate to water quality, soil degradation, air pollution and rural-urban interface issues. Land application of excessive quantities of nutrients is subject to surface run-off and leaching that may contaminate ground or surface waters. Phosphorus (P) entering surface waters can stimulate growth of algae and water plants. Decomposition of these plants results in an increased oxygen demand, which may interfere with the well-being of fish and wildlife. Nitrate leaching has been considered a major nitrogen (N) pollution concern with livestock farms. Ammonia toxicity to fish and altered effectiveness of chlorination are other concerns. Manure can be a major source of methane and nitrogen oxides that contribute to the accumulation of greenhouse gas. Volatilization of ammonia is the cause of the acid rain that resulted in forest dieback in western Europe (ApSimon et al, 1987). Emissions of nitrous oxide (N_2O) during nitrification and denitrification cause depletion of the stratospheric ozone layer (Christensen, 1983). Manure can be a source of odors that contribute to friction between urban and rural residents. Excessive contributions of some minerals from animal manure can create high salt concentration in the soil. High concentration of copper and zinc in the pig diets (Paik, 2001) can cause accumulation of these minerals in the soil. Major efforts are required to adopt all the best available technologies capable of reducing excretion of pollutants from animal industry before further restrictive legislation is enacted to control the problem. There are a number of possible solutions to this problem. The first option of manure management is developing ‘an environmentally sound’ nutritional management, that is, feeding program and feeds to result in less excreted nutrients that need to be managed. The present paper reports the results of experiments conducted at the author's laboratory regarding the nutritional management to control environment pollution from animal production.

Experiment

1.Phosphorus Control

1) Microbial Phytase

Layer experiments

It has been reported that hens consuming the low nonphytate P (NPP) diet with supplementary phytase performed as well as the hens fed with diets containing higher levels of NPP without supplementary phytase (Gordon and Roland, 1997;Van der Klis and Versteegh, 1996). In a feeding trial with laying hens the effectiveness of microbial phytase in diets based on corn-soya and wheat-soya was tested (Peter and Jeroch, 1993). The supplement of phytase (500 U/kg diet) or inorganic P (0.1% of diet) had a positive effect on the performance of the corn-soya group but no effect on that of the wheat-soya group. The highest breaking strength of the eggshell was recorded with hens that received the phytase supplement in the corn-soya group. Mineralization of the tibia bone was also improved with phytase addition. The response to the level of supplementary phytase was quadratic. Supplementation of 250 U of phytase/kg diet in laying hens was equivalent to 0.8g of P from monocalcium phosphate (MCP) (Van der Klis et al, 1994) while supplementation of 500 U to a corn-soybean meal diet was equivalent to 1g of P (Peter and Jeroch, 1993). Simons et al. (1992) reported that supplementation of diets with 250 U of phytase/kg resulted in the degradation of 62% and 56% of the phytate-P at low and high Ca levels, respectively. Increasing phytase from 250 to 500 U/kg of diet had a further effect on degradation, increasing it by 16% and 11% at respective Ca level. Three layer experiments were conducted to determine if microbial phytase supplementation can reduce non-phytate phosphorus (NPP) level in a practical laying diet and result in concomitant reductions in P excretion. Following in Table 1 are abstracts of layer feeding trials conducted at the author's laboratory.

In Layer Experiment 1, supplementation of the microbial phytase to normal corn-soybean diet improved egg production and can reduce TCP level in the diet without affecting egg production and egg quality. Significant reduction of P excretion can also be achieved. (Um and Paik, 1999)

In layer Experiment 2, the NPP concentration in the diet of Brown layers consuming about 130g/d of feed can be safely lowered from 0.27% (0.55% total P) to 0.16% (0.45% total P) and excretion of P was also reduced by the inclusion of 250 U phytase/kg of diet. (Um et al, 1999)

In Layer Experiment 3, supplementation of microbial phytase at a level of 300U per kg diet of laying hens can improve egg production, decrease broken and soft egg production rate and P excretion. The level of Ca and NPP significantly modifies the effects of phytase supplementation. (Lim et al, 2002)

Provided phytate P content and plant phytase activity are taken into account, it should be possible to mix layer diets which require minimum amount of supplementary inorganic P with 250 U phytase supplemented (Um et al., 1999) or do not require supplementary inorganic P sources with 500 U phytase supplemented (Um and Paik, 1999). In layers, the degradation of phytate and the absorption of P was slightly decreased by higher amounts of Ca in the diets (4.0% vs. 3.0% Ca in feed), nevertheless at both levels the efficacy of phytase addition was satisfactory. Addition of up to 300 units phytase per kg feed for laying hens resulted in a minimal equivalency of 0.3 g MCP P per 100 units phytase.

Table 1. Effects of supplemental phytases on the productivity and P excretion of laying birds.

Experiment	Level of NPP[1], %	Supplemental phytase, unit	Egg production	Feed/egg mass	P excretion
Layer-1	0.37	0	100	100	100
	0.37	500	102.2	99.6	88.5
	0.24	500	100.4	100.4	70.5
	0.12	500	100.4	100.4	59.0
Layer-2	0.27	0	100	100	100
	0.22	250	100.3	100.5	88.5
	0.16	250	101.4	98.6	67.3
	0.11	250	99.1	100.3	57.7
Layer-3	0.25(Ca 4%)	0	100	100	100
	0.25(Ca 4%)	300	103.1	99.8	94.4
	0.25(Ca 3%)	0	102.1	96.1	102.8
	0.25(Ca 3%)	300	104.5	91.6	86.1
	0.15(Ca 4%)	0	97.6	130.4	86.1
	0.15(Ca 4%)	300	97.2	101.6	72.2
	0.15(Ca 3%)	0	100.6	89.9	83.3

[1]Nonphytate phosphorus.

Broiler experiments

In broiler chickens, phytase supplementation at a level of 1,000 U/kg diet increased the bioavailability of P and Ca by 60% and 26%, respectively (Simons et al, 1990). The beneficial effects of phytase supplementation were illustrated by Zyla and Korelski (1993). The performance of birds fed with available P deficient diets was improved by the addition of phytase to the diets. The *in vitro* activity (i.e. ability to dephosphorylate phytate) was also demonstrated, confirming the proposed mode of action of this enzyme. The direct benefits of dietary phytase supplementation on bone mineralization have been shown by Farrel and Martin (Annison and Choct, 1993) who reported that tibial ash deposition was enhanced in birds fed with phytase supplemented diets. Simons and Versteegh (1993) summarized the results of several experiments conducted in Netherlands. A microbial phytase product from *Aspergillus niger* was added to broiler feed with a low inorganic P level. The availability of total P could be increased up to 70%. In comparison with feed with increased levels of inorganic feed phosphates, a significantly larger amount of the P consumed was absorbed. Improved utilization of P decreased its excretion by 40% or more. Growth and feed conversion ratios were comparable with feed to which inorganic feed phosphate was added. In broilers up to 500 units of phytase per kg feed, 250 units phytase was equivalent for P absorption with 0.5 g of P from MCP per kg feed. The following Table 2 presents abstracts of broiler feeding trials conducted at author's laboratory.

In Broiler Experiment 1, NPP level of corn-soy broiler diets can be safely lowered by approximately 0.2% by supplementing 600 U of microbial phytase/kg diet. With the adjusted level of NPP and phytase supplementation, P excretion could be reduced by 50%. (Um et al, 2000).

In Broiler Experiment 2, lowering NPP level in the broiler diet significantly depressed the performance. Supplementation of crude phytase preparation produced from Aspergillus ficuum could partially recover the depression. (Paik et al., 2000)

In Broiler Experiment 3, dietary phytase could reduce P excretion and alleviate adverse affects caused by feeding low dietary NPP. Effects of phytase supplementation were greater in the lower NPP diets. (Lim et al, 2001)

In broiler Experiment 4, supplementation of the crude phytase, produced from the broth of *Aspergillus ficuum* culture, to broiler diets containing low NPP level improved growth performance and mineral availability and reduced fecal P excretion. (Lee et al, 2000a).

Table 2. Effects of supplemental phytase on the productivity and P excretion of broiler

Experiment	Level of NPP[1], %		Supplemental	Performance index		
	Starter	Finisher	phytase, unit	Gain	Feed/gain	P excretion
Broiler Exp.1	0.45	0.40	0	100	100	100
	0.34	0.31	600	101.0	98.7	76.2
	0.23	0.22	600	99.3	101.3	54.8
	0.12	0.13	600	96.7	103.3	40.5
Broiler Exp.2	0.45	0.35	0	100	100	100
	0.35	0.25	0	89.4	100.6	84.8
	0.25	0.15	0	60.5	108.7	51.5
	0.25	0.15	600, Phyt-A[2]	82.2	109.3	39.4
	0.25	0.15	600, Phyt-B[3]	78.9	109.3	45.5
Broiler Exp. 3	0.45	0.35	0	100	100	100
	0.45	0.35	500	99.9	100	107.4
	0.35	0.25	0	87.3	102.5	85.2
	0.35	0.25	500	97.0	100.6	70.4
	0.25	0.15	0	57.3	101.2	81.5
	0.25	0.15	500	65.1	108.1	55.6
Broiler Exp.4	0.45	0.35	0	100	100	100
	0.45	0.35	600, Phyt-B[3]	100.6	100	92.7
	0.35	0.25	0	92.5	103.0	78.6
	0.35	0.25	600, Phyt-B[3]	100.5	101.2	72.9

[1]Nonphytate phosphorus, [2]Crude phytase A(soup + cell) from *Aspergillus ficuum*, [3]Crude phytase B(soup), from *Aspergillus ficuum*.

2) Plant Phytase

It is generally accepted that approximately one third of phosphorus in the plant origin feedstuffs are available to monogastric animals. However, proportion of phytate P of total P varies widely from 12% in tapioca to 83% in wheat bran. Natural phytase content in the feedstuffs also varies widely from almost none in corn to 2395U in wheat bran (Lee et al, 1999). Such differences should be considered in calculating available P content of diets. Three experiments have been conducted in the author's laboratory to study the characteristics of plant phytase and its application to feeding of broilers. The following are abstracts of experiments.

Plant Phytase Experiment 1

An experiment was conducted to measure the contents of phytate-P, total-P and phytase activity of cereals and cereal by-products. The effects of pH and temperature on the activity of wheat and microbial phytase were compared. Phytate-P content was higher in most cereal by-products than in cereal. Rice bran had the highest phytate-P (1,201mg/100g) followed by defatted rice bran (1,077mg/100g), corn gluten feed (896 mg/100g), wheat bran (742mg/100g) and rapeseed meal (535 mg/100g). The phytate-P contents of other ingredients were lower than 500 mg/100g. Total-P content was high in defatted rice bran (1,899 mg/100g), rice bran (1,889 mg/100g), and rapeseed meal (1,016 mg/100g) compared to other ingredients. Wheat and wheat bran had the highest phytase activity (1,121.9 and 2,935.1U/kg) among ingredients tested (Table 3).

Characteristics of wheat phytase and microbial phytase were compared. Both of them showed similar characteristics at varying pH and temperature. Maximum activities were achieved around pH5.5 and 50∞C (Figure 1 and 2). Considering these characteristics, plant phytase may be as effective as microbial phytase to the animals.

Table 3. Total P, phytate P content and phytase activity of plant origin feedstuffs

Ingredients	Phytate-P /100g	Total-P /100g	Phytate-P % of total P	Phytase activity, U/
Corn	60	182	32.7	0.2
Lupin	55	307	17.8	3.2
Tapioca	7	59	11.9	18.8
Wheat	199	295	67.5	1120
Sesame meal	542	816	66.4	3.0
Soybean meal	286	577	49.6	7.5
Cottonseed meal	303	678	44.7	2.4
Cocunut meal	204	539	37.8	350
Corn germ meal	32	130	24.4	12.6
Corn gluten meal	287	536	53.5	170
Corn gluten feed	896	1099	81.5	14.8
Rapseed meal	535	1016	52.7	103
Wheat bran	742	893	83.1	2935
Rice bran	1201	1886	63.7	-
Rice bran (fat-free)	1077	1899	56.7	114

(Lee et al., 1999)

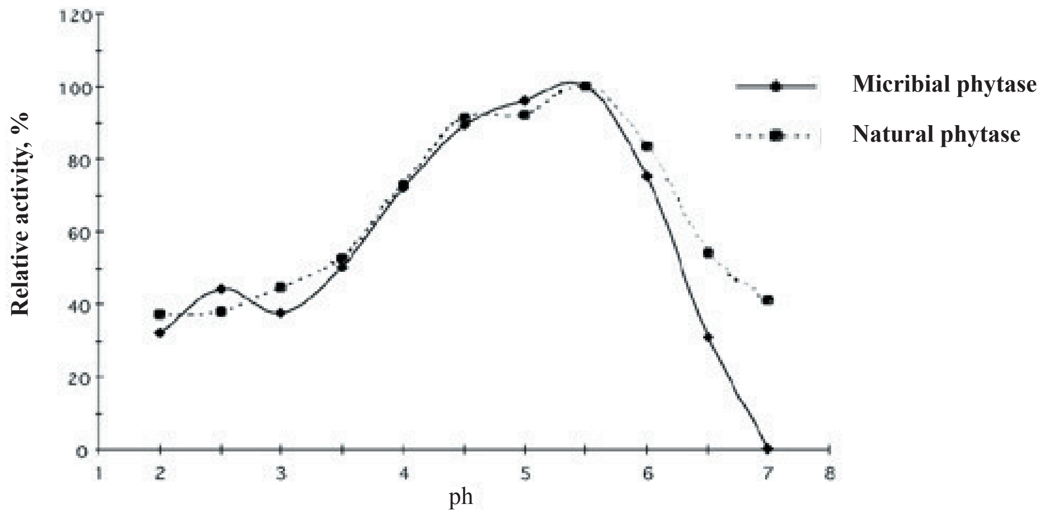


Fig 1. Activity of microbial and plant origin natural phytase at different pH

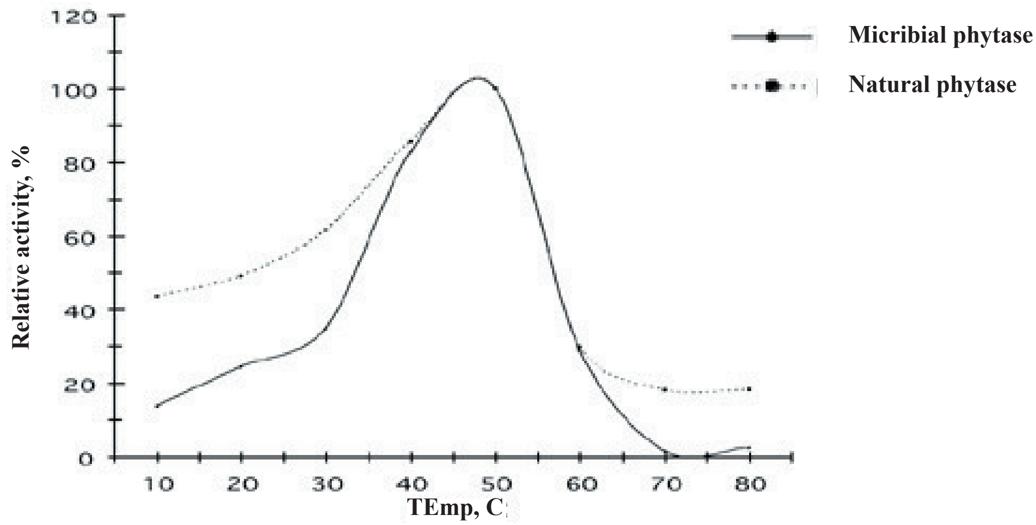


Fig 2. Activity of microbial and plant origin natural phytase at different temperature

Plant Phytase Experiment 2

This study was conducted to evaluate the efficacy of wheat and wheat bran as the source of phytase in a 5-week broiler feeding trial. One thousand day-old broiler chickens (Ross®) were divided into 20 pens of 50 broilers(25 male and 25 female) each. Four pens were randomly arranged to one of the five dietary treatments: T1, control diet containing normal NPP level ; T2, T1- 0.1% NPP; T3, T2£´600IU microbial phytase(NOVO®) per kg diet; T4, T2 £´600IU plant phytase from wheat and wheat bran; and T5, T2£´600IU plant phytase from wheat and hydrothermally treated wheat bran. Table 4 shows details of the feed formula of starter diets. Reduction of NPP level by 0.1% (T2) reduced weight gain and feed intake but plant phytase treatments (T4 and T5) recovered the lost performance. Plant phytase treatments showed better performance than the microbial phytase treatment (T3). There was no difference between regular wheat bran treatment (T4) and hydrothermally treated wheat bran treatment(T5). Mortality was highest in low NPP diet (T2) (Table 4). Availability of ether extract and crude ash of grower diet was highest in normal wheat bran diet (T4). Availability of Ca and P of grower diet was highest in T4 followed by T3 and T5. Availability of Mg, Fe and Zn was more drastically improved by phytase treatments (T3, T4 and T5) (Table 5). Excretion of Ca, P, Mg, Fe and Zn was lowest in microbial phytase treatment (T3). Serum level of Ca and Mg was highest in the low NPP treatment (T2). Tibial ash content of T2 and T3 was lower than that of T1, T4 and T5. However, tibial Ca content was higher in T1 and T2 than other treatments. Tibial P and Mg contents were highest in T1. It was concluded that plant phytase from wheat and wheat bran can be effectively used to improve P utilization of the broilers fed low NPP diets. Plant phytase improved the availability of crude ash and minerals such as Ca, P, Mg, Zn and Fe of the diets. Hydrothermal treatment of wheat bran prior to inclusion in the diet had no beneficial effects (Kim et al, 2002).

Table 4. Body weight gain, feed intake, feed/gain and mortality of broiler chickens fed experimental diets from 1 to 35 days

Item	Age (day)	Treatments[1] T1	T2	T3	T4	T5	SEM
Weight gain, g/bird	1-21	703.8[a]	577.1[c]	654.5[b]	683.6[a]	688.0[a]	8.89
	22-35	906.9[a]	712.3[c]	797.0[b]	880.7[a]	904.1[a]	18.06
	1-35	1610.7[a]	1289.5[c]	1451.5[b]	1564.3[a]	1592.1[a]	23.44
Feed intake, g/bird	1-21	973.6[a]	814.8[c]	919.5[b]	951.7[a]	965.6[a]	9.42
	22-35	1674.6[a]	13545.0[c]	1487.0[b]	1642.2[a]	1707.2[a]	35.69
	1-35	2648.2[a]	2160.6[c]	2407.4[b]	2594.9[a]	2672.8[a]	44.01
Feed/gain (g/g)	1-21	973.6[a]	814.8[c]	919.5[b]	951.7[a]	965.6[a]	9.42
	22-35	1674.6[a]	13545.0[c]	1487.0[b]	1642.2[a]	1707.2[a]	35.69
	1-35	2648.2[a]	2160.6[c]	2407.4[b]	2594.9[a]	2672.8[a]	44.01
Mortality, %	1-21	2.00	3.50	3.00	1.50	3.50	0.97
	22-35	0.00	3.62	2.06	0.00	1.04	0.92
	1-35	2.00[b]	7.00[a]	5.00[ab]	1.50[b]	4.50[ab]	1.27

[1]T1 = control diet containing normal NPP level, T2 = control diet - 0.1% NPP, T3 = control diet – 0.1% NPP + 600IU microbial phytase, T4 = control diet - 0.1% NPP + 600IU natural phytase(wheat +wheat bran), T5 = control diet - 0.1% NPP + 600IU natural phytase(wheat + soaked wheat bran)
[a-c] Values with different superscripts in the same row are significantly different (p<0.05).

Table 5. Availability of Ca, P, Mg, Fe and Zn of broiler grower diets

Item(%)	Treatments[1] T1	T2	T3	T4	T5	SEM
Calcium	26.0[d]	26.7[d]	46.1[b]	57.2[a]	38.9[c]	1.93
Phosphorus	33.5[b]	35.1[b]	47.5[a]	49.9[a]	37.0[b]	2.08
Magnesium	8.2[b]	13.9[b]	31.1[a]	30.7[a]	26.3[a]	2.10
Iron	3.36[d]	3.69[d]	15.98[c]	37.64[a]	23.04[b]	1.80
Zinc	17.6[c]	8.0[d]	29.0[b]	42.7[a]	21.3[b]	1.92

[1]T1 = control diet containing normal NPP level, T2 = control diet - 0.1% NPP, T3 = control diet – 0.1% NPP + 600IU microbial phytase, T4 = control diet - 0.1% NPP + 600IU natural phytase(wheat +wheat bran), T5 = control diet - 0.1% NPP + 600IU natural phytase(wheat + soaked wheat bran)
[a-d] Values with different superscripts in the same row are significantly different (p<0.05).

Plant Phytase Experiment 3

An in vitro test and a broiler feeding trial have been conducted to test the effect of hydrothermal treatment of wheat bran on phytate-P degradation and its feeding effect in broiler. Hydrothermal treatment of wheat bran was carried out at 55 ° with pH 5.5 buffer. Phytate-P content of wheat bran showed quadric decrease as the rate of wheat bran : buffer ratio increased from 1:0.5 to 1:5. Phytate-P degradation was not significantly affected by incubation time above 10 min., drying temperature (55°, 65° and 75°) or pH of buffer (5.5 and 7.0). Feeding trial was conducted with 240 sex separated day-old broiler chickens (Ross ®). Broilers were randomly housed to 24 cages of 10 birds each. Six cages (3 in each sex) were assigned to 4 treatments control; normal level of non-phytate-P (NPP), LP; low NPP treatment which has 0.1% lower NPP than the control, LPWB; LP with wheat bran, which provides 500IU of plant phytase per kg diet, LPHWB; LP with hydrothermally treated wheat bran. Results of feeding trial showed that broilers of LP treatment gained significantly lower than other treatments in starter period (1~21d) but only male broilers of LP gained significantly lower than the control in grower (22~35d) and overall period (Table 6). There were no significant differences among the birds of LPWB, LPHWB and control. Feed intake of overall period was not significantly different between LPWB and control but that of LP was lower than LPHWB and that of LPHWB was lower than control. Feed conversion ratio was significantly lower in LPHWB and LP than in control and LPWP. Mortality was highest in LPHWB. Utilizability of crude fat, crude ash and Ca was significantly lower but that of Fe was significantly higher in LP than other treatments. Utilizability of P, Mg and Zn was higher in LPWB and LPHWB than in control and LP. Excretion of P was significantly lower in low NPP treatments than in control (Table 7). Serum Ca level was highest but serum P level was lowest in LP. Tibial crude ash content was high in wheat bran treatments but tibial Ca content was high in control and LP. Tibial P content of LP and LPWB was lower than control. However, Tibial content of Fe was highest in LP. It was concluded that wheat bran, a source of plant phytase, can be used in low NPP broiler diet to prevent the depression of performance. Reduction of P excretion can be achieved concomitantly. Hydrothermal treatment of wheat bran was effective in improving utilizability of some minerals but was not effective in improving performance of broilers (Kim and Paik, 2002).

Table 6. Body weight gain of broiler chickens fed experimental diets from 1 to 35 days. (g/bird)

Age (day)	Sex	Treatments[1]				SEM
		T1	T2	T3	T4	
1-21	Male	773.3	704.0	772.6	766.9	23.36
	Female	719.6	678.4	709.7	729.7	17.27
	All	746.5[a]	691.2[b]	741.2[a]	748.3[a]	16.73
22-35	Male	874.8[a]	811.9[b]	863.8[ab]	866.8[ab]	18.04
	Female	782.7	764.9	773.7	790.2	19.64
	All	828.8	788.3	818.8	828.5	21.24
1-35	Male	1648.2[a]	1515.9[b]	1636.5[ab]	1633.7[ab]	36.69
	Female	1502.3	1443.6	1483.4	1502.3	23.57
	All	1575.2	1496.6	1559.9	1576.8	34.15

[1]T1 = control diet containing normal nonphytate P(NPP) level, T2 = control diet - 0.1% NPP, T3 = control diet - 0.1% NPP + 500IU plant phytase(wheat bran), T4 = control diet - 0.1% NPP + 500IU plant phytase(hydrothermally treated wheat bran)
[a,b] Values with different superscripts in the same row are different ($p<0.05$).

Table 7. Excretion of Ca, P, Mg, Fe and Zn of broilers fed grower diets

Item	Treatments[1]				SEM
	T1	T2	T3	T4	
	-------------- g/bird/d ----------------				
Calcium	0.396	0.363	0.346	0.348	0.018
Phosphorus	0.234[a]	0.174[b]	0.168[b]	0.172[b]	0.008
Magnesium	0.108	0.115	0.105	0.102	0.005
	------------- /bird/d ---------------				
Iron	93.71	91.94	99.16	101.02	4.74
Zinc	48.67	46.52	48.24	48.42	2.12

[1]T1 = control diet containing normal nonphytate P(NPP) level, T2 = control diet - 0.1% NPP, T3 = control diet - 0.1% NPP + 500IU plant phytase(wheat bran), T4 = control diet - 0.1% NPP + 500IU plant phytase(hydrothermally treated wheat bran)
[a,b] Values with different superscripts in the same row are different ($p<0.05$).

2. Nitrogen Control

1) Amino Acids Supplementation and Protein Restriction

The effects of protein levels and enzyme supplementation to corn-soy diets on daily N output in broiler are shown in Table 8.. Broilers fed with reduced protein diets supplemented with amino acids performed as well as, if not better, than the broilers on the control (normal) protein diets and showed a significant reduction in daily N output (24% at 2 wk and 17% at 5 wk).

A similar experiment with laying hens indicated that reducing crude protein levels of corn-soy diets from 17% to 13.5% with supplementation of synthetic amino acids significantly reduced the daily N output (24.8% and 35.6% in collection 1 and 2, respectively) with no significant effect on egg production except one treatment with phytase (Table 9).

Table 8. The effect of dietary protein and enzymes on the growth performance and daily N output of broilers

Diet description			Weight gain		Feed intake		Feed conversion		Daily N output (g/bird)	
Protein	Phytase	Pentosanase	2 wk	5 wk	2 wk	5 wk	2 wk	5 wk	2 wk	5 wk
Control[1]	no	no	643	2272	758^{ab}	2942	1.27^{b}	1.81	0.67^{abc}	2.12^{a}
Control	yes	no	626	2277	794^{a}	2907	1.37^{a}	1.76	0.73^{ab}	1.66^{bc}
Control	yes	yes	641	2326	793^{a}	2959	1.33^{ab}	1.76	0.80^{a}	1.80^{bc}
Control	no	yes	642	2325	761^{ab}	2961	1.28^{b}	1.77	0.63^{bcd}	1.92^{ab}
Average			638	2300	777	2942	1.31	1.78	0.71	1.88
Reduced[2]	no	no	635	2230	747^{ab}	2882	1.27^{b}	1.82	0.58^{bcd}	1.91^{ab}
Reduced	yes	no	608	2138	735^{b}	2765	1.31^{ab}	1.81	0.53^{cd}	1.74^{bc}
Reduced	yes	yes	598	2106	754^{b}	2747	1.36^{a}	1.82	0.48^{d}	1.39^{cd}
Reduced	no	yes	646	2250	758^{ab}	2894	1.26^{b}	1.80	0.56^{cd}	1.56^{bcd}
	Average		622	2181	749	2822	1.30	1.81	0.54	1.65

[1]The protein levels of control protein diet were 23% CP in starter and 21% CP in grower.
[2]The potein levels of reduced protein diet were 21% CP in starter and 17.5% CP in grower. Reduced protein diets were supplemented with synthetic amino acids to meet their requirements.
[a-d]Values with different superscripts in the same column are different ($p<0.05$).
(Jacob, et al. 2000a)

Table 9. The effect of dietary protein and enzymes on the egg production and daily outputs of dry matter and nitrogen of laying hens

Diet description			Egg production	Daily output (g/layer)			
				DM		N	
Protein	Phytase	β -glucanase	%	Collection 1	Collection 2	Collection 1	Collection 2
17	no	no	85.8^{a}	28.99^{a}	31.40^{a}	1.21^{a}	1.38^{ab}
17	yes	no	86.9^{a}	26.47^{ab}	26.17^{ab}	1.13^{abc}	1.21^{b}
17	yes	yes	89.1^{a}	30.24^{a}	30.92^{a}	1.36^{a}	1.45^{a}
17	no	yes	86.6^{a}	28.74^{a}	29.25^{a}	1.30^{ab}	1.38^{ab}
	Average		87.1	28.61	29.44	1.25	1.36
13.5[1]	no	no	85.0^{ab}	26.79^{ab}	26.17^{ab}	1.06^{bc}	0.98^{c}
13.5	yes	no	78.4^{b}	21.34^{c}	18.67^{c}	0.91^{c}	0.78^{c}
13.5	yes	yes	82.6^{ab}	21.92^{c}	22.53^{bc}	0.86^{c}	0.94^{c}
13.5	no	yes	84.9^{ab}	23.78^{bc}	22.51^{bc}	0.92^{c}	0.79^{c}
	Average		82.73	23.46	22.47	0.94	0.87

[1]13.5% CP diets were supplemented with synthetic amino acids to meet their requirements.
[a-c]Values with different superscripts in the same column are different ($p<0.05$).
(Jacob, et al. 2000b)

2) Carbohydrase Supplementation

Non-starch polysaccharides (NSP) in some feed grains (e.g. pentosans or arabinoxylans in wheat and rye, and b-glucans in barley and oat) are soluble fibers. Their presence can either block digestion of other nutrients (e.g., protein and starch), or can seriously inhibit absorptive capacity. Therefore, the digestibility of NSP is low in monogastric animals. It was found that the results of using enzymes (xylanase or b-glucanase) did not stem from complete hydrolysis of the non-starch polysaccharides but that relatively minor hydrolysis altered the ability of the medium to form a viscous solution and act as a barrier to endogenous enzyme activity. In the past few years a number of different feed enzymes have been developed. The use of multi-enzyme preparations in traditional wheat-based poultry diets was examined (Graham, 1992). The results demonstrated that with a diet based on 60% wheat, a mixed enzyme preparation was capable of increasing the rate of live-weight gain (+17%) and at the same time reducing feed conversion ratio (1.46 to 1.29). There was also an increase in the N utilization percentage (37.4 to 45.3%). Such improvements were attainable even after pelleting, which in itself was capable of solubilizing starch (Pettersson et al., 1991). A commercial multi-enzyme preparation from *Trichoderma viride* contained 11,150 U/g cellulase, 27,600 U/g glucanase and 37,150 U/g xylanase. This multi-enzyme product was tested with layers fed with a barley-based diet (Brufau et al., 1994) and a wheat-based diet (Um et al., 1998). The results showed that barley and wheat could replace corn as an energy source in layer diets if the enzyme is properly supplemented. For the better utilization of enzymes in feed industry, commercial enzyme preparations should be customized depending on the animal species, age of animals and major feed ingredients. Enzyme products that contained β -glucanase and xylanase in different proportion were produced from *Trichoderma longibrachiatum* and *Bacillus subtilis*. They were used with different diets (wheat-based or barley-based) in different animal species of different ages (poultry, starting pigs or growing-finishing pigs). Enzyme products supplemented to the respective diets reduced the viscosity caused by non-starch polysaccharides and increased amino acid availability as well as energy and P availability (Creswell, 1994). Low and Longland (1990) reported that N retention of pigs was slightly increased by enzyme supplementation. Contents of moisture and N were lower in the litter of birds given diets supplemented with β -glucanase. Measurement of ammonia release from the litter indicated that when a second flock of birds was raised on the same litter, the presence of a glucanase in the diet reduced the level of ammonia release by 80% (Williams and Kelly, 1994). An experiment was conducted to test the possible interaction of an enzyme complex and feed antibiotics on growth and metabolic parameters of broilers. The basal diet contained barley at a level of 40%. Both supplements, when added together in the diet, had almost an additive effect on growth parameters, and energy, fat and N utilization (Vukic Vranjes and Wenk, 1993). Overall nutritional management can result in the reduction of manure output. A proven and more direct method is enzyme supplementation. Reducing the DM content of the digesta in the intestinal tract with supplemental feed enzymes has a marked impact on excreta volume and composition. In a trial offering wheat or wheat/barley-based diets to broilers, excreta weight was reduced by 17 - 28% in fresh or 12 - 15% in DM by supplementation of a multi-carbohydrases enzyme product. The direct production benefits of lower excreta output and reduced fecal DM are seen in some broiler trials where observations on the frequency of hock lesions and breast blisters are recorded. Reductions in manure output and water content will improve litter quality, and possibly decrease carcass downgrade.

A layer experiment was conducted to evaluate the effect of a microbial enzyme (Roxazyme-G), a multi-carbohydrases preparation, supplementation to the wheat-based layer diets. Diets were formulated to include different levels of wheat replacing yellow corn on isocaloric and isonitrogenous basis. The energy value of wheat in the enzyme supplemented diets was adjusted (spec-modified) to have 5% more ME than the wheat in diets without enzyme. A total of 864 Hy-Line brown layers were assigned to 4 dietary treatments: 10% wheat (T1), 25% wheat (T2), 25% wheat (spec-modified)£´0.01% Roxazyme-G (T3), and all wheat (spec-modified)£´0.01% Roxazyme-G (T4). Overall performances are shown in Table 10.

Table 10. Overall performance of laying hens fed experimental diets during 20 to 40 wk of age

Parameters	Treatments[1]				SEM
	T1	T2	T3	T4	
Egg production (%, hen-day)	74.65^{a}	73.60^{b}	74.03^{ab}	74.78^{a}	0.33
Egg production (%, hen-housed)	67.10^{BC}	67.67^{AB}	66.23^{C}	68.72^{A}	0.33
Egg weight, g	58.73^{A}	58.65^{A}	58.51^{AB}	58.14^{B}	0.119
Feed consumption (g/hen/day)	128.83^{A}	126.35^{B}	129.05^{A}	129.23^{A}	0.339
Feed conversion (feed/egg mass)	2.93	2.92	2.97	2.95	0.039
Mortality (%)	7.84	6.05	7.84	6.38	1.143

[1]T1: 10% wheat, T2: 25% wheat £´ 5 ppm Carophyll Red, T3: 25% spec-modified wheat £´ 0.01% Roxazyme-G £´ 5 ppm Carophyll Red, T4: spec-modified wheat(no-restriction) £´ 0.01% Roxazyme-G £´ 5 ppm Carophyll Red £´ 25 ppm Carophyll Yellow.
[a,b, A-C] Means with different superscript in the same row are significantly different at p < 0.05 (a,b) and p < 0.01(A-C).

Hen-day egg productions of T1 and T4 were significantly ($P < 0.05$) greater than that of T2 but not different from T3. Hen-housed egg production of T4 was significantly ($P < 0.01$) greater than those of T1 and T3 but not different from T2. Egg weights of T1 and T2 were significantly ($P < 0.01$) greater than that of T4. Feed consumption of T2 was significantly ($P < 0.01$) lower than other treatments. Feed conversion ratio (feed/egg mass) was not significantly different among treatments. Eggshell thickness of T1 was significantly ($P < 0.01$) greater than other treatments but ratio of broken eggs was not significantly different among treatments. Haugh unit of T4 was significantly greater ($P < 0.05$) than that of T2. Egg yolk color was significantly ($P < 0.01$) influenced by treatments in which enzyme treatment potentiated the yolk pigmentation. It was concluded that a multi-carbohydrases supplementation enables complete replacement of yellow corn with wheat without loss of productivity and major egg quality parameters (Um et al., 1998).

3) Ammonia control

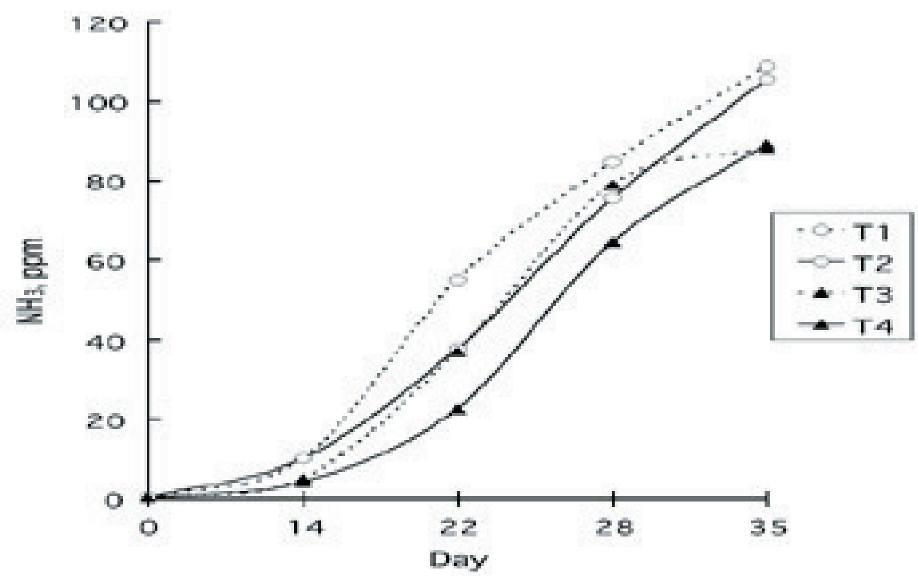
Ammonia release from animal manure should be controlled to avoid air pollution and conserve N in the manure for use as fertilizer. The smell of pig slurry has four times the intensity of cattle, broiler and poultry manure (Pain, 1990). In terms of odour control, ammonia reduction may only play a contributory role since Schaefer (1977) correlated odour intensity with the concentrations of volatile fatty acids (C2 -C5), phenol, *p*-cresol, indole, skatole and ammonia, the highest correlations were obtained with *p*-cresol. Conservation of N in manure is important because P or K usually limit use of poultry manure for crop production and other sources of N are needed when the manure application is limited to needs for fertilizer elements. Ammonia release from manure can be limited by using additives, by drying and by acidic conditions. Research into minimizing air pollution from animal wastes is continuing and taking many different paths. In the Netherlands, for example, they have identified a microorganism (aerobic denitrifier) which, under aerobic conditions, converts the nitrogen of ammonia and other nitrogen containing compounds into nitrogen gas. Nitrogen gas can be released into the atmosphere without causing pollution problems. Adding such bacteria to manure would reduce the emission of ammonia and reduce the nitrogen content of the manure. They are looking at the possibility of adding these bacteria to the feed (Holthuijzen, 1993). The ammonia-binding properties of the *Yucca* extract have been widely studied. The earlier reports on the action of a *Yucca* extract to prevent the accumulation of ammonia erroneously attributed its action to an inhibition of urease by its component three steroid saponins, i.e. sarsapogenin, smilagenin and hecogenin. But Headon et al. (1991) reported that the *Yucca* extract does not inhibit urease activity and that saponin-free De-Odorase had an ammonia-binding capacity similar to that of the unfractionated De-Odorase. Recent work by Headon and Power (unpublished, cited by Leek, 1993) demonstrated that the binding agents in the *Yucca* extract are glycocomponents. Because the ammonia-binding action starts to decline slowly from fourth day onwards, levels of atmospheric ammonia within the houses can be significantly reduced by including this product in the diet. Zeolite products have been used at a level of 1 to 2% of the diet to improve pelleting quality. It is also believed that zeolite may improve the litter condition and environment of the barn. Due to a high ion-exchange capacity, it is expected that zeolite may bind ammonium ion in the litter (Moon et al., 1991). However, dietary supplementation of zeolite or top dressing of zeolite on the broiler litter did not significantly influence the level of ammonia produced from the broiler litter (Blair and Jacob, unpublished).

Table 11 and Figure 3 are summaries of an experiment conducted to reduce ammonia level in the broiler barn. Diets were formulated to have different protein level with or without supplementary amino acids (arginine, threonine and tryptophan) and a probiotic product (*Bacillus subtilis and Lactobacillus*) (Lee at al., 2000b).

Table 11. Feed intake, weight gain, feed/gain and mortality in broiler chickens fed different protein level diets for 35 d

Diets	Feed intake	Weight gain	Feed/gain	Mortality
	(g)	(g)	(g:g)	%
T1 (21.5% CP)	2869.8	1636.0a	1.76b	3.60
T2 (21.5% CP+BIO-21[1])	2879.9	1626.8a	1.77b	2.00
T3 (18.5% CP+AA[2])	2794.5	1518.6b	1.85a	0.40
T4 (18.5% CP+AA+BIO-21)	2859.3	1511.6b	1.88a	2.00
SEM	32.74	12.09	0.02	1.31
	Main effects			
	CP			
21.5 %	2874.9	1631.4a	1.76b	2.80
18.5 %	2826.9	1515.1b	1.87a	1.20
BIO-21(SP)				
0 %	2832.1	1573.8	1.80	2.00
0.1 %	2869.6	1572.7	1.83	2.00

[1]BIO-21 is a commercial probiotics containing B. *subtilis, Lactobacillus* and yeast.
[2]AA: amino acids supplement of arginine, threonine and tryptophan.
a,b Values with different superscripts in the same column are significantly different($P<0.05$).



Footnotes : T1; 21.5% CP, T2; 21.5% CP+BIO-21, T3; 18.5% CP+AA T4; 18.5% CP+AA+BIO-21

Fig 3. Ammonia level at the litter of broiler barn, determined in the air collected for 60 sec using trapping box of 36 L × 27 W × 18H.

3. Mineral Control

Some micromineral supplements are produced in the form of protected forms. Metal amino acid chelate (Ashmead, 1992), metal proteinate and metal polysaccharide complex are protected minerals. The protected minerals may be more available and not react with digesta due to both their chemical (electrically neutral, ligand and metal make up) and physical structures (size and ligand source). If this is the case, we could use less to achieve the same result. This would be excellent as potentially it would save world resources and reduce pollution (Lowe, 1993).

1) Cu-Chelates

Growth performance- broilers and pigs

Summary of effects of copper sources on the growth performance of broilers and pigs is shown in Table 12. The effects of copper sources were compared with the results of non-supplemented control groups. In broiler experiments, supplemental copper sulfate at the level of 200ppm was effective for increasing weight gain in Cu-Exp 1 and 3 but not in Cu-Exp 2, 4 and 6. Supplementation of chelated copper products, especially SQM-Cu and Met-Cu, improved weight gain and feed conversion efficiency in broilers. In Cu-Exp 1, supplementation of 127ppm of Cu from SQM was as good as higher level of Cu (191ppm from SQM and 200ppm from $CuSO^4$) in broiler performance. In Cu-Exp 3, chelate mineral combination of Cu, Zn and Fe (Met-Cu-Zn-Fe), which are known to have strong interactions, did not perform any better than Met-Cu alone. In Cu-Exp 4, 125ppm of Cu in the form of Met-Cu performed as good as 200ppm of Cu of the same source. In Cu-Exp 5, the growth-promoting effect of 100ppm Cu from Met-Cu was better than those from chitosan chelate or yeast chelate. The effect of Met-Cu on the performance of broilers was high compared to those of sodium alginate-Cu (Cu-Exp.2) or fish meal-Cu (Cu-Exp.3). Supplementation of copper sources had a detrimental effect on rats (Cu-Exp.6), however. In Cu-Exp 8, weanling pigs fed diet supplemented with 100ppm of Cu in the form of Met-Cu performed as good as, if not better, those fed 200ppm of Cu from either Met–Cu or $CuSO_4$.

In general, feed conversion efficiency was consistently improved by Cu supplementation regardless of the sources of Cu. However, growth-promoting effect was variable depending on the sources of Cu, animal species and unidentified variables of experimental conditions. Met-Cu, SQM-Cu, and copper sulfate had a better growth promoting effect in pigs than in broilers

Considering the results of Cu-Exp 7 and 8 (pig), and 1,4 and 5 (broiler chickens), it appears that dietary level of 100~125ppm copper in the chelated form is enough to improve the performance of chickens and pigs. This will result in a reduction of fecal Cu excretion The growth-stimulating action of dietary Cu has been attributed to its antimicrobial actions (Fuller *et al*., 1960; Vogt *et al*., 1981). However, the antimicrobial hypothesis alone can not fully explain the effects of Cu. It has been demonstrated that intravenous injection of Cu stimulates the growth of weanling pigs (Zhou *et al*, 1994).

The results of this experiment indicated that Cu acts systemically to influence the growth regulatory system in many ways. It is also known that copper regulates cholesterol biosynthesis by reducing hepatic glutathione concentration (Kim et al, 1992). Therefore, copper deficiency induces hypercholesterolemia in rats (Klevay, 1973). In Cu-Exp 4 and 5, copper supplementation tended to reduce serum and muscle total cholesterol and increase serum HDL cholesterol level in broilers (Paik et al, 1999). Kratzer and Vohra (1986) reported that metal ion chelated with low molecule weight peptides are more stable, neutral electronically and therefore, chelated minerals are better able to pass through intestinal wall than are ionic minerals.

Laying performance

Pharmacological level of copper is not commonly used in layer diets because it can cause gizzard erosion. However, supplementation of copper in the form of Met-Cu improved performance of laying birds. In Cu-Exp 11, 75ppm Cu in the form of Met-Cu showed best performance in egg production, egg weight, feed conversion efficiency and eggshell strength. In Cu-Exp 12, 100ppm treatment showed slightly better performance than 50ppm treatment. Supplementation of Met-Cu to layer diet is a subject of further study (Lim and Paik, 2001).

Table 12. Effects of supplementary copper chelates on the performance of broilers and pigs

Copper Experiments	Animals	Source and level of Cu, ppm	Difference from the control, %		
			Gain	Feed intake	Feed/gain
1	Broiler	$CuSO^4$, 200	3.8	-0.2	-4.0
		SQM-Cu, 63.5	2.6	0.6	-3.5
		SQM-Cu, 127	3.5	-0.2	-4.0
		SQM-Cu, 191	3.8	1.7	-2.0
2	Broiler	$CuSO^4$, 200	-0.9	-0.6	0.0
		Met-Cu, 200	2.5	-0.5	-3.3
		SA-Cu, 200	1.1	-0.3	-1.6
3	Broiler	$CuSO^4$, 200	4.3	-1.4	-5.7
		Met-Cu, 200	6.3	3.1	-3.2
		Met-Cu-Zn-Fe, 200	2.2	0.0	-1.9
		FM-Cu, 200	2.0	1.2	-0.6
4	Broiler	$CuSO^4$, 250	-1.5	-2.2	-0.6
		Met-Cu, 125	4.6	2.3	-2.5
		Met-Cu, 250	4.0	2.4	-1.8
5	Broiler	Met-Cu, 100	5.3	2.8	-2.3
		Chitosan-Cu, 100	2.3	4.4	2.3
		Yeast-Cu, 100	1.8	4.9	3.4
6	Broiler	$CuSO^4$, 200	0.3	-2.0	-2.2
		Met-Cu, 200	2.1	-0.5	-2.2
		FM-Cu, 200	0.2	-1.4	-1.7
	Rat	$CuSO^4$, 200	-7.0	-5.3	1.9
		Met-Cu, 200	-7.5	-3.7	3.8
		FM-Cu, 200	-6.3	-3.0	3.4
7	Pig	$CuSO^4$, 200	6.4	4.0	-3.1
		SQM-Cu, 63.5	4.1	0.9	-3.5
		SQM-Cu, 127	7.5	3.1	-4.8
8	Pig	$CuSO^4$, 200	7.5	-5.9	-3.8
		Met-Cu, 100	10.1	0.4	-1.9
		Met-Cu, 200	8.2	9.6	0.0
9	Pig	$CuSO^4$, 200	5.5	2.6	-4.6
		Met-Cu, 200	17.8	-7.2	-9.8
		FM-Cu, 200	0.0	-16.4	-4.6
10	Pig	Met-Cu, 100	0.3	-2.1	-2.4
		Chitosan-Cu, 100	1.7	-3.7	-1.0

Footnotes: $CuSO_4$; $CuSO_4\ \sum 5H_2O$, SQM-Cu; sequestered mineral copper; Met-Cu; methionine-copper chelate, SA-Cu; sodium alginate-Cu complex, FM-Cu; fish meal digest-Cu complex, Met-Cu-Zn-Fe; methionine-copper, zinc and iron complex, Chitosan-Cu; chitosan-copper complex, Yeast-Cu; yeast-copper complex.

Table 13. Effects of supplementary methionine-copper chelate on the performance of laying birds

Copper Experiment	Level of Cu, ppm	Difference from the control, %				
		Egg production	Egg weight	Feed intake	Feed conversion	Eggshell strength
11	25	2.11	0.21	0.99	-1.30	1.63
	50	1.46	1.50	2.60	3.03	1.33
	75	3.84	2.16	3.74	-1.73	3.26
	100	3.66	1.85	4.01	-1.30	0.15
12	50	1.75	0.67	2.82	0.00	4.31
	100	2.33	0.98	1.13	-1.65	3.10

Conducted for 12 wks with 740 ISA Brown layers of 56wk old.
Conducted for 8 wks with 396 ISA Brown layers of 72wk old.

2) Zn-Chelates

The effects of supplemental zinc in weanling pigs are shown in Table 14. In the first experiment, 100 and 200ppm of Zn in the form of Met-Zn and 200ppm in the form of ZnO increased weight gain and feed intake compared to the control (100 ppm of Zn from ZnO). In the second experiment, 1,000 or 2,000ppm of Zn in the form of ZnO increased weight gain and feed intake. At the level of 100ppm in the form of Met-Zn improved weight gain and feed intake but high dietary level of Zn (1,000 and 2,000ppm) in this form had adverse effects on the performance. Zinc is an essential element being the prosthetic of many metalloenzymes, such as carbonic anhydrase, alcohol dehydrogenase, carboxy peptidase, alkaline phosphatase, thimidine kinase, RNA and DNA polymerase and so on. Zinc also plays a role in immune system (Miller et al, 1979; Beach et al., 1980; Dardenne and Bach, 1992) and reproduction system (Kirchgessner and Rothe, 1992). Kasahara and Anraku (1972; 1974) reported that Zn ion might be related to the inhibition of active transport system and respiratory chain of E. coli. Holm (1988) and Poulsen (1989) reported that supplementing high level of ZnO could control baby pig diarrhea caused by E. coli. In Zn-Exp 1 and 2, the activity of alkaline phophatase activity increased as the dietary level of Zn increased regardless of the source of Zn. Serum IgG concentration tended to be higher in Met-Zn treatments as compared to ZnO treatments at 100 and 200ppm Zn level. However, the opposite was true at 1,000 – 2,000ppm level of Zn. The results of the present experiments indicate the 100 - 200ppm of Zn in the form of methionine chelate may be adequate for the improvement of weanling pig performance (Ahn et al, 1998 a,b).

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Table 14. Effects of supplementary zinc oxide and methionine zinc chelate in weanling pigs

Zinc Experiment	Source and level of Zn, ppm	Difference from the control (ZnO, 100 ppm), %		
		Gain	Feed intake	Feed/gain
1	ZnO, 200	8.3	9.6	0.5
	Met-Zn, 100	3.0	3.0	0.5
	Met-Zn, 200	18.8	15.1	-3.8
2	ZnO, 1000	10.0	9.2	-1.4
	ZnO, 2000	11.0	12.8	1.4
	Met-Zn, 100	15.6	15.9	0.0
	Met-Zn, 1000	6.5	12.2	7.6
	Met-Zn, 2000	-2.0	9.4	11.7

Footnotes: Met-Zn; methionine-Zinc chelate

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Case Study on Development of the Sustainable Agricultural System for Various Agro-ecosystems Through Assessment of Nitrogen Flow

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Abstract

Importance in the sustainability of agricultural systems has long been recognized in relation to maintaining and improving agricultural productivity in harmony with the surrounding environment. In many cases, however, the sustainability is discussed rather qualitatively, not quantitatively. This is mainly because of lack of measurable indicators to express the degree of the sustainability in the system. The nutrient is an essential element for the agricultural systems and the appropriate management of such nutrient should be one of the key points for sustainable development of the system. Moreover, the nutrient flow within the system can be quantified at a certain degree and the nutrient budget that is a consequence of balance between input and output may be closely related to sustainability. Optimization of nitrogen cycling in the farm community is considered to be an important aspect as nitrogen is a major nutrient to increase agricultural production. In this paper, a whole picture of the nitrogen cycle for agricultural production that was constructed based on data collected from agricultural statistics, research reports, study reports, field observation, interview with farmers and information from experts, will be presented with particular focus on three areas in the East and Southeast Asian countries such as Shandong province in China, Northeast Thailand, and Mekong Delta. The obtained nitrogen budget is also discussed in order to improve sustainability of the system.

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Introduction

The nutrient flow, especially for nitrogen, has been studied to obtain accurate budget in the field even before issues on the sustainability became hot spot in the agricultural research. A nitrogen balance sheet makes it possible to (1) assess the flows of nitrogen through society in order to decide on the most efficient measures to reduce surpluses (in setting up such an overview, a number of uncertainties or knowledge gaps are invariably identified), and (2) to quantify complex variables that cannot be measured directly, for example,) excretion of nitrogen by farm animals and loss of nitrogen to air, soil, ground and surface water. Various models are now available to estimate the nutrient budget in the system. In order to assess inputs, redistribution and losses relative to soil fertility, Brown et al (1999) developed a nutrient budget model that can accept yield, input and management data obtained from farm interviews. The nitrogen turnover model developed by Rothamsted uses readily available input parameters to simulate N turnover in the soil-crop system. Nitrogen turnover is described in the model by a set of zero and first-order equations for (i) uptake of mineral N by the crop, (ii) mineralization-immo bilization turnover of organic matter, and (iii) gains and losses of N from the soil-crop system (Smith et al, 1996).

The nitrogen flow can be drawn not only for the particular farmland but also for regional and even sub-national or national level (Mishima et al. 1999, De Koning et al. 1997). As the spatial coverage is expanded, more parts of the flow should depend on speculation or extrapolation from the statistical data or other scientific information. Even though the accuracy may be reduced by the spatial expansion, it should be very important to have overall view on the nutrient flow in the target area as problems related to inflow and outflow in the farmland can be identified and the way to optimize the nitrogen flow can be proposed. Recent research reveals considerable potential to combine nitrogen balance and information from soil and other maps with statistical, mathematical and geographical information system (GIS) techniques for spatial expansion. The nutrient balances establish a link between agricultural nutrient use, and changes in environmental quality and the sustainable use of soil nutrient resources (Parris, 1998).

Although various types of farming systems can be seen in East and Southeast Asian countries, the dominant systems in the region largely depend on local biophysical conditions, especially climatic factors that most affect agricultural production and can not be modified by the effort of the individual farmer. The agro-ecosystem in the region can be broadly classified into six categories according to the FAO definition as can be seen in Fig. 1. The FAO agro-ecological zoning system is based on simple parameters such as length of growing period, mean monthly temperature and daily mean temperature (Pingali et al, 1997). In this paper, an example of typical farming operation will be picked up from three agro-ecosystems (warm semiarid subtropics with summer rainfall, warm sub-humid tropics and warm humid tropics) and direction of sustainable development of farming systems will be briefly discussed based on research outcomes that have been produced by the projects that the Japan International Research Center for Agricultural Sciences (JIRCAS) conducted in the region. Special attention will be placed to analyze agricultural production from the viewpoint of nitrogen flow for its sustainable development.

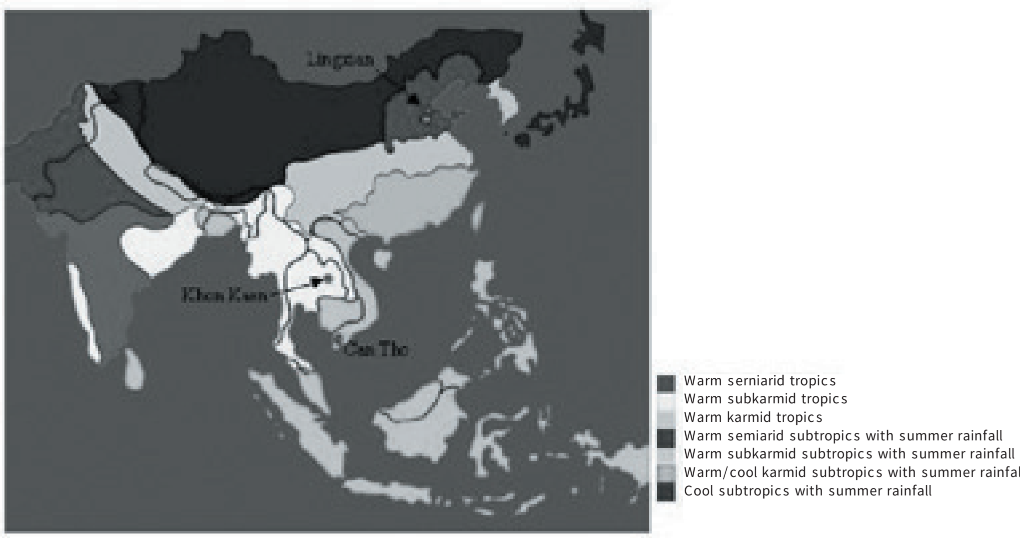

Fig 1 Agroecological zones in south, south east and east Asia
(modified from Pingali et al. 1997)

Estimation of Nitrogen Flow

A whole picture of the nitrogen cycle for agricultural production in three target regions was developed based on data collected from agricultural statistics, research reports, study reports, field observation, interview with farmers and information from experts (Matsumoto et al, 2000, Matsumoto et al, 2003).

Nitrogen Flow in Shandong Province in China

The first example is from Lingxian County, Shandong Province, China that belongs to warm semiarid subtropics with summer rainfall (Yagi and Hosen, 2000). The intensive upland cropping is dominant with wheat, maize, vegetables and cotton as major crops. The regional analysis of the nitrogen flow indicated an excessive load of nitrogen to arable land and the environment (Fig. 2). The load is mainly due to increasing consumption of chemical fertilizer in addition to increasing manure application. The analysis of nitrogen budget based on statistics suggested that the balance between input and output of nitrogen in arable land was 288 kg N/ha/year in 1997. There was an increasing trend in the nitrogen load; for example, the balance in 1981 was 159 kg N/ha/year that accounted for 55% of that in 1997. Nitrate pollution to groundwater due to excessive application of nitrogen fertilizer should be a major concern in near future, but the present level of nitrate in the groundwater collected from wells is still within the acceptable range, indicating that the nitrate pollution has not been widely spread in the region despite increasing amount of nitrogen application.

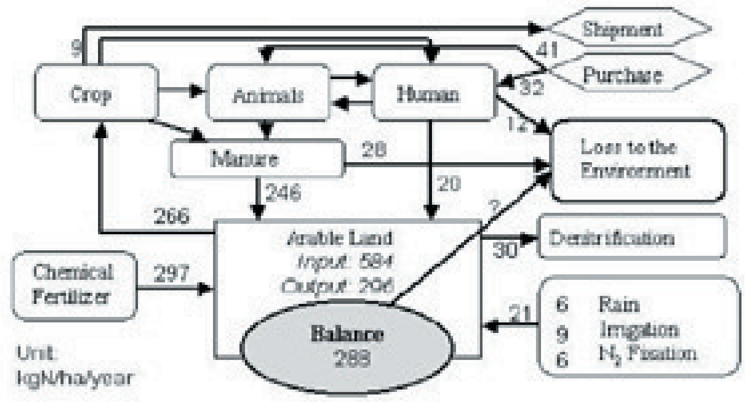

Fig 2 Nitrogen flow in agro-ecosystem of Lingxian province in China (1997) modified from Yagi and Hosen 2000

Nitrogen Flow in Northeast Thailand

The second example is from Northeast Thailand that belongs to the warm sub-humid tropics. Northeast Thailand receives annual rainfall ranging from 700 to 1600 mm, depending on location and year. More than 90% of the annual rainfall occurs between May and October. Major agricultural activities are carried out during the rainy season (Lindsay, 2000). Soils are often sandy or skeletal, and problems of salinity are extensive in this region. Nearly 55% of the total land area in Northeast Thailand has been already exploited for agricultural production. Within the area in agriculture, however, less than 10% is supplied with irrigation. Thus agriculture in Northeast Thailand depends primarily on the quantity and pattern of rainfall received (Pattanee, 2000). Rainfed lowland paddy, cassava and kenaf have been major crops since the 1960's, but lately sugarcane has become a major cash crop. Deforestation has led to changes in the hydrologic environment and has caused widespread salinity problems in this region. Soil erosion and soil fertility deterioration are also becoming serious problems in cassava growing areas. Because of these problems, the agricultural productivity is on the decline. One possible way to improve soil fertility may be more efficient use of locally available nutrient resources such as crop residues and animal feces. In order to identify the available resources, it is necessary to quantify nutrient cycle through agricultural activities such as crop and livestock production in the region, and clarify limiting factor for effective utilization of the nutrient resources.

Developing technologies to assure sustainable crop production requires a better understanding of the material cycling (especially nitrogen) of this region, together with efficient management and utilization of water resources, reforestation, minimization of soil erosion, arresting further decline in soil fertility, and crop diversification. Also, development of improved production systems that can utilize local resources and create employment opportunities for the local population should be promoted in this region. Livestock industry including dairy farming should be further promoted in Northeast Thailand as rapid economic growth in other parts of this country is expected to create a substantial demand for milk and meat in the near future. Thus, integrated agricultural development that can functionally link agricultural crop production and livestock industry together with vegetable and horticultural production should be the goal for improvement in the overall productivity of this region, which may reduce the negativity in the nitrogen balance owing to more availability of animal wastes as organic manure, and which should then lead to improvement of the soil fertility decline.

Although nitrogen in crop residues amounts to more than 50 kg N/ha/year, more than half of them is removed from the field or burned (Fig. 3). Most of animal feces are returned to the field, but its production is still limited because of underdevelopment of livestock industry. The return of human excrements and fresh garbage is insignificant. The local farmers do not actively practice yet the application of nitrogen fertilizer. Thus the nitrogen balance in the farmland results in negative value. Nitrogen that has been returned to the farmland is less than nitrogen that has not been returned to the farmland such as the one burned after harvest. It is important for optimization of nitrogen balance to establish the efficient use of those returnable organic resources.

Many workers have identified soil organic matter as a key factor in maintaining soil fertility and crop production. Its maintenance is an essential requirement for increasing and maintaining productivity. Long-term straw incorporation has improved soil fertility and productivity of the soils at the Surin Rice Experiment Station in Northeast Thailand (Withbread et al, 1999). However, the incorporation of rice straw can only return part of the nutrients to the soil as nutrients are removed in grain. The estimated nutrient removal from paddy fields in Northeast Thailand, with average rice grain yields of 1.7t/ha, is about 28 kgN, 6.2 kg P, 3.4 kg S, and 24 kg K ha/year. In the extremely sandy soils of Northeast Thailand with inherently low cation exchange capacity, organic matter amendments are essential if mineral N fertilizers are to be used without risk of acidification causing crop damage (McDonagh et al, 1995). Although nutrient balance analyses are seen as a powerful tool for the assessment of critical components of the sustainability of these land-use systems as shown here, such tools are challenged by the complexity of these systems. This complexity arises from spatio-temporal biophysical, socio-economic and institutional variability at different spatial scales and with different stakeholders being involved (Konboon et al, 2002).

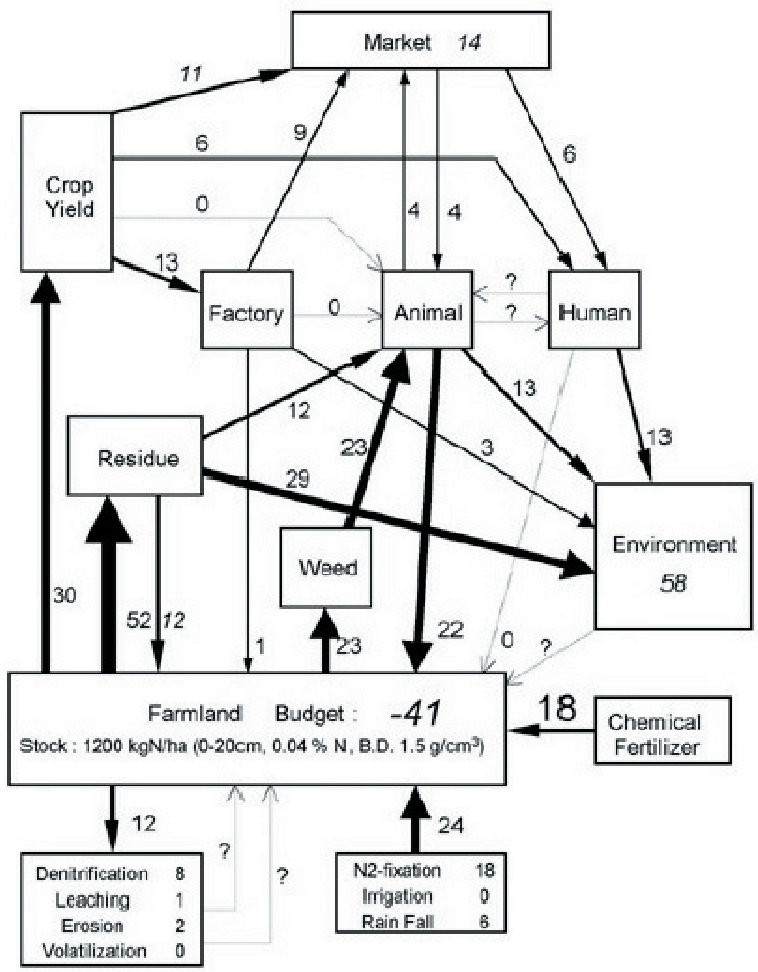

Fig 3 Nitrogen flow in Khon Kaen province, Thailand (Matsumoto et al. 2003)

Nitrogen Flow in Mekong Delta

The last example is from Mekong Delta that belongs to the humid tropics according to the FAO definition. The Mekong Delta is situated from 8 °35 ′N to 11 °N with average temperature 27 °C in Can Tho City. The annual rainfall is around 1,600mm, most of which occurs during rainy season with almost no rain in February and March, which are the middle of dry season. The Mekong Delta is rich in water resources with the dense network of canals that function as irrigation, drainage and transportation for various types of boats. Moreover, major road systems are constructed along the canals, indicating multifunctional importance of the canal network. In the area with less developed canal network, flooding is the most serious problem because of insufficient drainage. Currently, some 17 million people live in this area, but the number is expected to increase up to 21 million by the year 2010.

Although intensive rice production is the major agricultural activity in the region, integrated farming operation has been widely adopted by the local farmers. The system is specifically named VAC that stands for garden (Vuon), pond (Ao) and pen (Chuong) in Vietnamese language. The system has been very effective to sustain agricultural production of the region in the past. In the Mekong Delta, approximately 400,000 ha are suitable for freshwater aquaculture, but today less than 10% of the area is used for this purpose. After the Mekong Delta was turned to be major area for rice exportation, many problems that threaten the sustainable development of local agriculture become visible. One of the problems is the imbalance of inflow and outflow of nitrogen. The detailed study to normalize the balance through more efficient use of local resources was initiated as one of the international projects conducted by JIRCAS.

The application of nitrogen fertilizer is becoming excessive. Nearly half of the rice straw is burned after the harvest, resulting in loss of nitrogen into the atmosphere. It should be important to establish a more efficient way of usage for the rice straw. The Can Tho province belongs to a major rice-exporting region in the country, and export of nitrogen in milled grain is equivalent to one third of nitrogen applied as chemical fertilizer. The rice bran left after milling is effectively utilized as hog feed. Comparatively a large amount of nitrogen is put to the fishponds. Major nitrogen source to the ponds is animal excreta. In order to reduce the river pollution due to excessive dumping of animal excreta, it is important to introduce such processes as the use of a bio-digester and composting. Currently, nitrogen pollution in the river has not been quantitatively detected. This is mainly because of dilution by tremendous amount of water in the Mekong River. With increased dumping, the pollution may become serious in the near future. The nitrogen balance in the farmland of Can Tho province is showing already positive value and has tendency to be more positive. The rice-fish farming provides a sustainable alternative to rice monoculture, if the farmer takes full advantage of the natural productivity of the rice field ecosystem. The aim should be to reduce the resource use, avoid overuse of agrochemicals and improve production efficiency through increased recycling of nutrients and matter. The introduction of fish into the paddy fields has been shown to reduce the need for pesticides, increase the farm household income and diversify agriculture production. Thus, it is believed that integrated farming systems can help farmers increase their farm incomes and enhance sustainable agriculture and rural development (Berg et al, 2000).

Concluding Remarks

It is demonstrated by this study that approach to make a quantitative analysis of nitrogen flow in an administrative unit should be a very useful tool to identify constraints for sustainable development of farming systems in the region. As a result of analysis, the way to promote local resource utilization will be suggested, which provides decision makers with realistic options for sustainable development of agricultural production that best fits to the region.

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Toward Sustainable Agricultural Production System: Major Issues and Needs in Research

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Abstract

Current agricultural sciences are expected to contribute to find new values and functions of agriculture by taking environmental issues into account in addition to increased productivity. Modern agriculture has started harming environments, which include not only those surrounding the human life but also those that ensure sustainability of agricultural production. Development and progress in one aspect impose load on resources and threaten sustainability. Thus, we need to continue to find ways for sound coexistence between nature, environment and human activities. Long-term research is needed to understand the trade-off relationship between sustainability and productivity, which incorporates not only different disciplines of science but also includes social, cultural and economical components.

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1. Agricultural production and environmental issues

The expectations of society from agricultural sectors and the consequent roles of agricultural sciences have been changing with time. In Japan, agricultural productivity has remarkably increased especially after World War II, in which agricultural activities are supported by the progress of production technology. The target of agricultural sciences then was focused on increased productivity that is quite simple and clear. On the other hand, the current agricultural sciences are expected to contribute to the proposal of new values and functions of agriculture by taking environmental issues into account in addition to increased productivity, which is extremely difficult and challenging. That is the subject that will be examined in this paper.

The trend of the dependency on chemical materials for crop production that often leads to increased productivity had been intensified in the latter half of the 1960's in developed countries and later spread to developing countries. In many of the developing countries, the production of cash crop, especially those intended for export was more encouraged than the production of subsistent crop, which often reflects in statistics as increased agricultural production. On the other hand, the ecological implication of increased export of agricultural products is the removal of resources from the land, which has been causing various environmental degradations. In turn, it causes excess deposition of the resources in importing countries. In Japan, for example, importing large amount of bioproducts has been causing serious pollution in ground water, river and sea (Kawashima, 2002).

2. Establishment of agricultural production based on cycling and coexistence

Agriculture is, in principle, an industry that makes solar energy available to human utilization in sustainable ways by fully utilizing the cycling function of nature. In such sustainability, one of the most important issues has been the conservation of soil fertility. Such sustainability has been historically proven by examples in shifting cultivation system with a relatively long uncultivated period; farm lands along the Nile, which have been continuously supplied with nutrients; lowland rice fields in Asia, utilizing rotation cropping system with legumes. Prevention from soil erosion is also an important component for the sustainability. Thus various mulching systems and minimum tillage technology have been developed for that purpose (Evans, 1998).

On the other hand, examples of causes for land degradation include overgrazing, deforestration, salination due to inappropriate irrigation and ill drainage. Furthermore, in its long history, 'modern' agriculture has started harming environment rapidly. Such environments include not only those surrounding the human life but also those for agricultural production itself, which means agricultural activities tend to degrade the production environment and threaten sustainability.

Desertification, which is mainly caused by adverse human activities, is the typical example.

It is essential to understand that the issue of sustainability is not for agriculture only but it has now become a biosphere and global issue. The influences of the use of resources and energy by human activities have reached the global level. We have not yet found effective measures to combat poverty that is the major cause of environmental degradation. Development and progress in one aspect impose a load on resources and threaten the sustainability. This is the very reason why we need to continue to find ways for sound coexistence between nature, environment and human activities.

Degradation of global as well as agricultural production environments seriously affects food safety. It is important, however, to take into consideration the food safety not only for consumers but also producers. Especially in Japan that is a huge food import country where the food self-sufficiency rate is now as low as 40 % on calorie base, we are seriously challenged as to how to construct a sound coexistence relationship between producers and consumers beyond border, and between cities and rural areas (agricultural sectors). This issue is directly related to our policy for future agriculture as well as our own daily lives.

It is estimated that a total of approximately 12 million ha of farm land overseas is now being used to produce foods to feed the Japanese people, which is about double that cultivated in Japan (The Japanese Ministry of Agriculture, Forestry and Fisheries, 1996). Including others resources such as woods and fiber that are essential to our daily lives, a huge amount of lands are used for Japanese people. It is, therefore important to understand the fact that our lives in Japan are made possible only in relation with many people who are engaged in the production and processing of those foods. That must be the first step towards the establishment of a real society of coexistence.

3. Trade-off relationship between productivity and sustainability

Intensification of agricultural production that has been supported by the use of chemical materials and mechanization is often counter posed against sustainability. However, as discussed earlier, the increase in food production for the last few decades has been largely dependent on that in crop productivity per unit area. The environmental problems that were discussed above must have aggravated and the sustainability more adversely affected if the increased population for the period were fed only by the increased food production due to the increase in farm land area. The intensification itself only accelerates the rate of use of resources like nutrients and water but is neither directly related with the sustainability nor the cause of environmental degradation.

4. Direction for future research

The world population exceeded 6 billion in 1999, and is continuing to increase. Because it is not possible anymore to return to sustainable agricultural production with low input, emphases must be placed on long-term research that are intended to establish sustainable crop production technology while maintaining high productivity.

One of the key issues in such research is locality. For example, in the research during the Green Revolution, it was believed that a crop exists that guarantees high productivity in any parts of the world. The research indeed substantially increased crop productivity, while at the same time segmented cycling chains and had weakened the coexistence society. Afterwards, the International Rice Research Institute that was heavily involved in the Green Revolution, had shifted the research. The target region is first ecologically characterized. The rice plants that are grown under different ecological conditions are treated as if they are totally different crops. Then the scientists from various disciplines work together on the identified problems (IRRI, 2004). To further develop and establish the sustainable production technology, further integration of social, cultural and economical factors will be needed in the long-term research project.

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Chapter 2

Biotechnology for Sustainable Bioproduction

Regulation of Carbon Metabolism in Relation to Plant Productivity

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Abstract

Sustainable agriculture will be required to maintain the environment and to feed the growing world population. In addition to improved cultural practices (e.g., crop rotation, use of crop residues to build the soil, biological pest control), improved crops will certainly be part of the answer and genetically engineered plants will be an approach of choice. Early goals of genetic engineering were to transfer single genes that could influence pest resistance or herbicide resistance. Future goals will need to focus on multiple genes or global factors that impact pathways, and will also shift from gene identification to consider the impact of proteomics on phenotype. In addition, in order to impact on agriculture it will be necessary to involve teams of scientists that span traditional disciplinary boundaries. The University can truly function as an 'Architect of the New Century' by assembling such teams and providing the "seed" money needed to initiate programs that conduct fundamental research of applied problems that impact on agriculture. How might primary plant metabolism be manipulated to improve productivity or crop value? In general, we are trying to identify biological mechanisms controlling important plant processes that may provide opportunities for manipulation to produce 'improved' plants for agriculture. This paper briefly mentions a few examples from literature and focuses on some possible avenues for control of metabolism that are related to current research activities in the author's laboratory.

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Control of enzyme intracellular localization

Sucrose synthase (SuSy) is known to be an important enzyme involved in the initial metabolism of sucrose in many sink tissues. Recent results from several laboratories indicate that SuSy may be localized in several cellular compartments: 1) soluble in the cytosol (as traditionally assumed); 2) associated with membranes; and 3) associated with the actin cytoskeleton (Winter and Huber, 2000). The physiological significance of the enzyme in these different subcellular locations is not known, but may be important for directing the products of sucrose cleavage into specific biosynthetic pathways. Consequently, we are attempting to identify the lipid- and actin-binding domains on SuSy. As well, we are interested in what mechanisms control the distribution of enzyme among the three locations. In particular, efforts are focused on a possible role for phosphorylation of SuSy at the Ser-15 site. Controlling the intracellular localization of an enzyme may be one approach whereby manipulation of a single gene product can influence flux through metabolic pathways.

Control of enzyme degradation

The steady state level of an enzyme will reflect the balance between its synthesis and degradation. However, little is known about the mechanisms involved in degradation of plant metabolic enzymes. Recent studies of protein phosphorylation in our laboratory suggest that phosphorylation of certain sites may be a trigger for protein degradation via the 20S/26S proteasome. Phosphorylation of these 'cryptic sites' is somehow blocked in the native protein. Once they become accessible to protein kinases (perhaps in response to release of a binding protein or proteolytic nicking of the N- or C-terminus), the site(s) is phosphorylated and the protein is targeted for degradation. This appears to be the case for two different enzymes—maize SuSy and soybean cytosolic pyruvate kinase (PyrKinC). In the case of SuSy, phosphorylation of Ser-170 was predicted by sequence analysis. Sequence-and phosphorylation-state specific antibodies demonstrated that phosphorylation of Ser-170 occurs in vivo, but was primarily contained on fragments of SuSy that were associated with the 20S proteasome (Hardin et al. 2002). Similarly, phosphorylation of two sites on soybean PyrKinC occurred, but again was contained on fragments associated with the 26S proteasome (Tang et al. 2002). Understanding the mechanisms that target metabolic enzymes for degradation may provide new strategies to control the steady state level of important enzymes and thereby influence flux through metabolic pathways.

14-3-3 proteins: factors that interact broadly.

The '14-3-3 proteins' are highly conserved eukaryotic proteins that function as binding proteins, usually targeting the sequence: R-x-x-phosphoS-x-P. They are involved in many important plant processes; including the regulation of nitrate reductase activity in leaves in response to light/dark transitions (Kaiser and Huber, 2001) and subsequently have been shown to interact with a broad array of metabolic enzymes and trans factors. Because of their broad interactions, manipulation of 14-3-3s may offer the possibility to up- or down-regulate an entire pathway. We have been studying the regulation of 14-3-3 binding to target proteins, using phosphorylated nitrate reductase (pNR) as a model system. Binding of 14-3-3s to pNR requires a divalent cation or polyamine, which first bind to the 14-3-3 protein in the region of loop 8 (located near the C-terminus between helix 8 and 9; Athwal and Huber, 2002). The resulting conformational change partially involves displacement of the C-terminal tail, which functions as an autoinhibitor (Shen et al. 2002). Activation mutants are currently being expressed in transgenic plants to investigate the significance of cation regulation in vivo. Recent evidence also indicates that binding of 14-3-3s to pNR can influence its degradation. We are speculating that uncomplexed pNR may be selectively degraded, which would provide a mechanism to insure balance between the level of 14-3-3s and their target proteins. This is especially critical for NR, but if generally applicable, suggests that manipulation of 14-3-3 expression may impact the level of target proteins by affecting their degradation.

How these, and other, biological mechanisms can be exploited to increase plant performance in sustainable systems is a continuing challenge for the future.

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Control of Nitrate Uptake/Assimilation and Plant Productivity

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Abstract

Nitrogen is one of the major elements that limit plant growth and productivity in both natural environments and plowed fields. To increase the harvest yield, nitrogen fertilizers are widely used in agriculture. The form of nitrogen commonly used as fertilizer is ammonium (NH_4^+), but in temperate aerobic soils, ammonium is rapidly oxidized to nitrate (NO_3^-) by nitrification. The resulting nitrate hence serves as the major source of nitrogen for most cultivated plants. Nitrate is, however, known to cause environmental and health problems. This paper summarizes current knowledge about the critical steps that determine the nitrate flow in plants and discusses possible strategies for improving the nitrate use efficiency.

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Problems caused by nitrate in the environment and in the plant body

Although plants have active transporters for nitrate uptake, large amounts of nitrate are lost from the soil by leaching, resulting in increased nitrate concentrations in both the surface and underground water. Accumulation of nitrate in lakes and ponds leads to bloom of cyanobacteria (known as “aoko” in Japan). Nitrate in drinking water would cause health problems such as “blue baby syndrome,” and carcinogenesis when it is converted to nitrite (NO_2^-) in the human body. When taken up by plants, on the other hand, nitrate is reduced to ammonium via nitrite, and the ammonium is fixed as the amide nitrogen of glutamine. The amide nitrogen of glutamine is subsequently transferred to various organic compounds to form a variety of nitrogenous compounds essential for plant growth. It should be noted, however, that the plants accumulate high concentrations of nitrate (i.e., >150 mM) in the vacuole and do not assimilate all the nitrate they have absorbed from the soil. When used as food, nitrate in the plant body can cause health problems as described above. It is therefore desirable to prevent nitrate accumulation in the plant body. It is also important to improve the overall efficiency of nitrate assimilation so that the use of nitrogen fertilizer can be minimized.

Regulation of expression of the nitrate transporter genes

One of the possible strategies for reducing the intracellular nitrate is to modify the regulation of expression of the nitrate transporter genes in roots. Similar to other organisms capable of nitrate assimilation (i.e., certain bacteria, cyanobacteria, green algae, and fungi), higher plants seem to have two distinct mechanisms for regulation of the genes involved in nitrate assimilation. One of these is the “global nitrogen regulation”, which represses or downregulates expression of the genes involved in nitrogen acquisition when cells have sufficient amounts of fixed nitrogen. The other is the “substrate induction”, which involves the substrate of nitrate assimilation, i.e., nitrate (or nitrite), as the activator of expression of the relevant genes. Unlike in the other organisms capable of nitrate assimilation, the “substrate induction” seems to override the negative feedback by the “global nitrogen regulation” in higher plants. As a result, plant cells express the nitrate assimilation genes even when the plant is in nitrogen-replete conditions, if nitrate is present in the soil. This seems to cause continued uptake of nitrate into the cell, resulting in accumulation of excess nitrate in the plant body. Modification of the cis-acting regulatory elements involved in the substrate induction of the nitrate transporter genes may lead to specific decline in the expression level of the nitrate transporter genes and thereby reduce the intracellular nitrate level in the plant cell.

Control of relative contribution of roots and shoots in nitrate assimilation

Another possible means to lower the nitrate levels, specifically in leaves, is to modify the relative contribution of the roots and shoot in nitrate assimilation. The relative contribution of roots and shoots is variable among different species of plants; in some plants, the contribution of roots in nitrate assimilation is small and most of the nitrate is transported to the shoot. In certain plant species, on the other hand, nitrate is assimilated mostly in the root, and the fixed nitrogen is transported to the shoot as amino acids. It is therefore, theoretically possible to genetically engineer a plant that assimilates nitrate entirely in the root. To achieve this type of metabolic engineering, we need to control the expression levels of the enzymes involved in nitrate assimilation and also of the enzymes involved in supply of carbon skeletons and metabolic energy for nitrogen assimilation. Since the root cells are dependent on the supply of carbon and energy from the leaf cells, understanding of the metabolic interactions between the shoot and root is also necessary.

Importance of basic research for genetic modification of nitrate assimilation in plants

As has been discussed above, currently available information about nitrate assimilation in plants allows us to design some strategies for improvement of the nitrate use efficiency in plants. However, to actually construct a genetically modified plant, more detailed information about the regulation of the relevant genes is necessary; the molecular mechanism(s) regulating the nitrate transporter genes needs to be fully understood. The molecular basis for the different contribution of roots in nitrate assimilation in different plant species also needs to be elucidated. Thus, the importance of basic research on the nitrate assimilation pathway cannot be overemphasized.

Enzyme Engineering for Lipids

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Abstract

Lipids (edible fats and oils, phospholipids and glycolipids, etc) are one of major important food resources, in addition to carbohydrate (starch, sugar, etc.) and protein resources. Edible fats and oils are produced mostly from agricultural products such as plant seeds and animals. Animal-derived fats and oils are also utilized as energy sources in human nutrition. Fish oils have some functional fatty acids categorized as n-3 polyunsaturated fatty acids (PUFA) with 5 and 6 unconjugated methene double bonds. Phospholipids are utilized as food and cosmetic emulsifier (pure grade), and animal feed (crude). Enzymes, which are involved as catalysts (biocatalysts) in all metabolisms and biochemical reactions in living cells, are very tightly connected with all life phenomena. Two novel engineering disciplines relating to effective enzyme utilization have emerged in the late 20th century: enzyme engineering and protein engineering. Enzyme engineering is a branch of bioprocess engineering devoted to increasing efficacy of enzyme utilization as biocatalysts for various bioconversions. Protein engineering is one of major branches of biomolecular engineering, aiming at creation of enzymes of better nature through various genetic engineering techniques such as site-directed mutagenesis, error-prone PCR, DNA shuffling, molecular evolution technique, etc. Natural lipids are a mixture of hundreds or thousands of triacylglycerols when looked at from the viewpoint of organic chemistry. Recently, the so-called ‘structured lipids’ have attracted much attention. In the strictest sense, the structured lipids are those having definite chemical structure. From a number of clinical experiments in lipids nutrition science, structured triacylglycerols (sTAG) have been shown to confer various enhanced nutritional values so that they are useful as functional foods or nutritional supplements. Taking advantage of enzyme’s properties, the author and his co-researchers have been studying enzyme engineering for lipids bioconversions for many years. Recent studies showed success in making feasible the industrial production of 1,3-dioctanoyl -2-docosahexaenoyl-sn-glycerol by the action of immobilized lipases following a two-step process, i.e. ethanolysis of fish oil by immobilized *Candida antarctica* lipase followed by re-esterification of the resulting 2-monoacylglycerol with n-octanoic acid by immobilized *Rhizomuco miehei* lipase in neat system. Phosphatidylserine (PS), which is one of structured phospholipids (sPL), is found neither in soy- nor in egg-lecithin, but is contained highly in mammalian cerebral cortex, and is claimed to be effective for Age-Associated Memory Impairment (AAMI). Recently, an efficient high-yield synthesis technique of PS from lecithin by the transphophatidylation action of *Streptomyces* phospholipase D in non-solvent system has been developed.

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1. Lipids as Renewable Resource

There are three major food resources: carbohydrate, protein, and lipids. For the lipids, edible fats and oils are most predominant, but phospholipids and glycolipids are also included. When people talk about biomass, it usually includes starch, cellulose, chitin, xylan, and lignin. The author, however, would like to emphasize that lipids are also important, inexpensive, renewable, biodegradable, and energy-rich natural resources. Lipid resources are one of the major bio-resources and hence, are included in the green chemistry strategy. As for the plant seed oils, the major oils include palm oil, soybean oil, rapeseed oil, sunflower oil, peanut oil, cottonseed oil, olive oil, safflower oil and others.

The total consumption of these seed oils in 2001 was as huge as 118 million tones in the world. In some Southeast Asian countries such as Malaysia and Indonesia, very large-scale plantations of oil palm trees are widely seen. About 23 million tones of palm oil were produced in 2001 worldwide, of which Malaysia produced 12 millions tones (52 %). Glycerol and fatty acid are obtained from fats and oils by hydrolysis (chemically or lipase-catalyzed). The former is a starting material for nitroglycerine and propylene oxide, while fatty acids can be converted to methyl esters that are utilizable as automobile diesel fuels, and to amides, acid chlorides, and alcohols, all of which are raw materials of various commodity and fine chemicals.

People utilize animal fats and oils as well, such as beef tallow, lard, milk fat, and fish oil. In 1998, the total consumption of animal fats and oils in the world was 18 million. This figure is huge but is much less than that of plant seed oil.

Among the edible oils, fish oils are quite unique because they have the so-called n-3 polyunsaturated fatty acid, which is also called PUFA for short. In addition to the conventional plant seed oils and animal fats, novel edible oils have been exploited. These are single cell oils (SCO), which are produced by microorganisms. The SCO producers are *Mortierella* sp., *Schizochytrium* sp., and *Crypthecodinium* sp. These microorganisms have been screened as producers of oils containing specific PUFAs.

Table 1 summarizes the lipids bio-resources in the world. PUFAs are classified into two (Figure 1): n-6 PUFA such as eicosatrienoic acid, and eicosapentaenoic acid (commonly called arachidonic acid, ALA), and n-3 PUFA such as eicosapentaenoic acid and docosahexaenoic acid. They are shortly named EPA, and DHA, respectively. From many clinical tests, these PUFAs have a number of physiological benefits so that these may be called functional fatty acids or neutaceuticals. Because of many double bonds franking active methylene groups, PUFAs are very unstable. They are easily oxidized, isomerized from E configuration to Z configuration, and polymerized. Therefore, any reactions, whether or not chemical or biochemical, should be carried out under mild conditions without oxygen.

Major natural resources of phospholipids are soybean lecithin, and egg yolk lecithin. They are obtained as byproducts of soybean oil and egg products. The annual production of soybean lecithin and egg yolk lecithin in Japan in 2001 was 6500 tones, and 250 tones, respectively. Although they are now utilized mainly as food and cosmetic emulsifiers as well as fodder feed, they have great potential as resources for neutraceuticals.

Table 1. Lipid bio-resources in the world

1) Triacylglycerols

Plant seed oils	Animal oils	Single cell oils
Palm oil	Lard	EPA oil
Rape seed oil	Milk fat	DHA oil
Sunflower oil	Fish oil	Others
Peanut oil	Others	
Cotton seed oil		
Olive oil		
Safflower oil		
Others		

2) Phospholipids
Soybean lecithin
Egg yolk lecithin

3) Glycolipids
glycoglycerolipids (galactosyldiacylglycerol, etc)
glycosphingolipids (gangliosides, etc)

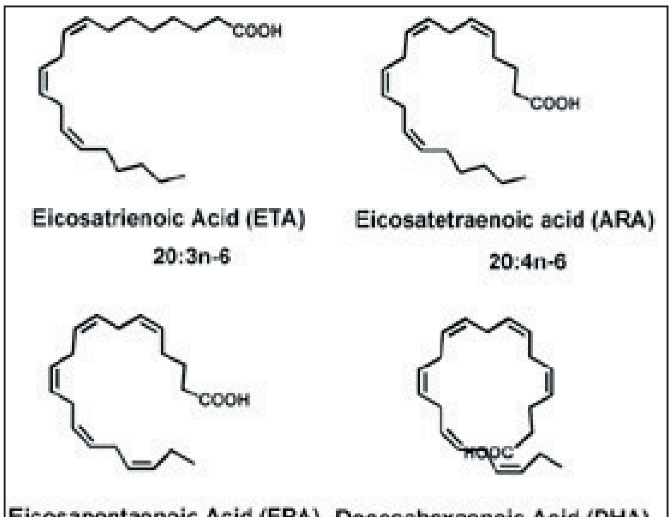

Fig 1. Structures of Major Polyunsaturated Fatty Acids (PUFAS)

2. Enzyme as catalyst

Enzymes are involved in all the metabolism and biochemical reactions in living cells so that they are very tightly connected with all life phenomena. From the viewpoint of being a catalyst, enzymes are characterized by high molecular activity, being active under mild conditions, and high specificity (or selectivity) (substrate specificity, reaction specificity, enantiospecificity, sequence specificity, positional specificity, etc). Enzymes are also “tender to the earth” because they are proteins, non-toxic, and quickly decompose in natural environment. Because of these merits, people have utilized a number of enzymes in various fields since early civilization. Among these merits, specificity or selectivity is the most important characteristic of enzyme. If one wants to synthesize a chemical compound or to modify it enzymatically, he has to take maximum advantage of enzyme specificity. In the next section, the author is going to introduce his work on syntheses of particular lipid using lipase and phospholipase so that specificity of both lipases and phospholises are mentioned briefly. Lipases, which split ester bonds of triacylgylcerol, are classified into two: 1,3-specific, and non-specific. There are five phospholipases depending on their position of splitting. Phospholipase A_1 hydolyses *sn*-1 ester bond, phospholipase A_2 does *sn*-2 bond, phospholipase C cleaves O-P bond of *sn*-3 position, and finally phospholipase D splits P-X bond of phosphate diester, respectivity. Phospholipase B hydrolyzes ester bond either on sn-1 or sn-2, or both. Thanks to these specificities, one can carry out particular bioconversion of lipids without the introduction of a protecting group and its deprotection.

Two novel engineering disciplines relating to effective utilization of enzymes emerged in the late 20th century. They are enzyme engineering and protein engineering.

Enzyme engineering is a branch of bioprocess engineering devoted to the increasing efficacy of enzyme utilization as biocatalysts for various bioconversions. Enzyme screening, production, purification, immobilization, bioreactor system, are some of technologies involved in enzyme engineering. Among them enzyme immobilization is notably effective for its reuse and continuous reaction.

Protein engineering is one of the major disciplines under biomolecular engineering, which aims at creation of enzymes of a better nature. It involves various genetic engineering techniques such as site-directed mutagenesis, saturation mutagenesis, combinatorial mutagenesis, error-prone PCR, overlapping PCR, DNA shuffling, molecular evolution technique, high throughput screening, etc.

3. Enzymatic syntheses of ‘structured lipids’ (1,2)

Natural lipids are simply a mixture of hundreds or thousands of chemical compounds when they are looked at from the viewpoint of organic chemistry. Natural edible fats and oils are simply a mixture of a number of triacylglycerols (TAGs) that are different in terms of both fatty acid species and their distribution along the glycerol backbone. Recently, the so-called ‘structured lipids’ have attracted much of the people’s attention. In contrast to natural edible lipids, the structured lipids are, in the broadest sense, lipids that have been restructured to change positions of fatty acids and/or have been modified chemically or enzymatically to change fatty acid compositions from the native state to either the type of fatty acid or the position of the fatty acids. In a less broad sense, structured triacylglycerols (sTAGs) are structured TAGs containing mixtures of either short-chain fatty acids, or medium-chain fatty acids (MCFA), or both, and long-chain fatty acids, in the same glycerol molecule. A number of studies have been carried out for the synthesis of sTAGs having (medium chain)-(lon g-chain)-(medium-chain)-type fatty acids. This type sTAG is sometimes called symmetrical structured triacylglycerol (SST). These sTAGs are claimed to provide fewer metabolizable calories per gram than do traditional fats and oils, and to be efficient food sources for patients with pancreatic insufficiency and other forms of malabsorption. Cocoa-butter substitute, which consists predominantly of stearoyl-oleoyl-stearoy lglycerol (SOS) or more generally SUS (saturated fatty acid)-(unsaturated fatty acid)-(saturated fatty acid) type TAG, and ‘Betapol’ manufactured by Uniliver Company, which has the structure of oeo yl-palmitoyl-oleoylglycerol (OPO), are included in this category of sTAGs.

In recent years, the concept of sTAGs has been extended such that sTAGs are designer TAGs with desired fatty acids in terms of their structures and positions as ‘nutraceuticals, functional food, or pharmaceuticals' to target the optimal nutrition, better metabolic conditions, and specific diseases. Along this trend, in the strictest sense, the term 'Structured TAG' is given to a TAG with a particular fatty acid at a specific position of glycerol hydroxyl moieties. The strictest definition of sTAG can be referred to its classification as shown in Table 2: sTAG is either monoacid sTAG, diacid sTAG, or triacid sTAG. Note that in Table 2, fatty acids are shown in the order of their positions located at *sn*-1, *sn*-2 or *sn*-3 of the glycerol backbone. Thus AAB is not identical to BAA, but they are enantiomers. AAB (or BAA) type diacid sTAGs and all triacid sTAGs are chiral.

The objective to produce 'structured lipids' is to enhance their functionalities. Lipid's functionalities are, i) physical properties such as melting point, polymorphism of crystals, etc, ii) chemical properties such as stability against oxidation, and iii) nutritional properties such as calorie, absorption through intestine, digestion, pharmacological effects, etc. From a number of clinical experiments in lipids nutrition science, sTAGs have been shown to confer various enhanced nutritional values so that they are useful as functional foods or nutritional supplements.

STAGs containing PUFAs such as EPA, DHA or ALA, have become of great interest because of various pharmacological effects of these fatty acids. These effects include several health benefits on cardiovascular diseases, immune disorders and inflammation, renal disorders, allergies, diabetes, cancer, etc. These fatty acids may also be essential for brain and retina development in humans.

Among sTAGs containing PUFA, those containing one molecule PUFA and two molecules of medium-chain fatty acids are very noticeable. Several studies have been performed for the synthesis of sTAG containing PUFA at specific sites of the glycerol backbone. The absorption of PUFA into the body depends upon the position of PUFA along the glycerol backbone, i.e. at sn-1 (or 3) or *sn*-2 position. Those sTAGs containing PUFA at *sn*-2 position and MCFA at *sn*-1 and –3 positions can be hydrolyzed into 2-monoacylglycerol (2-MAG) containing PUFA and FA by pancreatic lipase and are efficiently absorbed into intestinal mucosa cells in normal adults. It is to be noted that mammalian pancreatic lipases hydrolyze the ester linkages at the *sn*-1 and *sn*-3 positions with a preference for MCFA over long-chain ones. Therefore, for dietary supplement for adult health, sTAG containing PUFA at *sn*-2 position and MCFA at the *sn*-1 and *sn*-3 positions may be suitable. On the other hand, due to the antiatherogenic, antineoplastic, and anti-inflammatory effects of n-3 PUFA, their intake is important for newborns for eicosanoid synthesis as well as for normal neonatal brain nervous system development and cell membrane structure. Although PUFA are essential to the neonate for both normal growth and metabolism, neonatal intestinal function is immature, resulting in reduced levels of pancreatic lipase and bile acid salts. In addition, pancreatic lipase does not hydrolyze ester bonds containing long-chain n-3 PUFA. Therefore, in the case of the newborn, PUFA absorption by pancreatic lipase is not feasible. However, for neonatal adsorption of PUFA, there is an alternative mechanism. PUFAs are released from gastric digestion, and gastric lipase exhibits stereospecificity for the α -position of TAG and hydrolyzes the sn-3 position twice as fast as the sn-1 position. Therefore, for PUFA therapy for neonates, sTAG containing PUFA at *sn*-1 (or -3) position and MCFA at the other sites may be suitable.

The sTAG can be synthesized either chemically or enzymatically. However, an enzymatic synthesis of sTAG is more advantageous over a chemical process with regard to several aspects. Enzymes are generally specific, thus, giving rise to less or no byproducts, and exhibiting catalytic action under mild conditions. Enzymatic reactions have another advantage for the synthesis of sTAG containing PUFA because PUFAs are very unstable as mentioned before. They are prone to be easily isomerised, oxidised and polymerised. These properties necessitate the use of as mild conditions as possible, especially oxygen-free conditions.

Table 2. Classification of structured triacylglycerols (sTAG).

No. of different FA	Type	Chirality	Stereoisomer
Monoacid-	AAA	Achiral	
Diacid-	ABA	Achiral	
	AAB, BAA	Chiral	Enantiomers
Triacid-	ABC, CBA	Chiral	Enantiomers
	BCA, ACB	Chiral	Enantiomers
	CAB, BAC	Chiral	Enantiomers

Taking advantages of the enzyme's properties, the author and his coworkers have been studying enzyme engineering for lipids bioconversions for many years. Enzymes involved in lipids bioconversion are mostly hydrolytic enzymes such as esterases, lipases and phospholipases. One must take some points into consideration in order to carry out enzyme-catalyzed bioconversion of lipids effectively, such as water-insolubility of the substrates, instability of the substrate, effect of trace amount of water in both ester synthesis and transesterification reactions, etc.

1) Synthesis of 1,3-dioctanoyl-2-docosahexaenoyl-sn-glycerolfrom fish oil (3)

Fish oil is an inexpensive source of PUFA - containing TAGs. The content of DHA and EPA and also their positional distribution in TAGs varies among the fish species. Fish oils with a high content of DHA and EPA at the second position can be used as starting materials for production of nutritionally valuable symmetrical structured triacylglycerol (SST) with medium chain fatty acids at the primary positions.

Some research groups used fish oil or DHA-rich oils such as single cell oil for the production of SST by acidolysis with octanoic acid catalyzed by 1,3-regiospecific lipases. DHA residues situated at the outer positions could not be exchanged (due to the low specificity of 1,3-regiospecific lipases for DHA) resulting in a limited yield of SST. The same problem was encountered in another work where SSTs were obtained in two steps. 2-MAGs were obtained by ethanolysis of TAGs in an organic solvent with a 1,3-regiospecific lipase and then reesterified with oleic acid. The yields of ethanolysis were less than 40% for fish oils with 8% DHA content or more. A large amount of 1-MAGs was formed probably due to acyl migration.

Recently the author and his coworkers succeeded in a fast and straightforward two-step method for synthesis of SST with octanoic acid residues at the outer positions from DHA and EPA-rich bonito oil. This is industrially feasible production of 1,3-dioctanoyl-2-docosahexaenoyl-sn-glycerol, which is classified as a 'MCFA-PUFA-MCFA'. Fish oil TAGs (bonito oil) were subjected to ethanolysis with immobilized *Candida antarctica* lipase (Novozym 435) to yield 2-MAGs, which were subsequently reesterified with ethyl octanoate catalyzed by immobilized *Rhizomucor miehei* lipase (Lipozyme IM) to form SST in neat system. Typical time course of this reaction process is shown in Figure 2.

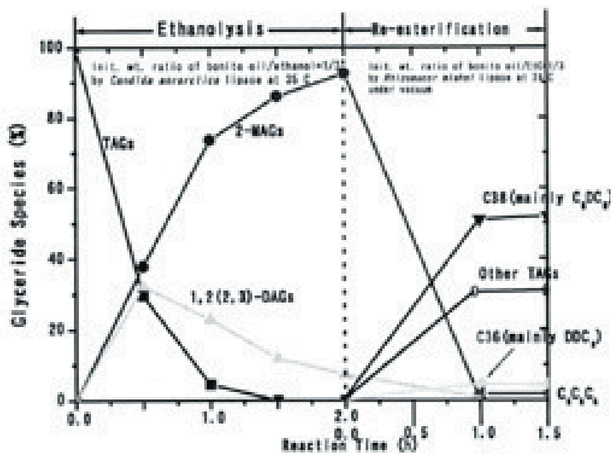

Fig 2. sTAG production from bonito oil via 2-MAG

The ethanolysis reaction was very fast. The acylglycerol composition at 2 h was 92.5% 2-MAG and 7.5% 1,2(2,3)-DAG (area %). The TLC analysis of the ethanolysis product showed that the formed MAGs were 100% 2-MAGs. No spot of 1-MAGs or 1,3-DAGs was detected. The reaction mixture composition (area %) at 2 h was 69.55% ethyl esters, 2.3% 1,2(2,3)-DAGs, and 28.25% 2-MAGs determined by TLC-FID. The FID response for ethyl esters is higher than for partial acylglycerols so that its actual weight % might be lower. No free fatty acids were detected in the reaction mixture.

The fatty acid composition of 2-MAGs resulting from ethanolysis was in good agreement with the composition of 2-MAGs obtained by Grignard degradation of the initial oil except EPA and DHA contents. Similar differences of the results obtained by enzymatic hydrolysis and Grignard degradation applied for fish oil were also mentioned in another work. The composition of ethyl esters resulting from ethanolysis was also determined. These ethyl esters are theoretically removed only from the primary positions of TAGs and thus the fatty acid composition of the initial TAGs might be recalculated using the fatty acid compositions of 2-MAGs and ethyl esters resulting from ethanolysis. The result of these calculations was very close to the initial composition determined directly after derivatization of initial TAGs to fatty acid methyl esters and thus the above hypothesis was confirmed. The analytical procedure using Grignard degradation might cause partial damage of PUFA resulting in the observed difference of the results for 2-MAGs composition determined by the two methods.

The results of fatty acid composition analysis of the ethanolysis reaction products (2-MAGs and ethyl esters) demonstrate that Novozym 435 displays very strict 1,3-regiospecificy in this reaction under the employed reaction conditions. Bonito oil is a very complex mixture of TAGs with regard to the large variety of fatty acid species and their positional distribution in TAG and therefore it is an appropriate substrate to test the fatty acid specificity of Novozym 435 in ethanolysis. The fatty acid composition of 2-MAGs and ethyl esters formed after 2 h of ethanolysis indicated no distinguishable preference of Novozym 435 for any of the fatty acid species present in TAGs. The high conversion of the original TAGs to 2-MAGs at 2 h might have alleviated the effect of enzyme's fatty acid specificity. The acyl migration reactions were limited by the low water content of the ethanolysis reaction mixture (only the water contained in the enzyme preparation and reactants), the absence of fatty acids, and the low reaction temperature. Therefore, ethanolysis did not proceed to the removal of fatty acid residues of the second position of TGs, which usually affects analytical methods based on TAG hydrolysis with 1,3-specific lipases. Reduced acyl migration, strict 1,3-regiospecificity and good activity of Novozym 435 on PUFA enable the use of the ethyl esters resulted from ethanolysis for the determination of fatty acid composition of the secondary position of TAGs.

SSTs were obtained by reesterification with ethyl ocanoate of 2-MAGs formed in the first step. The ethanolysis reaction mixture was used directly in the second step after the catalyst was filtered and the excess of ethanol was removed. Novozym 435 showed no regiospecificity in this reaction so that it had to be replaced with a 1,3-regiospecific lipase, which can work at low water concentrations of the reaction medium. Lipozyme IM gave good results for a similar reaction and therefore, it was used also for this work. The value of ethyl octanoate excess adopted in the reesterification step was chosen according to some previous results showing that higher ethyl ocanoate/partial acylglycerol ratios improve the final reaction yield. The reaction equilibrium was pushed to high yields by removing the resulting ethanol under reduced pressure.

The reaction was completed after 1 h as shown by the disappearance of the 2-MAG and 1,2-DAG spots in TLC analysis. The separation of the finally purified SSTs by high-temperature GC was much better than that of the initial TGs. The final SST had lower molecular weight and therefore, higher volatility resulting in shorter retention times and better resolution. The area percentages of C38 (TAGs with two octanoic acid residues and one 22:6, 22:5 or 22:4 residue), and C36 (TAGs with two octanoic acid residues and one 20:5, 20:4, 20:1 or 20:0 residue) were: 51.0 and 4.5%, respectively. The percentage of trioctanoylglycerol was 1.7 %.

2) Synthesis of phsphatidylserine (4)

Phosphatidylserine (PS) is one of the structured phospholipids (sPL). PS is found neither in soybean nor in egg yolk lecithin, but is contained highly in mammalian cerebral cortex, and is claimed to be effective for Age-Associated Memory Impairment (AMMI). In 1983, Weihauch and Son determined PS contents of some food materials. According to their data, bovine brain has the highest PS content. Since then, PS was prepared by extraction of bovine brain. However, PS content is still quite small (only 1g/bovine head) so that PS is very expensive. Moreover, PS prepared from bovine brain was said to possibly cause BSE (Bovine Spongeform Enphalopasy). Due to these reasons, people searched for other cheaper and safer biomaterials.

By nature, phospholipase D (PLD) catalyzes hydrolysis of lecithin such as phosphatidylcholine (PC) to give rise to phosphatidic acid (PA). In addition to this, PLD catalyzes transphosphatidylation reaction, which is a base-exchange reaction (Figure 3). In the presence of excessive serine, PS can be easily produced by the action of PLD.

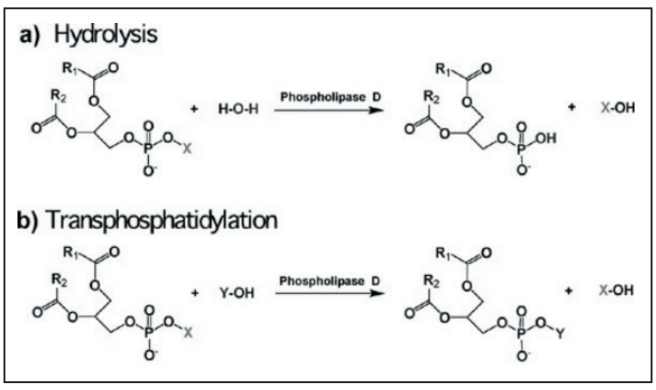

Fig3. Catalytic Action of Phospholipase D (PLD)

Lecithin is not soluble in water so that conventional PLD-catalyzed reaction is carried out in two-liquid phase system. That is, lecithin is dissolved in an organic solvent such as ethyl ether or ethyl acetate or chloroform, and serine and PLD are dissolved in water phase. These two-liquid phases are then mixed vigorously. The product PS can be produced with as high yield as 85% in 20-30 minutes. However, use of these organic solvents makes the reaction system unsuitable for the practical food product. It is highly advisable not to use such organic solvents from the viewpoints of the health of both consumers and the workers in factory. The n-hexane is one of several safe solvents that are allowed for use in the food industry. However, unfortunately, no transphosphatidylation reaction occurs in hexane-water system.

The author and his coworkers have recently developed an efficient high-yield synthesis technique of PS from abundantly safe lecithin such as soybean lecithin by the transphosphatidylation of *Strteptomyces antibioticus* phospholipase D in non-solvent system.

The reaction in aqueous system without any organic solvents resulted in as low yield as 20 %. The author and his coworkers thought that the low yield of PS formation would be due to poor dispersion of lecithin, and tried the use of lecithin adsorbed on silica gel particles. First, lecithin was dissolved in ethanol, and then silica gel particles were added, followed by removal of ethanol by reduced pressure to get lecithin-silica gel complex. The complex was added in aqueous buffer containing serine and PLD. About 40% of PS was obtained in one hour. The effect of ratio of lecithin per silica gel particles was then examined. Serine concentration was also increased up to its saturation. The ratio of 1/5, and the increased serine concentration gave us 80 % yield in 24 hours. In order to seek for recovery procedure of PS after the reaction, the author and his coworkers tried to determine the location of the PS. Initially, the PC was on the surface of silica gel particles as expected. After the reaction, it was found that PS was in the supernatant, not in the precipitates, that is, not on the surface of silica gel particles. This makes it difficult to separate PS from the remaining serine existing in excess. A number of solid carrier particles were then screened to select better ones, including $CaCO_3$, $CaSO_4$, $Ca_3(PO_4)_2$, active carbon, etc. Among them, Calcium sulfate fine powder gave the best result. It yielded more than 99 % of conversion, more than 80 % of PS yield, and less than 10 % of PA (byproduct) content. The author and his coworkers had the same question as for calcium sulfate fine powders: where was PS located when lecithin adsorbed on calcium sulfate was used? At time zero, unexpectedly PC was dispersed in the supernatant. This means that PC was not adsorbed on $CaSO_4$ particles. At 24 hours, PS was in the precipitates, indicating that PS was selectively adsorbed on $CaSO_4$ particles. This makes easy separation of PS after the reaction. Then, the reaction operation was simplified. In the preceding experiments, lecithin was first dissolved in ethanol, followed by the addition of fine solid particles. In this experiment, the author and coworkers just added lecithin and CaSO4 powder to the serine-saturated aqueous solution containing acetate buffer and PLD to start the reaction. The time course of the reaction is shown in Figure 4. It is almost the same as in the old operation. PC was completely converted to PS in 20 minutes. The next attempt was to improve volumetric productivity by examining the effect of lecithin concentration in the reaction mixture while keeping the same amounts of $CaSO_4$, serine, and PLD. It was found that the higher its concentration, the slower the PS formation rate, but the final PS content of 80 % was still possible even though it took longer time. The final experiment of the author and his coworkers was to establish the method of recovering PS from the reaction mixture. As mentioned before, PS was adsorbed on $CaSO_4$ powders. The author and his coworkers used the following procedure: (i) reaction mixture was centrifuged, (ii) precipitates were washed with water first, then (iii) $CaSO_4$ particles were extracted with a mixed solvent composed of hexane, ethyl alcohol, water and 1N HCl., then (iv) the system was centrifuged, resulting in three parts, namely: the precipitate, the lower liquid phase and the upper liquid phase. By the analyses of three parts, it was found that PS was exclusively in the upper liquid phase. The total recovery yield that was calculated by this recovery experiment was ca. 80 %.

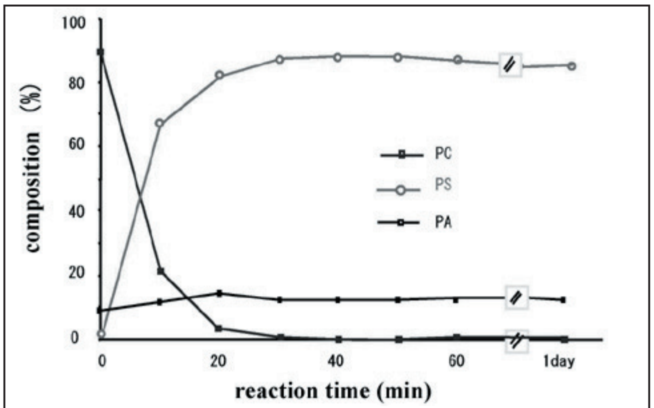

Fig 4. High Yield of PS Production from Lecithin By Adding Fine Powders of CaSO4 in Aqueous System

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Protective Role of Dietary Antioxidants in Oxidative Stress

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Oxygen radical and free radicals are normal by-products in biological systems during numerous physiological and pathophysiological processes. Oxidant by-products of normal metabolism cause extensive damage to DNA, proteins, and lipids. This oxidative damage appears to be a major contributor to aging and to degenerative diseases of aging such as cancer, cardiovascular disease, cataracts, immune system decline, and brain dysfunction. Antioxidants, which can neutralize free radicals, may be of central importance in the prevention of these diseases. The antioxidative and free radical scavenging properties of polyphenolic compounds in several plant extracts have recently been reported, suggesting possible protective role of polyphenolic compounds. Thus, the search for antioxidants in edible plants has drawn much attention.

The herb *Mesona procumbens* Hemsl., called Hsian-tsao in China, is consumed as an herb drink and jelly-type dessert in the Orient. It is also used as herbal remedy in folk medicine in China against heat-shock,

hypertension, diabetes, and muscle and joint pains. Most research on this product has focused on its gelation property and proximate composition.

The result from the investigation on the antioxidative activities showed that the water extracts of Hsian-tsao exhibited strong activities against linoleic acid peroxidation and correlated with its polyphenol contents. The water extracts of Hsian-tsao showed positive concentraction-dependent scavenging effect on DPPH radical, superoxide anion, hydrogen peroxide, nitric oxide and peroxyl radical. Furthermore, the water extracts of Hsian-tsao exhibited the inhibitory effect on oxidative damage to biomolecules. The extracts also showed inhibitory effects, both on the lipid peroxidation of ghost membrane and Chang liver cells induced by hydrogen peroxide. No toxicity was found in the water extracts of Hsian-tsao towards Chang liver cells. The water extracts of Hsian-tsao could inhibit oxidative DNA damage induced by hydrogen peroxide and exhibit protective effect against oxidative damage in Chang liver cells and intracellular reactive oxygen species (ROS).

Du-zhong (*Eucommia ulmoides* Oliv.) tea (the aqueous extract of leaves) is commonly used in Japan and Taiwan for treatment of hypertension and is thought to be a functional food. Investigation also showed that leaf extract of Du-zhong may have recuperative effects from hypercholesterolemia and fatty liver. Du-zhong (leaf) tea had a suppressing effect on mutagenicity and chromosome aberration following mutagen treatment. The effect on oxidative damage in biomolecules and free radical-/ or ROS-/ scavenging effects of water extracts of Du-zhong (WEDZ) were investigated. The WEDZ was prepared from leaves, raw cortex, and roasted cortex. All of these WEDZ inhibited the oxidation of deoxyribose induced by Fe^{3+}-EDTA/H_2O_2/ascorbic acid, in a concentration-dependent manner. At a concentration of 1.14 mg/ml, the inhibitory effect of the extracts of leaves, roasted cortex, and raw cortex was 85.2%, 68.0% and 49.3%, respectively. The extract of leaves inhibited the strand breaking of DNA induced by the Fenton reaction. WEDZ also inhibited the oxidation of 2’-dG to 8-OH-2’-dG induced by Fe^{3+}-EDTA/H_2O_2/ascorbic acid. The leaf extract of Du-zhong had inhibitory effect on oxidative damage in biomolecules. Therefore, drinking of Du-zhong tea (leaf) over a long period of time may have anticancer potential. The WEDZ also showed remarkable activity as a ROS-scavenger, and the scavenging effect was concentration dependent. Also scavenging activity of WEDZ on ROS was closely correlated to protocatechuic acid (PCA) content. The content of PCA in Du-zhong measured by HPLC followed the order: leaves > roasted cortex > raw cortex. The extract of Du-zhong possibly act as a prophylactic agent to prevent from free radical-related diseases.

Jue-ming-zi", the seed of *Cassia tora* L., has been used as a laxative and a tonic Chinese herb for several centuries. The recent investigation showed that Jue-ming-zi, had physiological functions as an antiseptic, diuretic, diarrheal, antioxidant, and antimutagen. The effects of water extracts from *Cassia tora* L. (WECT) treated with different degrees of roasting on benzo[ ] pyrene (B[ ]P)-induced DNA damage in human hepatoma cell line HepG2 were investigated via the comet assay WECT alone, showed neither cytotoxic nor genotoxic effect toward HepG2 cells. B[ ]P-induced DNA damage in HepG2 cells could be reduced by WECT in a dose-dependent manner. The inhibitory effects of WECT on DNA damage were in the order unroasted roasted at 150 roasted at 250. Ethoxyresorufin-*O*-dealkylase activity of HepG2 cells was effectively inhibited by WECT, and a similar trend of inhibition in the same order was observed. The activity of NADPH cytochrome P-450 reductase was also decreased by the unroasted samples and by 150 ¢J-roasted samples (50 % and 38 %, respectively). The contents of anthraquinones (AQs) in WECT, including chrysophanol, emodin, and rhein, were decreased with increasing roasting temperature. Each of these AQs also demonstrated significant antigenotoxic activity in the comet assay. The inhibitory effects of chrysophanol, emodin, and rhein on B[£\]P-mediated DNA damage in HepG2 cells were 78, 86, and 71 %, respectively, at 100M. These findings suggested that decreased antigenotoxicity of the roasted samples might be due to a reduction in their AQs content.

Adlay (soft-shelled job's tears," *Coix lachryma-jobi* L. var. *ma-yuen* Stapf) is a grass crop that has long been used in traditional Chinese medicine and as a nourishing food. The pharmacological activities of the seed adlay were used in China for treatment of warts, chapped skin, rheumatism, and neuralgia, and also used as an anti-inflammatory or antihelmintic agent. Adlay also pointed out to have stomachic, diuretic, antipholgistic, anodynic, antispasmodic, and antitumor effects. It is widely planted in Taiwan, China, and Japan, and it is considered to be a supplement healthy food.

The anti-tumor effect of adlay processing food (APF) on animals was investigated. The experimental diets containing amount of APF were fed to ICR male mice during a subcutaneous injection of Sarcoma-180 tumor cells. The accessory anti-tumor effect was determined by the tumor weight, transplantation speed of tumor cells, and mean survival time. The tumor weights of the test group fed with the diets containing APF levels of 9%, 18% and 36% were significantly lighter than the tumor weights of the control group. In the test group (APF 18%), tumor cell transfer was undiscovered after 60 feeding days. However. 25% of the mice in the control group on day 45 and 50% on day 60 were discovered to have tumor cells transferred to the lungs. The average survival time of the test group (106.5 days) was significantly longer than the control group (77 days). The results indicate that APF has an accessory anti-tumor effect, and the recommended daily intake is approximately 2.85 g/kg for cancer patients.

The investigations on the antioxidative effects of methanolic extracts from different parts of adlay seed and their antiproliferative activity in malignant human cells have been conducted. The methanolic extracts from the hull (AHM), testa (ATM), bran (ABM), and polished adlay (PAM) were prepared. AHM exhibited greater capacity to scavenge superoxide anion radicals in the PMS-NADH system than ATM, ABM, or PAM. The scavenging capacities of AHM and ATM on hydrogen peroxides were about 20% at a dose of 250 g/mL. By using the method of deoxyribose degradation to assess damage caused by hydroxyl radicals, AHM was found to inhibit damage in deoxyribose at a higher concentration. The inhibitory effect on enzymatic oxidation of xanthine to uric acid was found to follow the order: AHM > ATM > ABM >PAM. Exposing human histolytic lymphoma U937 manocytic cells to tert-butyl hydroperoxide, AHM protected the cells against the cytotoxicity. In addition, AHM exhibited antiproliferative activity against human histolytic lymphoma U937 monocytic cells in a dose-dependent manner. The antiproliferative properties of AHM appeared to be attributable to its induction of apoptotic cell death as determined by flow cytometry. These results showed that AHM displayed multiple antioxidant effects and induced apoptosis of malignant human cells.

Betel quid, a natural masticatory in south-eastern Asia, is composed of various components in different countries or areas. Taiwanese betel quid includes an entire fresh green areca fruit (containing the husk), *Piper betle* (leaf or inflorescence) and slaked lime paste. The slaked lime, handled as pasty form, is either white (white lime paste), with no additives, or brown (red lime paste) due to the addition of catechum, an extract of Acacia catechu. An average of 14-23 betel quids are chewed per day by a Taiwanese chewer, relatively higher compared with the amount consumed by chewers in India or the Philippines.

Betel quid chewing appears to be closely associated with an elevated risk of pre-invasive lesions such as leukoplakia or submucous fibrosis and oral cancer. The habit alone or in combination with tobacco smoking has been condemned as the major aetiology of oral cancer in some south Asian countries.

Areca fruit contains some alkaloids, of which arecoline is the major one. N-nitrosoguvacoline (NG), one of the N-nitrosation products of arecloine, is the only one N-nitrosamine found in Taiwanese chewing saliva. The mutagenic studies in Ames Salmonella microsome test showed that crude alkaloid extracts of areca fruit and arecoline were active in *Salmonella typhimurium* TA100, and NG was weakly active in TA98 and TA100. The activities in both arecoline and NG decreased further in the presence of rat liver S9 mix. Nitrite was significantly consumed during the N-nitrosation of arecoline and at acidic condition (pH3), whereas the formation of NG was favored at neutral condition (pH7). Crude phenolic extracts of leaf and inflorescence of *Piper betel* inhibited the formation of NG by blocking the nitrite. However, a high amount of crude phenolic extracts of areca fruit enhanced the formation of NG.

In the genotoxic study, the Ames *Salmonella microsome* test showed that an aqueous extract of betel quid did not induce mutagenicity in *salmonella typhimurium* strains TA98 and TA100. Mammalian cell studies (Chinese hamster ovary K1 cell; CHO-K1 cell) revealed that only higher concentrations (100 and 1000 μg/ml) of aqueous extract increased the frequencies of sister-chromatid exchange (SCE) in the absence of S9. Animal (male Sprague-Dawley rat) studies showed that low-dose feeding (0.53g dry aqueous extract/kg diet) significantly increased the activities of glutathione (GSH) peroxidase and cytoplasmic glutathione S-transferase (cGST) of liver, whereas high-dose feeding (26.5g dry aqueous extract/kg diet) lowered the contents of GSH and total glutathione. The effect of an aqueous extract of betel quid on the oxidation of 2'-deoxyguanosine (2'-dG) to 8-hydroxy-2' -deoxyguanosine (8-OH-dG) revealed that this aqueous extract may act as a pro-oxidant at lower dosage and may be Fe-dependent in the model system. However, the aqueous extract of betel quid showed antioxidant activity at higher doses by the scavenging effect of the hydroxyl radicals.

Through the introduction to antioxidant physiological functions of Taiwan edible plants, the cooperative studies on the subject should be established among the Asian universities. It is also our goal to promote extensive cooperation and research scientist development. These studies will improve human health from the benefit of

Biotechnology for insect pest control

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Abstract

Insect pests are a major constraint to increased global production of food and fiber. Biological control agents including arthropod natural enemies, entomopathogens (bacteria, nematode, virus, and fungus), plant-derived insecticides and insect hormones are receiving significant interest as alternatives to chemical pesticides and as key components of integrated pest management system. Biotechnology has a significant role in improving efficacy, cost-effectiveness and in expanding the markets for these bioinsecticides. Several molecular techniques have been employed for identifying and monitoring establishment and dispersal of specific biotypes of natural enemies. Genetic engineering and insect transformation technology provide opportunities for the development of insect natural enemies conferring beneficial traits such as pesticide resistance, cold hardiness and sex ratio alteration. Modern technologies provide an effective extraction process, formulation solvents and adjuvants, which can enhance insecticidal activity of plant-derived insecticides. Production, formulation and storage, which are extremely important for the utilization of entomopathogenic fungi and nematodes, can be dramatically improved through biotechnology and genetic engineering. The introduction of gene coding for proteinaceous insect toxins (scorpion toxin, mite toxin, trypsin inhibitor), hormones (eclosion hormone, diuretic hormone) or metabolic enzymes (juvenile hormone esterase) into nucleopolyhedroviruses genome are some approaches to increase speed of kill, enhance virulent and extend host specificity of the virus. Genetic manipulation of *Bacillus thuringiensis* (*Bt*) genes encoding for proteins toxic to insects offers an opportunity to produce genetically modified strains with more potent and transgenic plant expressing Bt toxin. In addition to the *Bt* delta-endotoxin, several proteins that are effective against certain insects such as the vegetative insecticidal proteins (VIP), alpha-endotoxin, a variety of secondary metabolites and proteins of plant origin are amenable to genetic manipulation. Biological control strategies involving beneficial insects, microorganisms that attack insect pests and plant-derived insecticide will provide sustainable control practices that work in harmony with genetically engineered plants. Biotechnology can have a positive impact on food security from insect attack and can contribute to the sustainability of modern agriculture. However, the use of biotechnology brings questions regarding the potential impact of those genetically modified organisms (GMOs) or plants to human, animal and environment. National biosafety and regulatory systems for proper management of GMOs must be in place to enable the full exploitation of biotechnology. Insect control strategies that integrate advance knowledge in biotechnology with traditional wisdom and technology will contribute to the sustainability of agriculture.

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Introduction

An estimated one third of global agricultural production, valued at several billion dollars is destroyed annually by over 20,000 species of field and storage pests. Synthetic, broad-spectrum insecticide is a satisfactory and permanent solution for pest control; however, the excessive use of chemical insecticides is a threat to human health, natural ecosystem and environment. Societal concerns over pesticide use have resulted in the development of new biologically based pest management strategies that are ecologically sound, reliable, economical and practical. These lead to the development and registration of naturally occurring and genetically altered bio-insecticides, which include arthropod natural enemies, entomopathogens (bacteria, nematode, virus, and fungus), plant-derived insecticides and insect hormones. Recent global bio-pesticide products registered include bacteria (104 products, mostly are *B. thuringiensis*), nematodes (44 products), fungi (12 products), viruses (8 products), protozoa (6 products) and arthropod natural enemies (107 products) (Waage, 1996). Bio-pesticides, unlike the chemical pesticides, can be produced at an appropriate scale with technologies that are well within reach of most developing countries. This could make possible the development of local bio-pesticide products that target local pests. However, advance knowledge in biotechnology and molecular biology can help assess the production of more potent and cost-effective bio-pesticides. Most of the modern technologies are directed at improving the performance of an engineered product relative to its wild type competition by broadening their host range, increasing the speed of action, enhancing the delivery of the product to the pest, and improving their persistence in the environment. This paper addresses the biological control agents that are receiving interest as alternatives to chemical insecticides and the recent progress that has demonstrated the potential of biotechnology in enhancing efficacy of those bio-insecticides for sustainable agricultural productivity. Development of genetic engineering bio-insecticides and community perception of these novel biological control agents are also discussed.

Insect natural enemies as bio-control agents

Biotechnology could provide solutions to a number of basic and applied problems that limit the use of insect natural enemies as biological control agents. Mass rearing of insect natural enemies for classical or augmentative release is the main task of this insect control strategy. Maintaining quality in laboratory-reared insects is difficult due to possible genetic changes caused by accidental selection, inbreeding, genetic drift and founder effects (Hopper *et al*., 1993). New DNA-based methods for monitoring genetic variations are now available such as: mitochondrial DNA analysis, DNA sequencing, restriction fragment length polymorphism (RFLP), polymerase chain reaction (PCR), random amplified polymorphic DNA (RAPD)-PCR and ribosomal DNA analysis. Some of these methods are also of potential value for identifying and monitoring establishment and dispersal of specific biotypes of insect natural enemies (Edwards and Hoy, 1993). Currently maintaining insect natural enemies is only by continuous rearing or holding specimens in diapause. The development of cryobiological method for preserving embryos of insects can significantly save the rearing costs, and the valuable collection of insect natural enemies could be maintained indefinitely.

Genetic improvement is a potential approach to increase the efficacy of insect natural enemies. Transgenic techniques provide the opportunity to introduce and express foreign genes and/or disrupt existing gene functions so that the desirable characteristics may be inherited by subsequent generations, thus reducing frequent mass releases. Introduction of DNA into insect germ cells can be achieved by using physical means such as microinjection, biolistics and electroporation or by using biological means in which several transposable elements, Sindbis viruses and retrovirus are used as gene vectors (Atkinson *et al*., 2001). Microinjection is the best method for penetrating insect chorions and delivering vector DNA to the germ cells. Efforts have been most intense and successful with *Drosophila melanogaster*. Inserting cloned target DNA into the chromosome of insect cells was rarely successful until the P-transposable element was genetically manipulated to serve as a vector (Rubin and Spradling, 1982). Micro-injecting DNA carried in P-element vectors had been used for gene transfer in several insect species (McGrane *et al*., 1988, Morris *et al*., 1989).

A technique called *maternal microinjection* in which the exogenous DNA microinjected through the cuticle of gravid females without the aid of any transposable-element vector, is developed for certain species of insect (Presnail and Hoy, 1992). The four transposable-element vectors, Minos element from *D. hydei*, Hermes element from the housefly, *Musca domestica*, MosI element from *D. mauritiana* and piggyBac element from the cabbage looper, *Trichoplusia ni*, have been developed for the generation of transgenic insects and for stable genetic transformation in non-drosophilid insect species. Sindbis alphavirus and pseudotyped pantropic retroviruses have been developed as vertebrate gene expression tools, however, these two viral systems are limited to the expression of genes in individuals that have been directly infected with engineered virus (Atkinson *et al*., 2001).

Other insect transformation methods including soaking embryos in a DNA solution, injecting and transplanting nuclei and pole cells into eggs, using bacterial symbionts as vehicles for expressing foreign genes, baculovirus expression vector and yeast recombinase-mediated recombination are currently explored (Hoy, 1996). However, many of them are limited to *Drosophila* species. A universal transformation system that can be routinely applied for introducing exogenous DNA into insect species, nonetheless their genetic information are barely known, will highlight the future of transgenic insect production.

There are several potentially useful genes that can be used to improve the performance of insect natural enemies. Resistance genes for chemical insecticides will probably be the most available genes, which include a parathion hydrolase gene from *Pseudomonas diminuta* and *Flavobacterium*;, an acetylcholinesterase gene from *D. melanogaster* and *Anopheles stephensi*; the amplification core and esterase B1 gene isolated from *Culex* mosquito, which confers resistance to organophosphorous insecticide. Freeze resistance and heat tolerance genes can help the insect natural enemies to adapt to a broader range of climates and become useful and effective as biological control agents (Hoy, 1996).

The power of biotechnology on genetic manipulation of insect natural enemies is enormous, however, public concerns on the release of transgenic insect emphasized the need to assess the biological consequences of such a release; for example, the risk of any transgene being transferred to non target species. Releases of transgenic insect natural enemies into the environment should be planned and strictly following the appropriate regulatory oversight system set by responsible persons or institutes.

Table 1. Imported chemical and microbial insecticides of Thailand in 1997-2000.

Imported Product	Year 1997		Year 1998		Year 1999		Year 2000	
	Amount	Value	Amount	Value	Amount	Value	Amount	Value
Chemical Insecticide	12,543	1,645,547	12,823	2,044,493	19,525	6,589,279	12,532	2,000,546
Microbial Insecticide	73 (0.5%)	36,833 (2.2%)	78 (0.6%)	51,229 (2.5%)	43 (0.2%)	13,321 (0.2%)	20 (0.15%)	5,984 (0.30%)

Amount : x 1000 kg
Value : x 1000 Baht (1US$~40 Baht)
Source : Department of Agriculture, Ministry of Agriculture and Cooperative, Thailand

Entomopathogens

Entomopathogen is a major segment of biological pesticides worldwide. Asian countries, where two phenomena on the widespread resistance to synthetic pesticides and the unacceptable negative consequences are so intense, have recognized the need for biological insecticide in which entomopathogen received the most attention. For instance, the imported biological insecticides of Thailand are almost exclusively entomopathogens, which include bacteria, virus, nematode and fungi. Recent figures as shown in Table 1 demonstrated the total amount of imported microbial insecticides in 1997-2000, which account for less than 1% of chemical insecticides and the total value of those microbial insecticides is less than 3% of chemical insecticides. *Bt* dominates the biopesticide market in Thailand but recently, fungus is increasing its role in integrated insect management program and is expected to increase its share in the market. Currently, efforts have been contributed to local production of *Bt*, nematode and nucleopolyhedrovirus in China, Vietnam and Thailand. It is, thus forecasted that the growth rate of microbial insecticides over the next ten years should be higher than chemical insecticides. This paper will highlight the principal factors constraining the use of those entomopathogens and to examine how far modern biotechnological processes may overcome these constraints in order to increase the market share for microbial insecticide products.

Bacillus thuringiensis and transgenic insect resistant plants

Bacillus thuringiensis (*Bt*) is a ubiquitous, spore-forming, rod-shaped, Gram-positive bacterium that produces massive amounts of one or more proteins that crystallize intracellularly during sporulation stage. These proteins (*Cry* proteins) are toxic mainly to insect larvae in order Lepidoptera, Diptera, and Coleoptera, but isolates with toxicity toward Hymenoptera, Homoptera, Orthoptera and Mallophaga and against nematode, mites, lice and protozoa have been recently discovered (Lacey and Goettel, 1995). The genes encoding the insecticidal proteins known as *cry* genes have been of particular interest. They have been classified into some 30 different groups by amino acid sequences of the proteins encoded by the genes (Yamamoto, 2001). The genetic manipulation of *cry* genes in *Bt* offers promising means of improving the efficacy and cost effectiveness of *Bt*-based bioinsecticide products. In Asian countries, *Bt* products have been used almost exclusively as direct spray for the control of foliar-feeding lepidopteran insects. Poor persistence under field condition and the dissemination of large amount of spores are two limitations of *Bt* for spray application. Cell Cap technology had been developed in which *Bt* toxin genes were cloned into a common plant-colonizing bacterium, *Pseudomanas fluorescens*. The bacteria were killed, resulting in encapsulated insecticidal proteins that had enhanced residual property in the field and had no *Bt* spores. These novel formulations provide environmentally safe and stabilized *Bt*-based bioinsecticides (Gaertner *et al.*,1993). The gene encoding Cry1Ac protein has been engineered into the endophytic, xylem-inhabiting bacterium, *Clavibacter xyli*. The engineered bacterium was then introduced into corn, and damage caused by stem borer was significantly reduced (Tomasino *et al.*, 1995). In this alternative approach, the endophytic microbe help to enhance delivery of toxin to leaf and stem-feeding lepidopteran insects. Combining genes from different strains of *Bt* to increase the activity and broaden their host range is underway using nonrecombinant and recombinant technologies. A self-transmissible *cry* gene from a *Bt aizawai* strain was transferred via conjugation-like process to a *kurstaki* recipient strain (Gawron-Burke and Baum, 1991). Recent development of *Bt*-based cloning vector system enables the construction of recombinant *Bt* strains with improved spectrum of insecticidal activity and these genetically modified *Bt* products are currently commercially available.

Advances in plant transformation, tissue culture and molecular biology offer great potential for incorporation of genes that produce the *Bt* delta-endotoxin into crops to confer resistance against insects. The two most widely used methods of transforming plant are *Agrobacterium*-mediated transfer of DNA and bombardment of cells with DNA-coated particles. *Bt* transgenic crop has received more attention when *cry* genes had been reconstructed by a combination of mutagenesis and oligonucleotide synthesis to produce synthetic genes. These genes encoded the same proteins but had codon usages typical for plant genomes and which had all aberrant processing signals removed. Expressing level of *Bt* toxin from these synthetic genes was increased by nearly two orders of magnitude when expressed in transgenic plants (Perlak *et al.*, 1991). Since then many other crops, including cereals, root crops, leafy vegetables, forage crops, and tree are/or being engineered to express *Bt* toxins. Currently *Bt* crops have been commercialized for field corn, sweet corn and cotton. Plant varieties that incorporate both *Bt* and virus resistant traits or *Bt* and herbicide resistance have been produced.

Global commercialized transgenic crops in 2001 has been reviewed by James (2001). Herbicide tolerant soybean occupied 33.3 million hectares, representing 63% of the global transgenic crop area of 52.6 million hectares. *Bt* crops occupy 7.8 million hectares, representing 15%, which include *Bt* maize, the second most dominant transgenic crop that occupied 5.9 million hectares; and *Bt* cotton, which occupied 1.9 million hectares. Stacked genes for herbicide tolerance and insect resistance deployed in both cotton and corn occupy 8% of the global area of transgenic crops (Table 2). It is interesting to note that the area of crops with stacked genes for *Bt* and herbicide tolerance increased from 3.2 million hectares in 2000 to 4.2 million hectares in 2001. It is expected that stacked genes will continue to gain an increasing share of the global transgenic crop market. Despite the ongoing debate on genetically-modified (GM) crops, millions of large and small farmers in both industrial and developing countries continue to increase their planting of GM crops. Their decision was based on evidences that clearly demonstrated the benefits of GM crops, such as more sustainable and resource-efficient crop management practices; more effective control of insect pests; and reduction of fumonisin mycotoxin level in maize that provides safer and healthier food and feed products (James, 2001). The number of farmers that benefited from GM crops increased from 3.5 million in 2000 to an estimated 5.5 million in 2001. More than three-quarters of this number were resource- poor farmers planting *Bt* cotton, mainly in China and South Africa. The experience of China with *Bt* cotton presents a remarkable case study where poor farmers are already benefiting from significant agronomic, environmental, health and economic advantages (James, 2001).

In addition to the *Bt* delta-endotoxin, a second class of protein that is effective against certain insects such as the vegetative insecticidal proteins (VIP), alpha-endotoxin, and a variety of secondary metabolites including Zwittermycin from *B. cereus* strains may be amenable to genetic manipulation (Baum *et al*., 1999). Several single gene products of plant origin have been proven to confer resistance to insect damage and have been transferred to another plant species. Lectin and lectin-like proteins are carbohydrate binding molecules that are abundant in seeds and storage tissue of plants. The role for lectin as defensive protein in plants against insect is well documented particularly for homopteran plant pests such as aphids, leafhoppers and planthoppers, which routinely feed by phloem abstraction (Powell *et al*., 1993). Genes encoding the pea lectin (*P-Lec*) and the snowdrop lectin (*GNA*) have been engineered into transgenic plants resulting in significant reduction of insect damage. Enzyme inhibitors that have insecticidal and/or antimetabolic activity in insects such as protease inhibitor, cysteine, alpha-amylase inhibitor and cholesterol oxidase have been proven to reduce insect damage to transgenic plants expressing these proteins (Gatehouse and Gatehouse, 1998). With these tremendous opportunities provided by modern biotechnology, new resistance genes must continue to be identified from both conventional and transgenic sources for the advent of more environment-friendly control strategies.

New genetically engineered and improved *Bt* products may provide more opportunity and choice for growers. It is expected that transgenic plants resistant to insects will be a major component of future pest-control system in agriculture. The risk of developing greater resistance of insects to *Bt* transgenic plants than to *Bt* formulations applied as sprays has been raised and will be one of the major constraints for the utilization of *Bt* crops. However, strategies have been developed to delay the evolution of resistance involving establishment of refugia for sensitive insect, high dose expression in engineered plants, pyramiding traits and agronomic practices (Gould, 1998).

Table 2. Dominant transgenic crops, 2001.

Crop	Million hectares	% Transgenic
Herbicide tolerant soybean	33.3	63
Bt maize	5.9	11
Herbicide tolerant canola	2.7	5
Herbicide tolerant cotton	2.5	5
Bt/Herbicide tolerant cotton	2.4	5
Herbicide tolerant maize	2.1	4
Bt cotton	1.9	4
Bt/Herbicide tolerant maize	1.8	3
Total	52.6	100

Source: Clive James, 2001

Entomopathogenic nematode

Insect nematodes have enormous potential for inoculative and inundative release and control of a wide range of insect pests. They are probably second only to bacteria (i.e., *Bt*) in terms of commercially important microbial insecticides. Commercially available species of nematode as bioinsecticide are in three families: Rhabditidae, Steinernematidae, and Heterorhabditidae. Nematodes parasitize their hosts by direct penetration either through the cuticle or natural opening in the host integument (i.e., spiracles, mouth, or anus). Insect death is not due to nematode itself but a symbiotic bacterium that is released upon entry into the host. The symbionts are specific with members of the genus *Xenorhabdus* associated with the steinernematids and *Photorhabdus* associated with the heterorhabditids (Lacey and Goettel, 1995). In general, both steinernematids and heterorhabditids tend to do best against soil-inhabiting insects and borers. There have been limited successes when applying to other insects. Strain selection and new formulations may be able to address this limitation. Molecular techniques such as RFLP, RAPD-PCR, AFLP, ribosomal internal transcribed spacer (ITS) analysis, satellite DNA analysis have been applied to measure genetic diversity of the nematodes and provide an initial screen to identify useful strains. The development of large- scale *in vitro* rearing systems and formulations that would allow for adequate shelf life and infectivity in the field are underway. Currently, nematodes are successfully grown in large-scale bioreactors similar to those used for the production of *Bt* or antibiotics. Formulation by chilling the produced nematodes prior to formulation and then mixing with materials that will enhance their handling, application, persistence, and storage will help to create a commercial venture. Another limitation of nematodes for insect control is their susceptibility to environmental stress, extreme temperature, solar radiation and desiccation. The potential of genetic engineering to enhance these traits is being explored. In addition, genes that confer resistance to insecticide or fungicides could also be incorporated for protective purposes (Harrison and Bonning, 1998).

Efforts to engineer entomopathogenic nematodes have been immense and relied heavily on knowledge and techniques for manipulating of the *Caenorhabditis elegans* genome (Poinar, 1991). The research has been focused mainly on enhancing the environmental stability with respect to heat tolerance. The nematode, *Heterorhabditis bacteriophora* was engineered to express C. *elegans* Hsp70A (heat-shock protein genes) to enhance tolerance of high temperatures (Hashmi *et al*., 1998). Research on genetic of heterorhabditid and steinernematid nematodes especially on pathogenicity traits are required for future genetic manipulation of more efficient strains of nematode for insect control.

Recombinant Baculoviruses for Insect Control

Entomopathogenic viruses have been employed as bioinsecticides for a wide range of situations from forest and field to food stores and greenhouses. Baculoviruses, particularly the nucleopolyhedroviruses (NPVs) are the most commonly used or considered for development as microbial insecticides mainly for the control of lepidopteran insects on field and vegetable crops. NPVs are formulated for application as sprays in the same fashion as chemical insecticide and *Bt* strains. However, only moderate success has been achieved due to several key limitations, which include a relatively slow speed of kill, a narrow spectrum of activity, less persistence in the field, and lack of a cost-effective system for mass production *in vitro*. Fermentation technology for their mass production on a large-scale commercial basis is extensively investigated to reduce the production cost.

Approaches to engineer NPVs as improved biological insecticide include deletion of genes that encode products prolonging host survival, and insertion of genes that express an insecticidal protein during viral replication. O' Reilly and Miller (1991) demonstrated that deletion of the ecdysteroid UDP-glucosyltransferase (*EGT*) gene of *Autographa californica* NPV caused infected fall armyworm, *Spodoptera frugiperda* to feed less and die about 30% sooner than larvae infected with wild-type AcNPV. Research to insert specific toxin genes or disrupters of larval development genes into baculovirus genome is progressing. The most common used strategy for engineering baculoviruses has exploited the polyhedrin or p10 promoters and the construction of recombinant baculovirus is achieved by allelic replacement of the polyhedrin gene by foreign genes. When the recombination is successful, the polyhedrin of p10 promoters drive the expression of the foreign gene to levels equivalent to those of polyhedrin or p10 in wild type virus (Miller, 1995). Hundreds of proteins from viral, bacteria, animal and plant origin have now been produced via such recombinant baculovirus expression vectors. Candidate genes for insertion into baculoviruses and potential to enhance pathogenicity and insecticidal activity are listed in Table 3 (Vlak, 1993). Introducing an insect-specific neurotoxin gene from the Algerian scorpion, *Androctonus australis* and from the straw itch mite, *Pyemotes tritici* into insect genome using the baculovirus expression system have received the greatest attention to date (Treacy, 1999). There are several insect hormones that play vital role in the control of insect morphogenesis and reproduction and are focused for engineering into baculoviruses. These include eclosion hormone that initiates ecdysis, the process leading to the shedding of old cuticle, prothoracicotropic hormone (PTTH), which is involved in triggering the molting process; allatostatins and allatotropins, which regulate the release of juvenile hormone; and diuretic hormone (DH) that regulates water balance and possibly blood pressure in insect. Another interesting gene for genetic manipulation of baculovirus is the enzyme gene, juvenile hormone esterase (JHE) that caused the reduction in JH level. A reduction in the titer of JH early in the last instar initiates metamorphosis and leads to cessation of feeding. Insertion of two or more toxin genes into baculoviruses has been studied and Hermann *et al.*(1995) found that binary mixtures of scorpion toxin, AaIT and LqhIT injected into larval of *Helicoverpa virescens* induced 5-10 fold the levels of activity. The authors suggested that simultaneous expression in baculoviruses of synergistic combinations of insecticidal proteins could lead to even more potent, insect-selective bioinsecticides.

The development of baculovirus expression system and the accomplishment of insect cell culture technology have broadened the utility of insect viruses as effective insecticides and as expression vector of foreign genes in eukaryote host for the production of useful proteins. Production, formulation and application technology in conjunction with genetic engineering for fast kill and broader host range will be necessary to enable the development of more economic and efficacious viral products for insect control.

Table 3. Candidate genes for introduction into baculoviruses and potential to enhance insecticidal activity.

Gene class	Protein	Insecticida[1] potential
Toxins	Bt-toxin	+/-
	Scorpion toxin	+++
	Mite toxin	+++
	Trypsin inhibitor	?
Hormones	Eclosion hormone	+/-
	Diuretic hormone	+
	Prothoracicotropic hormone	+
	Allatoropin	-
	Allatostain	+
	Proctolin	+
Enzymes	Juvenile	+

Source : Vlak, J. M. 1993

Entomopathogenic fungi

Although over 750 species of entomopathogenic fungi were reported to infect insects, few have received serious consideration as potential commercial candidates. The first registered mycoinsecticide was *Hirsutella thompsonii*, which has been known to cause dramatic epizootics in spider mites. The next mycoinsecticides are *Verticillium lecanii* and *Paecilomyces fumosoroseus*, which have been recently registered for control of whitefly, thrips, aphids and spider mites. Insect fungi that have much broader host range are *Beauveria bassiana* and *Metarhizium anisopliae*, which are effective against homopteran and lepidopteran greenhouse insects as well as coleopteran and lepidopteran field insects (Flexner and Belnavis, 1998). The broad host range of some insect fungi is an attractive characteristic for insect pests control. Nevertheless, there are numerous biotic and abiotic constraints on the ability of fungi to infect their hosts. These include dessication, UV light, host behavior, temperature, pathogen vigor and age. Certain aspects of the insecticidal efficacy of these fungi such as production, stability and application have been optimized by nongenetic means. For instance, advances in production and formulation technologies have contributed substantially to the cost-effectiveness and viability of mycoinsecticide as practical insect control agents.

Optimization of entomopathogenic fungi by genetic engineering is limited due to lack of knowledge of molecular and biochemical bases for fungal pathogenesis, and the unavailability of good cloning system for species other than deuteromycete fungi. The molecular and biochemical bases of pathogenicity of *M. anisopliae* which cause green muscardine diseases, have been well studied especially on host cuticle penetration by the fungus. Various genes related to formation of the appressorium (a specialized structure involved in penetration of the insect cuticle by the fungus), virulence, and nutritional stress had been cloned from *M. anisopliae*. Additional copies of the *PrI* gene, which encodes a subtilisin-like protease involved in host cuticle penetration were engineered into the genome of *M. anisopliae*. The larvae infected with recombinant strains died 25% sooner and feeding damage was reduced by 40% (St. Leger *et al*., 1996). The prospect of using recombinant fungi for insect control highlights the need for further research in identifying and manipulating genes involved in pathogenesis and monitoring of genetic exchange between strains by using isolate-specific molecular markers. (Harrison and Bonning, 1998). Despite a potentially wide array of insecticidal proteins produced by entomopathogenic fungi, fungal genes have played little part in agricultural biotechnology to date.

Botanical Insecticide

More than 2,400 plant species around the world are currently known to possess pest control properties. The promising species include the neem tree, sweet flag, onion, garlic, custard apple, pyretrum, derris, common latana, holy basil, black pepper, and common ginger (Weinzierl, 1998). Botanical insecticides may be in the form of dust or powder of crude preparations of plant parts that may be used in full-strength or diluted in a carrier. Some preparations are the water extracts or organic solvent extract of insecticidal components of plants. The most processed forms are purified insecticidal compounds that are isolated from plant materials by a series of extraction and distillations. The use of botanical insecticide is well documented in Asian countries and extracts from neem tree, *Azadirachta indica* appear to be the most widely used. In Thailand, the availability of neem-based bioinsecticide was a prerequisite to the emergence in the early 1990s of a new market of organic vegetables, fruit and rice, now widely sold through a network of “green” shops. More than 15 complex chemicals having repellent, antifeedant, insect growth regulator and insecticidal properties have been identified in aqueous and chemical extracts of neem leaves, bark, stem seed and other parts. Seeds or seed kernels provide the greatest amounts of insecticidal compounds (Schmutterer, 1990). Neem is generally considered to be most effective against the soft-bodied, immature stages of plant pests, including whiteflies, thrips, mealybugs, and various caterpillars (Weinzierl, 1998). Neem’ s broad activity against plant-eating insects, its virtual nontoxicity to mammals, beneficial insects and environment make it an extremely appealing insecticide.

Despite several appealing traits, however, botanical insecticides continue to fill only a minor role, primarily because most are very expensive in comparison with synthetic insecticides. Their availability is often limited because production levels are not sufficient to meet a highly fluctuating global market demand and bioactivity of some products often varies among seeming identical preparations (Weinzierl, 1998). Research should be focused on increasing natural production, improving extraction rates of the toxic compound and improving formulation for spray application. Gene transfer into bacteria or directly into food crops for the production of toxic compound is encouraging.

Pheromone for Insect Pest Control

Pheromones are signal compounds used by insects to communicate. The direct insect control approaches using pheromone includes mass trapping, lure and kill tactics and mating disruption tactics. The most efficient way is the lure and kill technique. Combination of pheromone and pathogen is designed not to kill the insects right away, but rather to use them as vector of the disease into the wider population. Mating disruption technology has received considerable attention, however it only works with isolated population. A large number of pheromone dispensers were deployed to interfere with orientation toward conspecifics and interrupt the life cycle of the insect by preventing mating (Suckling and Karg, 1998). All the pheromones currently marketed are made by chemical synthesis, but biotechnology is of potential interest. For instance, pheromone consists of two stereo-isomeric variants, only one of which has the desired biochemical effect. The use of enzyme technology will allow the effective form only to be produced, whereas in chemical synthesis both variants are produced. Accurate identification, increased stability and longevity, and more uniform release rate following field exposure, can enhance the performance of pheromones. These improvements can be achieved through the continued progress of biotechnology (Suckling and Karg, 1998). However, the adoption by growers of pheromone-based biological control will depend on how well the system can meet grower concerns about efficacy and cost. A better understanding of how and why the technology works will lead to the design of a more cost-effective technology.

Table 4 Awareness of cotton growers in Thailand on the impact of *Bt* cotton on the environment.

Awareness	Number of growers	%
Aware of (positive & negative)	15	24.19
Not aware of	38	61.29
Not indicated	9	14.52

Source : Kunalasiri, A. and S. Buskaew (2000)

Table 5. Acceptance of *Bt* cotton by cotton growers in Thailand.

Acceptance	Number of growers	%
Accept	48	77.42
Not accept	3	4.84
Not certain	6	9.68
Not indicated	5	8.06

Source : Kunalasiri, A. and S. Buskaew (2000)

Community Perception on Genetically Modified Organisms

Most of the agricultural countries recognize the potential of biotechnology as an important tool for agricultural productivity. In the past decades, many genetically modified (GM) microorganisms and plants have been produced and used in agriculture primarily for insect and disease control. There are growing concerns of the community over GM plants and products derived. Those who are in favor of the technology believe that GM plant could help the farmers reduce pesticide use and increase crop productivity. On the other hand, the opponents are anxious about the possible risk that may be associated with GM technology. The production of GMOs is now being considered as biosafety, trade and political issue. Community perception on GMOs will be presented here with special reference to public and farmer's perception of GM plants and products particularly the cotton engineered with *Bt* toxin genes in Thailand.

Cotton has been considered an important economic crop for Thailand since 1961 due to its high demand for the textile industry. The major constraint for cotton production in Thailand is the presence of insect pests especially the cotton bollworm, *Helicoverpa armigera*. *Bt* cotton resistant to insect attack, therefore, received much of public attention and demonstrated high potential for commercialization. The NuCOTN 33B *Bt* cotton was first introduced by Monsanto Ltd. Thailand Company in 1995 for screenhouse testing. This cotton line was described as having the *crylAc* gene from *B. thuringiensis* that is effective against the cotton bollworm, *H. armigera*. In 1996, *Bt* cotton was approved for isolated small scale field trial in Chiang Mai Province. By 2000, nine isolated large scale field trials of *Bt* Cotton were conducted in the Department of Agriculture (DOA) experiment stations and farmer's fields. During these field trials, GMO debates were so intense among the Thai community. In 1999, the National Center for Genetic Engineering and Biotechnology (BIOTEC) had conducted a survey on public awareness, understanding and opinions about genetically modified organisms (GMOs). On the understanding of GM technology, 34.15% indicated that they have no knowledge about it. Those who understand the technology at good, average and basic levels were at 15.57, 32.51 and 16.39%, respectively. Most of the Thais (90.71%) were aware of the GMOs but they have fewer concerns on GM food as compared to chemical residues being food contaminants. It is obvious that media plays an important role in public awareness (Noppakornvisate *et al*., 2000).

In the same year, the DOA made a survey on the socio-economic effect of the transgenic *Bt*-cotton to cotton growers in six provinces in Thailand. Generally, cotton growers (91.93%) knew about *Bt* cotton from the media and seed companies. They have heard of the advantages and disadvantages of the so called GM plants. Yet, only 24.19% were aware of the possible adverse effects of *Bt*-cotton on the environment (Table 4). About 77.42% of the farmers in the survey were willing to plant *Bt*-cotton as soon as it is permitted and only 4.84% denied to accept *Bt* cotton (Table 5). Most of the farmers believed that *Bt*-cotton could reduce the cost of production and lessen the use of chemical insecticides, which consequently contribute to their better living conditions (Kunalasiri and Bukaew, 2000). However, due to the strong movement of the anti-GMO and NGO groups campaigning against the technology monopoly and possible adverse effects on biodiversity, the government decision on deregulation of transgenic *Bt*-cotton for commercialization has not been made. The surveys clearly showed that the scientific community in Thailand is open-minded to the GM technology. Yet, there is a need to help the public understand the technology better, especially those who are not in the field of biological science.

Conclusion

Sustainable agriculture could be achieved not only through proper agricultural practices but also through continuous research and development of new technologies, particularly agricultural biotechnology, which is probably a very important investment to achieve greater competitiveness in the world market. Knowledge and continuous research is the key to assess the potential of biotechnology to increase agricultural productivity and to contribute to sustainability of agricultural systems. Potential improvements of bio-control agents involving beneficial insects and microorganisms that work in harmony with genetically engineered plants are examples of the utilization of biotechnology that lead to sustainable control practices.

Public concerns on extensive use of chemical insecticides, insect resistance development, and the rising cost of developing new synthetic insecticides, all suggest that integrated insect pest management utilizing biological control products will become increasingly important in the years to come. However, products of biotechnology should be handled and marketed in much the same way as chemical pesticides. It is important to provide appropriate regulatory mechanisms to ensure that products produced by using new techniques are as safe as the products of traditional biotechnology. It is wiser, especially for the Asian countries to look into bio-control products that complement synthetic pesticide instead of replaces them. Bio-insecticides should bring great benefit in reducing the use of synthetic pesticides, especially those that are toxic and persistent. An integrated insect pest management underlying less input, cost effective and friendly environment is the key for sustainable agriculture.

Despite tremendous benefits of biotechnology in insect pest management, there are still questions that required answers especially in Asian countries where biotechnology could be most profitable. Specific examples are the uncertainty of the technology in terms of successful research and adoption by the end users; high start-up investment; public awareness and acceptance; national policies on bio-safety and intellectual property issues; technology dissemination and proper implementation; human resource and institutional development; and limited funding due to long-term and continuous nature of the research. Responsible national institutes and other affiliated research centers should engage in educational and training programs aimed at the general public for better understanding of the risks and benefits of biotechnology application.

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Biotechnology of Crop Production and International Consortium

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Abstract

Session 2 of this Forum, which I chaired, tackled the topic on Biotechnology for Sustainable Bioproduction. All speakers shared with us their research findings and technical knowledge on carbon metabolism and nitrogen metabolism in relation to biotechnology for crop productivity; enzyme engineering of lipids and dietary antioxidants as related to biotechnology for food production; and biotechnology for biotic stress tolerance. While we discussed various concerns about agriculture in Asia, we did not discuss about abiotic stress tolerance in plants. So, I would like to share with you some problems and recent developments in research in this field, which result from our works.

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Recently, global warming has accelerated desertification all over the world. To prevent the desertification and keep agriculture sustainable, we have been studying on the mechanism of salt, drought and heat tolerance in barley (11,12,13) and highly drought- tolerant sheep grass, *Aneurolepidium chinense* (6). We obtained hundreds of salt, drought and heat inducible genes and are now looking for strong genes to confer salt, drought and heat tolerance to rice (Japonica). We have been discussing about possible collaboration with Kasetsart University because Thailand has salty desert area and it is a serious problem not only in Thailand, but also the whole of Asia and other countries including developed countries. Our group has established transformation systems of Japonica rice and Indica rice (poplar trees also recently). We now recognize that collaboration between universities in Asia and our University is of great advantage to resolve this serious environmental problem for sustainable agriculture.

I would like to introduce the following strong transgenic model and rice plants towards abiotic stress analyzed in my laboratory:

WT Dnak-rice

WT Dnak-rice

1) Transgenic tobacco and rice with DnaK from highly salt-tolerant cyanobacterium Aphanothece halophytica

I have been using *Aphanothece halophytica* for quite some time to study on subunit structure and function of CO_2 fixation enzyme, RuBP carboxylase/oxygenase (Rubisco). *Aphanothece halophytica* accumulates glycinebetaine ca. 2 M in the cell. I noticed that this cyanobacterium has quite unique enzymes depending on glycinebetaine or highly salt-tolerant enzymes. We then started cloning a kind of heat shock protein (HSP70) gene, *DnaK*. Usually, DnaKs have a molecular weight of 70kD. But our DnaK has an extra C-tail (9 kD) at the end of the protein compared to other HSP 70 groups. This C-tail is important to make the DnaK strong under both salt and heat stress (1). We introduced this gene into tobacco plants first (8). The transgenic tobacco acquired resistance to salt stress at the vegetative stage. We also confirmed that the transgenic tobacco has highly enhanced heat tolerance at the germination stage and young vegetative stage (5). We were astonished that these transgenic plants have a high productivity (almost twice compared to that of WT) of seeds under heat stress at the reproductive stage. We also made transgenic rice plants using *DnaK*. DnaK-rice acquired high heat tolerance at both young vegetative and reproductive stages. The DnaK-rice has grown better than WT at the normal temperature (28 ℃ /23 ℃) and at high temperature (35 ℃ /23℃). The yield of seeds also increased twice in the transgenic rice like in transgenic tobacco as described above. We are now field-testing the phenotype of DnaK-rice in a strictly regulated area for the safety of genetically modified crops under the collaboration with Dr. Takiko Shimada (Ishikawa Prefecture Univ.). This transgenic rice could be applicable to agriculture under salt, drought and heat stress conditions. We also introduced this gene into poplar and are now analyzing the phenotype. We are expecting that DnaK-poplar trees grow better under normal conditions and stress conditions.

2) Transgenic rice transformed with GSII gene

GSII is glutamine synthetase, which is localized in chloroplasts and involved in photorespiration. GSII is the limiting step in photorespiration as well as Calvin-Benson cycle. Photorespiration is essential in plants that grow under stressful conditions, such as high light. We tested this transgenic rice with salt tolerance. We confirmed that the transgenic rice plants have highly increased tolerance to salt stress (2).

3) Transgenic rice plants transformed with KatE and yeast mitocondrial Mn-SOD genes

We also made transgenic rice plants using catalase gene (*KatE*) from *E. coli* . This transgenic rice also showed a strong phenotype about salt tolerance.

We also examined transgenic rice overexpressing yeast mitochondrial Mn-SOD in chloroplasts. Actually this transgenic rice came from Plantec Research Institute in Japan. Seeds were T7, which showed a weak phenotype of salt tolerance (9). We believe that gene silencing occurred in this transgenic rice (T7). About 50% of the seeds lost the yeast Mn-SOD gene. This is a problem of genetic engineering of plants sometime. We also made transgenic *Arabidopsis* and rice using heat-inducible peroxisomal APX. Those transgenic plants showed enhanced heat tolerance at both vegetative and reproductive stage (7).

We found that glycinebetaine synthesis is induced by H_2O_2 (3). This is an interesting finding. A low level of H_2O_2 enhanced growth of rice under salt and heat stress (10), although it is toxic with high concentrations.

4) Other transgenic plants and rules for collaboration

We have been making transgenic rice producing glycinebetaine (4). Rice is a very salt-sensitive plant and does not accumulate glycinebetaine. We used modified gene (*betA*) of choline oxidizing enzyme from *E. coli* to transform rice, because codon usage is different between *E. coli* and rice. We collaborated with a Japanese company. The company obtained very good data about salt tolerance, although we were competing with another big group. Finally they did not publish the paper at all and obtained the patent for the genetically engineered rice without me. Although I do not mind, I think there are some difficulties to collaborate with companies. However we have to be patient in breeding new crops for our future. Both the university and company people must mutually understand more. Although almost five years have passed after collaboration with the company, I am looking for a possibility of studying the transgenic rice from other points of view, such as acid rain or heavy metal stresses. This experience became a case story in my laboratory, after we made many stronger transgenic plants towards abiotic stresses. I also had a similar experience in collaboration with an Asian university. I realized that any genes from developed countries are kind gifts for Asian people. I think it is a great idea and I am very pleased if they can use the genes we developed for agriculture. However I started the research as a collaborative work. But the Asian scientists wanted to study by themselves. We must establish rules on how to collaborate with not only companies, but also Asian universities, before implementing any activity. Rules on patents and authorships should be well defined to avoid problems.

5) Academic International Consortium

Our laboratory is now open to anyone in the world, if collaboration is honestly carried out between two or more collaborating institutions. We have many candidate genes to develop strong transgenic rice or other plants including poplar trees. Our genes can be used for sustainable agriculture in Asia and an international consortium for this purpose is welcome anytime. The Japanese professors must have at least one postdoctoral fellow and one technician, just like in research institutes or universities in the USA. Our situation in Japan is too stiff to consider any collaborative work with Asian scientists now. I am training two graduate students from Asian countries. It is not easy to train them by myself, although it gives me great pleasure and I enjoy guiding them. The School of Bioagricultural Sciences in Nagoya University needs not only high impact papers on basic sciences, but also high levels of application studies to produce crops and develop and improve tree species for forestry in Asia, including Japan. It is my worry that the time will come when shortage of food will be experienced in Japan. It is my hope that grants are given to the more applied fields in agriculture and forestry.

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Chapter 3

International Collaboration for Sustainable Bioproduction

Perspectives for Development of Research and Education by International Collaboration in Graduate School of Bioagricultural Sciences, Nagoya University

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The total number of foreign students in Japan has increased rapidly to 80,000 during the last three years. This increase was due to the rise in number of self-financed students. The number of students under the Japanese government scholarship remained rather constant and comprises only 10% of the total number. This situation poses a serious problem, which needs the attention of the Japanese government. One possible solution is to request the Japanese government to increase the number of state-supported fellowships.

At Nagoya University, about 1100 students are now studying on campus, which implies that the research and educational activities of Nagoya University are highly evaluated abroad. The changes in the number of the foreign students of Nagoya University are similar to the general trend at the country level where the number of self-financed students increased and reached about 70% of the total foreign students (Fig.1). The number of students under the Japanese government scholarship remained rather constant. However, the ratio of the Japanese government scholarship students to the self-financed students in Nagoya University is significantly higher than that at the national level (Fig.2).

Seventy percent (70%) of the foreign students are studying to receive doctorate degrees, since Nagoya University is one of the research universities in Japan and aims to provide higher education for graduate students. Eighty-five percent (85%) of students are from Asian countries, while only 7% are from Europe and United States, and 5% are from Africa and Central and South America. The majority of foreign students are from China and they comprise about 45% of the total foreign students, which causes some disadvantage to them, for example, to get fellowships (Fig.3).

Foreign students are confronted with issues and problems not only in their research but also in their life in Japan. The main problems shared by students are 1) problems caused by cultural differences, 2) needs for scholarships and housing, and 3) research projects.

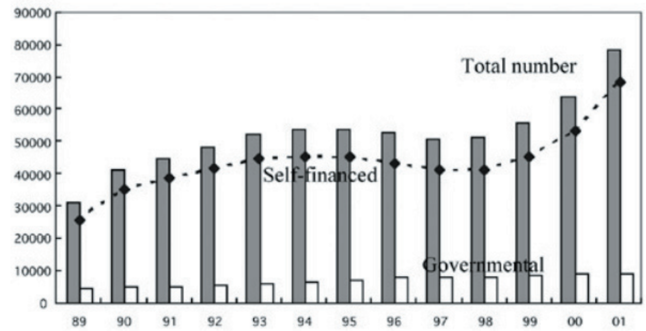

Fig.1 Changes in numbers of foreign students in Japan

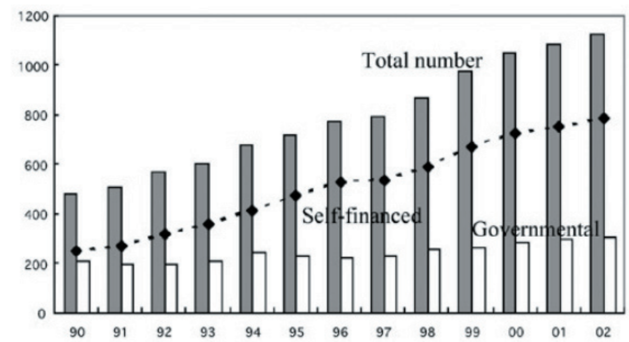

Fig.2 Changes in number of foreign students in Nagoya University

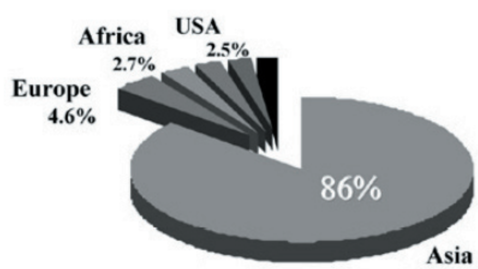

Fig.3 Countries and areas represented by students in Nagoya University

Foreign students in Graduate School of Bioagricultural Sciences

We have admitted altogether 366 students from 27 countries up to 2002. Seventy-three (73) students admitted at the School of Bioagricultural Sciences is the largest number received in our school so far (Fig.4). However, this number has reduced to only 56 students studying in our School in 2002. Noticeably, the number of self-financed students has increased. The countries and areas represented by the students in our School and their relative ratios are also similar to those of entire Nagoya University (Fig. 5).

The research facilities in our school are of top levels in Japan and we have many advanced equipments. Foreign students find it convenient to conduct their researches in their own laboratories. Most of the faculty members have experiences in doing research abroad and they are making efforts to maintain their high level of research through cooperative works with foreign scientists. To achieve high quality level of research, foreign students are requested to do experiments on complex problems requiring intensive research. As far as foreign students of our school are concerned, they perform very well and do their best to respond to the requests made by the academic advisors. So far, 188 students obtained PhD and 150 students obtained Master degree.

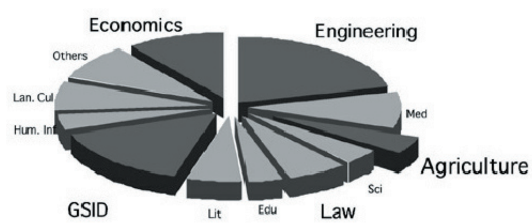

Fig.4 Numbers of foreign students in each school

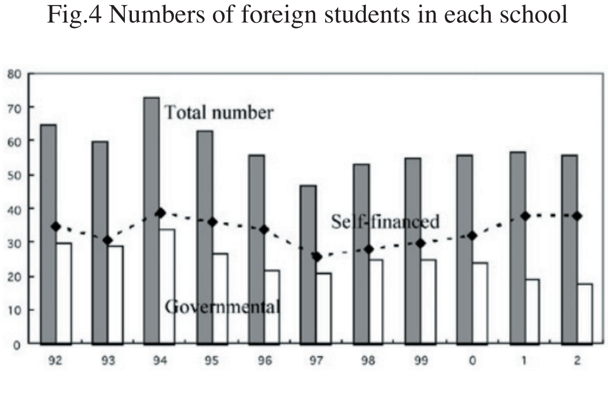

Fig. 5 Changes in numbers of foreign students in Graduate School of Bioagricultural Sciences

International exchange programs in Graduate School of Bioagricultural Sciences

We have altogether 11 exchange programs with 11 universities and institutes from nine different countries. Implementation of activities based on agreements with Kasetsart University and North Carolina State University has been quite active (Table 1). These are university-wide agreements, which enable the faculty members of other schools to participate in exchanges. These exchange agreements aim to promote cooperative researches and exchange of faculty members between our school and the other institutions. Exchange of students, usually graduate students, is only a part of the agreement and research projects are mainly emphasized. Since Nagoya University is a research university, it is inevitable to place more emphasis on faculty exchanges than on student exchanges. To activate the agreements and implement the academic exchange of the faculty members for the joint researches, we need financial support. In the past, we were quite lucky and obtained twice the University-University cooperative research grants to conduct joint researches with NCSU (1987-1989) and Rosario National University (1995-1997). In addition to this type of grants, we can apply for national grants to conduct joint researches with foreign scientists at the individual level. I have obtained such joint research funds with University of Nottingham in UK and Melbourne University in Australia. Through these joint researches, I was able to make good and strong relations with my counterparts. I did not, however, exert personal efforts to conclude any departmental or university-wide agreements with those universities. There is no administrative assistance from the university in carrying out all paper works necessary in concluding the agreements. Individual faculty members concerned do all the works. The faculty members including myself simply have no time for these administrative works and therefore are very reluctant to be involved with the exchange agreements. I feel that there are many similar cases in this School. It is important now to look for joint research programs for future development of our School and make efforts to conclude agreements.

International Exchange Committee in Graduate School of Bioagricultural Sciences

The External Review Committee evaluates our international exchange activities twice. In general, our activities are considered to have reached a high level by current Japanese university standards. However, several suggestions have been made as follows: 1) acceptance of foreign students from both developed and developing countries, 2) establishment of a system that provides post-departure follow-up of foreign students and feedback to the School, and 3) education of Japanese students on their international awareness.

Future Perspectives

A former foreign student suggested several things in his memoirs, which he contributed to the 50 years history of the School of Agriculture. These are as follows: 1) active exchanges at the level of graduate and undergraduate students, 2) exchanges of advanced information as well as planning of joint researches, and 3) financial support of researches for former students. We might be able to materialize some of these suggestions in the future. We should discuss about these possibilities in our international exchange committee. I would like to take this opportunity to propose a discussion on the possibility to organize a new Consortium to cooperate on research and education for sustainable bioproduction around the world. I would like to conclude this lecture by quoting the comment made by Dr. Shang Fa Yang, one of the members of the External Review Committee:

"During the 1960's and 1970's, the USA played a very important role by providing the training for many international students and visiting scholars around the world. Now, Japan is in a good position to do the same. I sincerely hope that Japanese government takes a more active role in this endeavor, by providing more funds so that Japanese universities, including Nagoya University, would be able to more actively participate in this program. I trust this is the privilege and also the responsibility of Japanese people."

Table 1 Academic exchange agreements in Graduate School of Bioagricultural Sciences and ICCAE

1) Kasetsart University	Thailand	1981	University-wide
2) The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA)	Philippines	1983	University-wide
3) North Carolina State University	USA	1985	University-wide
4) University California, Berkeley	USA	1989	Departmental
5) Rosario National University	Argentina	1993	Departmental
6) The Research Institute of Biochemistry, "Luis F. Leloir, Capomar Foundation"	Argentina	1994	Departmental
7) Nottingham University, The Faculty of Agricultural and Food Sciences	England	1994	Departmental
8) The Institute of Cytology and Genetics, Siberian Division of the Russian Academy of Sciences	Russia	1997	Departmental
9) Australian National University,	Australia	1997	Departmental
10) Bangladesh Agricultural University The Research School of Biology	Bangladesh	2000	Departmental
11) African Institute for Capacity Development	Kenya	2002	Institutional

Tasks in Research, Education and International Collaboration in Agriculture Biotechnology at Kasetsart University With Special Emphasis on the Role of Former Students Who Studied Abroad

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Abstract

Thailand is considered as one of the food producing countries of the world. For centuries, Thailand has a large number of skilled farmers engaged in food production. With the increasing demand for agricultural products for export, animal and crop production systems are moving toward high inputs for higher yields. High cost of agricultural production results in less income for farmers and creates an unhealthy environment.

Biotechnology offers a challenge to sustainable bioagriculture production and friendly environment. Some of the key features for biotechnological products are the less use of chemical pesticides, crop varieties that fit the unfavorable environment and crop quality that meets the market needs. Innovation in biotechnology requires a starting point, mainly the university where technology transfer and diffusion can be made available for farmers, general public or industry. This is the case for Thailand where Kasetsart University plays a major role in bioagriculture production.

The development of biotechnology at Kasetsart University was very much in line with the close collaboration between Kasetsart University and the Japanese Government under KU-JICA project since 1980. As a result, the Central Laboratory and Greenhouse Complex (CLGC) was established at Kamphaengsaen Campus. The CLGC is one of the most modernized centers in the region that houses research facilities and well-trained researchers particularly in the area of agriculture biotechnology. In 1985, the Plant Genetic Engineering Unit (PGEU) was established within the CLGC through the collaborative arrangement between Kasetsart University and the National Center for Genetic Engineering and Biotechnology (BIOTEC) of Thailand. This unit focuses on the development of crop varieties for insect and disease resistance by genetic transformation. In 1999 and for the first time, the College of Agriculture offered an undergraduate degree program in Agriculture Biotechnology. During the same period, the Agriculture Biotechnology Center (ABC), Kasetsart University, was established to offer the M.S. and Ph.D. degrees in Agriculture Biotechnology by forming a consortium with four local universities. The Asian Development Bank (ADB) financially supported the program.

From the brief history of human resource development on agriculture biotechnology at Kasetsart University, it is well recognized that international collaboration is essential to success. However, the application aspect of the technology must come from high quality basic research and contribution of well-trained researchers. The outputs of KU-Nagoya collaboration during the past several years have clearly demonstrated the importance of this partnership. International collaboration needs to be strengthened in the future since research institutions like universities will have to attract a group of young, highly qualified scientists to tackle some common issues such as intellectual property rights, biosafety and bioethics. Commercialization of bioagriculture products will be placed under international rules and regulations, which, in many cases, are being used as trade barriers. These tasks are so critical and vital to future development in the area of agriculture biotechnology which can be achieved by close collaboration at national and international levels.

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Introduction

An increasing demand of food production and the conservation of natural resources greatly affect agricultural systems in many countries including Thailand. In the past, countries producing food crops and other agricultural products have utilized lands and water exhaustively for their productivity and incomes. These common practices resulted in severe deforestation and adverse effects on the environment. Recognizing the potential danger to the global environment, the World Summit of 1992 addressed in the Agenda 21 of the Rio Principles for the sustainable development including "better health care, enhanced food security, improved supplies of portable water, more efficient industrial processes, sustainable methods of afforestation and reforestation, and detoxification of harzardous waste". This framework of global agreement has several key elements that each country participating in the summit should realize and implement accordingly.

Science and technology, particularly biotechnology, were given high priority to solve the pressing problems facing food production. Therefore, it is an urgent need for human resource development to implement the technology for sustainable development. This is the main challenge of universities and educational institutions to respond to the needs of society by producing graduates and well-trained researchers who are capable of performing their functions with great care and responsibility.

Sustainable Bioproduction: The Thai Perspective

Thailand is considered as one of the food producing countries of the world. The country is the world leader in rice production and export since rice farming has been practiced for over 5,000 years. Thai agriculture has gone through a significant change from subsistence farming to commercial farming. Commercial farming causes the expansion of cultivated land and several detrimental effects on the environment. In addition, the market-oriented agriculture requires high inputs such as chemical fertilizers, pesticides and farm machineries. Farmers will have to rely heavily on the price of their commodities, which in most cases generate less incomes. This kind of trend for non-sustainable bioproduction seems to show clearly in Thailand and other countries in the region.

Sustainable agriculture has been introduced as a new concept for bioproduction. There are varying definitions as to what sustainability in agriculture means. However, most agree on an efficient use of resources that causes as little harm to the environment as possible (Sriwatanapongse, 1997). Recently, the concept of "self-sufficient economy" has been initiated by His Majesty the King of Thailand and now being applied in almost all sectors, especially agricultural production. To be "self-sufficient" in agriculture is to maintain the (wheel of) three factors including the farmer, the environment and the production in a well-balanced way (Fig. 1). This balance will undoubtedly lead to benefit sharing among the concerned factors where "sustainability" clearly reveals itself. As long as we are able to maintain the balance and be competitive, the whole system will certainly move forward to the goal of "sustainable bioproduction".

In terms of sustainable bioproduction, biotechnology offers a new challenge for conventional practices. New generation of biotechnological products should be causing less or no pollutant, consuming less energy and should be safe to consumers. Innovation in biotechnology requires a starting point, mainly the university where technology transfer and diffusion can be made available to the production sector.

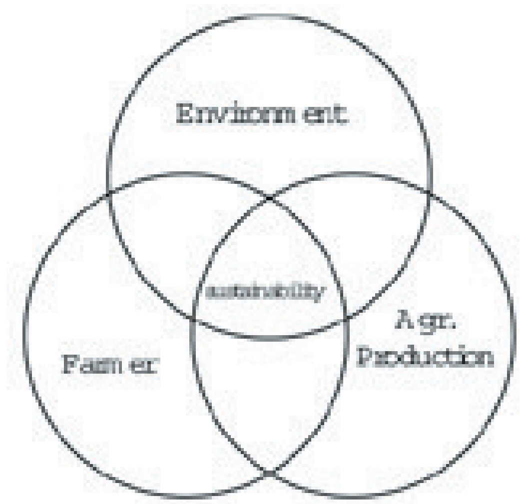

Fig.1 A model of sustainable agricultural production in Thailand.

Research and development in Agriculture Biotechnology

Biotechnology covers a wide range of technologies. It is, therefore, fair to say that agriculture itself is also a part of biotechnology. However, a modern biotechnology generally known as recombinant DNA technology or genetic engineering has emerged recently with so many diverse applications. In the simplest way, a known gene from any living organism can be precisely transferred into plant or animal resulting in so-called "genetically engineered or transgenic" plant or animal. This organism will then express the character of the transferred gene while the overall genotypic characters remain intact. Research and development in agriculture biotechnology, particularly in the tropical countries like Thailand, are focused mainly on the production of insect, disease and abiotic stress resistant plants (Attathom, 2001). Shelf-life of fruits and vegetables can be prolonged by delaying the ripening process through genetic engineering. Transgenic rice containing vitamin A, which is now being tested in the Philippines is also an example of the improvement of crop nutrition by genetic manipulation.

It is quite clear that biotechnology can lead to the development of crop variety, which depends less on chemical pesticides. This is an advantage for farmers and consumers since chemical pesticides deteriorate the health of farmers, pollute the environment, and contribute to the higher production cost. Products derived from agriculture biotechnology per se thus facilitate sustainable agriculture development.

Agriculture biotechnology as well as molecular biology is developing at fast pace. Biotechnology is now being applied in agriculture in three main areas: animal and crop variety improvement, renewable energy and biodiversity conservation. There are different degrees of complexity in the application of biotechnology in agriculture. For example, the improvement of crop variety may begin with the selection process for the parental lines, the production of pathogen free planting stocks, the development of biofertilizer and biocontrol agents, and the development of genetically-engineered or transgenic plant for specific trait, respectively.

Newly developed agricultural-biotechnology product not only requires technology input and qualified technical staff, but also has to meet the basic requirement in accordance with the international guidelines and regulations as well as consumer acceptance in the global market. In addition, issues concerning intellectual property and biosafety have to be taken into consideration before commercialization of the product can be made (Attathom et. al., 1996). These conditions, on the other hands, are considered to be constraints for the application of biotechnology in agriculture.

Kasetsart University and Agriculture Biotechnology

Kasetsart University (KU), established in 1943, is the country's leading university in agriculture. The university produced a large number of graduates serving in nearly every sector of bioproduction including agriculture, fishery, forestry and agroindustry. Several commercial plant varieties and livestock have been developed at KU by conventional breeding and selection programs. The development of biotechnology at KU was very much in line with the close collaboration between KU and the Japanese Government under KU-JICA project since 1980. As a result, the Central Laboratory and Greenhouse Complex (CLGC) was established at Kamphaengsaen Campus, Nakhon Pathom. The CLGC is one of the most modernized centers in the region that houses research facilities and well-trained researchers particularly in the area of agriculture biotechnology. In 1985, the Plant Genetic Engineering Unit (PGEU) was established within the CLGC through the collaboration arrangement between KU and the National Center for Genetic Engineering and Biotechnology (BIOTEC) of Thailand. This unit focuses on the development of crop varieties for insect and disease resistance by genetic transformation. In 1999 and for the first time, the College of Agriculture offered an undergraduate degree program in Agriculture Biotechnology. During the same period, the Center of Agriculture Biotechnology (CAB), KU, was established to offer the M.S. and Ph.D. degrees in Agriculture Biotechnology by forming a consortium with four local universities. The Asian Development Bank (ADB) financially supported the program. This is the real challenge for the university and the country to mobilize human resource and facilities in agriculture biotechnology for the benefit of the Thai people.

KU-Nagoya U Partnership: An Academic Exchange and Cooperation

From the brief history of human resource development in agriculture biotechnology at KU, it is recognized that international collaboration is an essential component to success. The university always seeks for the opportunity to collaborate with universities and research institutes outside Thailand to strengthen their research and teaching activities. Collaboration between KU and Nagoya University (NU) initiated in 1981 became the classic example of an academic exchange and cooperation among universities in Thailand and Japan. This agreement was continued and subjected to a fourth renewal recently signed by President Thira Sutabutra of KU and President

Minoru Matsuo of NU on May 14, 1999. The newly signed agreement is valid for another five years and renewable before the expiration date.

Within the scope of this agreement, both universities will perform the following activities:

1. Exchange of students by nominating and accepting from time to time students of the faculty of the university to be associated with the host university as a degree/non-degree student for research.
2. Exchange of faculty members and research scholars.
3. Exchange of scientific materials, publication and information.
4. Joint research activities.

Until now, there are a number of staffs, students and researchers from KU who went to NU for their studies and research programs and vice versa. Those who have been trained at NU returned home and contributed significantly in agriculture biotechnology, particularly in crop and animal production. They have organized themselves by forming "The Nagoya University Alumni, Thailand", with 106 members (as of March 2001). This is quite a unique group of scholars that has strong potential to lead the country in research and development in agricultural and social sciences.

Recommendation for Future Collaboration

The long-term relationship of KU and NU shows a successful case of collaboration. Yet, there is still much room for improvement. In my own opinion, there are three areas that need to be focused, namely: the technology assessment, the joint-degree program, and the collaborative R&D projects.

Technology assessment can be done by a group of experts in science, business, law, and economics to evaluate the potential impact of a given technology for the development of Thailand and Japan. The group will have to identify the strengths and weaknesses and other constraints such as the intellectual property issue that could prevent technology to be available to the public. Other dimensions of technology development and application will have to be determined as well. For example, is it better to "buy" a technology than to "develop" it within the country where human resource and know-how are very limited?

The joint-degree program can be implemented immediately since the MS and Ph.D. degrees in agriculture biotechnology at KU have been adjusted into research-oriented degree programs. This system is compatible with most of the degree programs at NU. No course work is required for graduate students who may have language barrier.

The collaborative R&D projects can be initiated in the following areas: agriculture environment, bioenergy and biosafety (Sukondhasingha, 1998). Exchange students and researchers should be part of project activities that lead to common goals. The primary objective of the collaborative project is to produce any product that causes no harmful effect on the environment, uses less or renewable energy and possesses no risk to consumer health. Above all, this is an important step toward the development of sustainable bioproduction.

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The Role of SEAMEO SEARCA in Human Development in Southeast Asia

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Abstract

Having predominantly agricultural economies, Southeast Asian countries need to develop its support infrastructures and services to remain sustainable and globally competitive. This may be done through capacity building activities focused on institutions, communities, and people in the agriculture sector. Formal degree programs, specialized short-term training, curriculum development, institution building and strengthening, and research on new technologies and methodologies to accelerate growth, rural development, and environmental conservation are vital ingredients of this overall endeavor. The SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA) was founded in 1966 to address the agricultural development needs of Southeast Asia. Being its flagship program, the Center's human resource development activities are carried out through graduate scholarship (MS and PhD in agriculture and related fields) tenable in five leading agricultural universities in Southeast Asia, and through short-term training. In support of these efforts in human resource development, SEARCA manages and coordinates research activities to strengthen institutional capacity in sustainable agriculture for a food-secure Southeast Asia. Its more than three decades of experience in research and development, broad network of partners and linkages, and multidisciplinary pool of experts have also enabled SEARCA to render consulting services to clients by harnessing required technical expertise in the region. SEARCA's experience over the past 36 years has proven that investment in human resource development is vital to the well being of the agricultural sector. This highlights the need for investments, not only in formal degree and short-term training programs, but also in research and development infrastructure and information sharing.

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I. Southeast Asia and its Requirement for Development

Southeast Asia is largely an agricultural region, with 40-70 percent of its labor force engaged in agriculture and its arable land per capita being 0.25 to 0.98 ha. However, considering the much larger global perspective, agriculture in Southeast Asian countries is still relatively behind their "northern" counterparts. There are many fields not fully developed, particularly in aspects of support infrastructures and services and the present levels of science and technology. This situation thus necessitates attention and efforts in developing the agriculture sector in the region in such a way as to procure sufficient food supply for increasing populations as well as to support the economies of Southeast Asian countries.

One component of overall development efforts is the focus on capacity building, particularly investments in human capital. This would refer to the building of capacities of people who actually depend on, as well as drive the agriculture sector. The review and improvement of traditional agriculture methods, research on new technologies, and building human resource capacity through formal education must be given high priority. Toward this end, much is expected from educational institutions to deliver and address this need. The emphasis must be on producing agriculture professionals of high quality, enhancing teaching curricula to incorporate sustainable agriculture principles, and raising awareness on the importance of agriculture development.

A purposive analysis of the region as regards this aspect of development would reveal that there is a need for the following:

1) Improvement of agriculture professionals' job knowledge and performance.
2) Creation of opportunities for formal degree programs as well as specialized and short-term training in agriculture available to

the greatest number of people in the region.

3) Development of curricula to include sustainable agriculture principles, strategies, and technologies.

4) Institution building and strengthening to better address the needs of the agriculture sector.

5) Research and development to develop new technologies and methodologies that accelerate growth and development not only to address the problems of agriculture in the region, but also to build the capacity of communities and individuals engaged in agriculture.

II. SEARCA: A Response to the Needs of the Region

There are many development agencies and institutions that are similarly concerned with the needs of Southeast Asian countries. One such institution is the SEAMEO Regional Center for Graduate Study and Research in Agriculture (SEARCA).

Founded in 1966, SEARCA has been serving the agricultural development needs of the 10 SEAMEO member countries, namely: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. It is the first center of excellence established by the Southeast Asian Ministers of Education Organization (SEAMEO), an intergovernmental body founded in 1965 to promote cooperation among Southeast Asian nations through activities in education, science, and culture.

Essentially created to address the agricultural development needs of the region, SEARCA primarily carries out the following:

1) Provide nationals of SEAMEO member countries with high-quality graduate education (MS and PhD) and short-term training in agriculture and related fields.

2) Promote, undertake, and coordinate applied research programs related to the needs and important problems of agriculture in the region.

3) Disseminate research findings to enhance agricultural development in the region and in support of policy formulation.

4) Provide development services through consulting to address the needs of SEAMEO member countries.

Through more than three decades, agricultural human resource development has been SEARCA's flagship program, which is mainly carried out through graduate scholarship, the University Consortium (UC), and short-term training.

Graduate Scholarship

SEARCA's graduate program was initiated in academic year 1968-69 to ensure relevance and responsiveness of SEAMEO member countries to agricultural development issues and problems. Specifically, it provides nationals of countries in the region with scholarships to pursue advance degrees in agriculture and related fields. Through the program, SEARCA seeks to prepare scholarship grantees for positions of leadership in the developing economies of SEAMEO member countries.

To date, SEARCA continues to provide support for MS and PhD degrees in agriculture, forestry, and related fields to personnel of academic, government, and non-government institutions dealing with agriculture. The scholarships are tenable in five leading agricultural universities in Southeast Asia and three universities in other parts of the world, particularly located in Australia, Canada, and Germany.

Since SEARCA's Graduate Scholarship Program started, 1,037 study grants have been awarded. Of this number, 369 PhD and 507 MS degrees have been completed. The country breakdown is 1 for Brunei Darussalam, 26 for Cambodia, 272 for Indonesia, 11 for Lao PDR, 300 for the Philippines, 62 for Malaysia, 10 for Myanmar, 4 for Singapore, 275 for Thailand, and 76 for Vietnam.

In the past decade, the scope of SEARCA's graduate scholarship program has been expanded to include institutional development and networking activities and services to enhance graduate education in the region.

University Consortium

The Southeast Asian University Consortium for Graduate Education in Agriculture and

Natural Resources is one of SEARCA's major vehicles for regional academic cooperation. It is a commitment forged among leading agricultural higher education institutions in Southeast Asia to share academic expertise and resources in order to produce top-quality graduate degree programs in agriculture and natural resources. Its founding members are Institut Pertanian Bogor (IPB) and Universitas Gadjah Mada (UGM) in Indonesia, Universiti Putra Malaysia (UPM), University of the Philippines Los Baños (UPLB), and Kasetsart University (KU) in Thailand.

SEARCA serves as Secretariat and partner of the University Consortium (UC), providing more than half of the funds to support the consortium's activities in addition to the pool of funds contributed by the UC members and associate members. Associate members are University of British Columbia (UBC) in Canada and University of Queensland (UQ) in Australia, which joined the UC in 1992 and 1993, respectively.

The major UC components are student and faculty exchanges, research fellowships, professorial chairs, and thesis grants. Occasionally, the UC conducts meetings and workshops on topics of regional interest and relevance. So far, such workshops have been convened to discuss the following topics: retooling of agriculture faculties, academic networking, integrated management of acid upland soils, food and agriculture policy, curriculum development for sustainable agriculture, and development of sustainable agriculture courses.

One of the groundbreaking projects of the UC is Project SHARE (Sharing Resources in Higher Agricultural Education). It resulted from a workshop on higher education in Vietnam, organized by the SEAMEO Regional Centre for Higher Education and Development (RIHED) in November 1996, which identified the need for sub-regional linkages to render technical assistance for educational institutions in Cambodia, Lao PDR, and Vietnam.

The assumption of such technical assistance is that whatever happens to an agricultural university will have far-reaching effects on the agricultural economy and general welfare of the country's population. The impact of institution building on food security, poverty alleviation, sustainable development, and agro-industrialization should bear some positive effects on national development and improve the welfare of the common citizen.

Sharing resources for institution building is deemed the most efficient way of improving the capability of a developing college or university as it endeavors to undertake instruction, research, and service functions. With institution building among agricultural universities as the ultimate goal, SEARCA laid the groundwork for such academic cooperation through Project SHARE. The general objective of the project is to accelerate the development of agricultural universities in Cambodia, Lao PDR, and Vietnam in order to improve their capabilities in teaching, research, and extension by sharing the expertise of consortium universities under twinning arrangements.

Meanwhile, SEARCA scholars who have completed their graduate programs (called SEARCA fellows) represent a major strength for the Center and can be a potent force in its efforts to promote sustainable agriculture. Currently, SEARCA is completing a database for the SEARCA-ASEAN Foundation Project on Regional Volunteer Experts for Agricultural Modernization (REVEAM), which taps SEARCA fellows to assist institutions in their development needs. The project hopes to foster and sponsor twinning arrangements between the UC and other universities to spur capacity building and institutional development in Southeast Asia.

Short-term Training

Another mainstay of SEARCA's human resource development efforts is the Short-term Training Program, which was launched in 1971. The program aims to upgrade the skills and competencies of SEAMEO nationals to tackle problems and concerns in agricultural development.

After having conducted hundreds of training courses over the past 32 years, SEARCA has identified its training target niche in the region, that is, middle- and high-level managers and administrators who occupy strategic positions in their institutions, determine policy, and generate the most impact in their respective work places. In addition, to broaden its reach and stay competitive, SEARCA goes into resource-sharing arrangements with collaborating agencies, purposive consultations with clients to tailor-fit training programs to client needs, and exploring new working arrangements with like-minded institutions.

Past training courses covered the areas of technical agriculture and social organizations, technology transfer, agribusiness management, research management, crop and livestock production, information processing and documentation, and development strategies and planning for farmers' communities, among others. Since 1971, SEARCA has produced 11,216 training alumni from Southeast Asia as well as outside the region.

Research and Development

In support of its efforts in human resource development, SEARCA coordinates and manages research activities to strengthen institutional capacity in sustainable agriculture for a food-secure Southeast Asia.

The Center's Research and Development Program focuses on strategic issues of regional importance, with the linchpin of research activities being agricultural development and the promotion of sustainable agriculture. Moreover, SEARCA's research interest is mainly on upland, lowland, and coastal zones in a landscape continuum that emphasizes the holistic and integrated nature of ecosystems and landscapes.

While it identifies and develops research projects, the Center relies on partnerships and collaborations to implement these projects. In-house research is undertaken but on a limited scale and primarily for project development, piloting, and resource and socioeconomic profiling.

In carrying out its research activities, SEARCA does not confine its efforts to technology development, but more assiduously focuses on the development and transfer/ adoption of methodologies and on lessons learned. To achieve these, it espouses and favors participatory and community-based approaches that ultimately contribute to policy formulation.

The keystone of SEARCA's research and development efforts is the recognition that sustainability concerns and environmental degradation are the two most pressing problems in the region. The Center's active bid to solve problems affecting environmental sustainability is carried out through its Natural Resource Management Program, which covers concerns in the entire landscape continuum to include proper management of forests, grasslands, upland and lowland agricultural areas, inland water, and coastal resources. Moreover, in cognizance of the importance of industry linkage to agricultural development, SEARCA also pursues an Agro-Industrial Development Program that focuses on developing models of technology transfer, enterprise development, cleaner production, and sustainable agro-industrial communities.

SEARCA has also invested in information and knowledge networks that provide access to information that catalyze development in the region, giving inputs to informed decision- and policymaking. Said networks also feed into the development of curricula that facilitate and enhance research of academic institutions and other development agencies.

Adopting the interdisciplinary and multidisciplinary approach, SEARCA's research integrates its programs on natural resource management, agro-industrial development, knowledge management, and cross-cutting projects on gender and development and policy studies. Knowledge management or the processing of information generated by research projects to applicable knowledge, and policy studies, which lay empirical and scientific bases for policy recommendations, are two vehicles through which SEARCA hopes to effectively bridge the gap between research results and their functional and commercial use.

At present, SEARCA directs its research on issues and concerns that fall within the Center's five priority themes defined in its Strategic Plan for 1999-2004, which include the related and integrative issues of food security, biotechnology, biodiversity conservation, water resource management, and environmental risk management.

The value and impact of SEARCA's research may spur development only if they reach a critical mass and are translated into action by their users. While the target beneficiaries of SEARCA's research efforts are farmers and fisherfolk, the Center works directly with institutions in need of assistance, i.e., government agencies, research organizations, academic institutions, and other development agencies and non-government organizations involved in agricultural and rural development.

To respond with relevant and functional research initiatives and projects to current and emerging needs of SEAMEO member countries, SEARCA follows a complex and meticulous process in selecting and prioritizing research efforts. Through consultative meetings, workshops, and scientific fora where representatives from member countries, partner institutions, and donors participate, SEARCA tunes in to regional agricultural conditions in a purposive appraisal of the situation in the agriculture and rural sectors of the region. The Center also uses its established networks, particularly the University Consortium, as feelers to determine the prevailing problems and gaps in agricultural development in Southeast Asia.

Consulting Services

Combining more than 35 years of experience in research and development, a broad network of partners and linkages, and a multidisciplinary pool of experts, SEARCA developed and formally organized in 1991 its Consulting Services (ConServ).

ConServ provides technical assistance to client institutions in project development for possible funding by financial institutions and other donors, and offers services in the client's perceived need areas by providing the required technical expertise. By 1997, ConServ was implementing projects in East and Southeast Asia and the Pacific for varied clients such as the United Nations Development Program, the World Bank-Economic Development Institute, the Asian Development Bank, the Government of the Philippines, and private companies. Through the implementation of regional consulting projects, SEARCA has widened the scope of its professional services and gained recognition from counterpart agencies and direct project beneficiaries.

Tapping the expertise of Southeast Asian professionals and international experts and forging partnerships with reputable international consulting firms in bidding for projects has also strengthened SEARCA's regional presence. ConServ has nominated 60 Southeast Asian professionals in at least 50 percent of available slots in its consulting projects. With its new contracts, ConServ has used the services of 155 Southeast Asian professionals and experts.

III. Promotion of Sustainable Agriculture and the Role of Higher Education Institutions

Even before the emphasis on sustainable agriculture (SA), SEARCA's academic and research programs have already been focused on environmental management and natural resource conservation. SEARCA's Seventh Five-Year Plan covering fiscal years 1999 to 2004 as discussed earlier in this paper gave more emphasis on SA with its vision of being Southeast Asia's leader in sustainable agriculture. SEARCA continues its advocacy on environment and natural resource conservation with SA as the core philosophy.

SEARCA's main goal of promoting SA in the region is based on purposive and validated assessment of the situation prevailing in the region, i.e. the increased importance of agriculture to provide food to a rapidly growing Southeast Asian population. The emphasis on the need to protect our environment and conserve our natural resources for increased agricultural productivity without sacrificing the welfare of society has highlighted the importance of sustainable agriculture development.

In order to achieve agricultural and agro-industrial development in resource-limited countries in Southeast Asia, there is a need to produce manpower and future leaders who will advance agricultural technologies and systems that are productive and sustainable. This is the role of agricultural colleges and universities, which because of the dynamic nature and demands of the agriculture sector must continuously examine and re-examine their curricula toward the adoption of sustainable agriculture concepts.

Since 1995, the Center has been assisting agricultural colleges and universities in facilitating workshops aimed at the adoption of SA through curriculum development not only at the national level but also at the regional level.

In all of these seminar-workshops at the regional level, the following were common considerations that need to be addressed by the agricultural colleges and universities:

a) In the next millennium, the fight for food security would be in the uplands; hence the need to include sustainable agroforestry curriculum development.

b) SA will have to be adopted under each country's political system.

c) In translating the framework into an SA curriculum, the following should be considered:

1. cultural/social dimension
2. educational system, which differs from country to country
3. reskilling of faculty, teaching children how and where to learn

d) Graduates of the BSA curriculum should be able to conceptualize, implement and direct projects with farmers; analyze ecological and conventional food production systems; integrate biology, humanities, economics, and ecology in food systems; use systems approach for complex problems; and analyze policies on agriculture and food as they relate to sustainability.

e. SA advocacy should be done at the policy level to involve the representatives from the ministries of education to facilitate the approval process.

f. Other critical elements are goals of education, value system, process of curriculum development, course contents and emphasis, teaching methodologies and approaches, teacher's attitude, values, and knowledge about SA, learning resources, policy, material and financial support, research, extension program.

It is also a must for agricultural colleges and universities that aim to integrate sustainable agriculture concepts into the agriculture curriculum or even modify existing curricula towards an SA-oriented one to have a full understanding of what they are introducing, why they are introducing it, and how it should be implemented.

IV. Strategies for Strengthening Human Resource Development and Research in Agriculture in Asia

The call for internationalization of education and modernization of agriculture requires higher education institutions to effect the necessary transformations in order to be globally competitive. Institutional autonomy, organizational restructuring, innovations in academic and administrative management, adjustments in curriculum design, expanding linkages and adjusting to market demands, creation of innovative evaluation systems, etc, are changes that are likely to occur in educational institutions in order to address concerns for the human resource development and research in agriculture in Asia. To effect the needed changes and innovations would require well thought-of strategies that Japanese universities, particularly the Nagoya University Graduate School of Bioagricultural Sciences could implement such as:

a. **Forging strategic alliances with partners for complementation of programs and activities.** This would require bilateral or multilateral agreements on the implementation of activities for mutual advantage. An example is establishing networks or partnerships for academic exchange and collaborative research projects. The Asian Association of Agricultural Colleges and Universities (AAACU), where the Nagoya University and four other Japanese universities are members, will soon implement academic exchange programs (faculty and student exchanges, administrator study tours); publication exchanges; and come up with an agricultural bulletin or journal effective this year 2002. The announcement on the availability of limited grants for the academic exchange will soon be disseminated (probably first week of July 2002) after the President of AAACU has approved the funding. AAACU is a network of 48 agricultural colleges and universities in Asia. SEARCA is an affiliate member of AAACU and manages the Secretariat. Funding for the AAACU activities come from the pooled membership fees of the Association and donations from interested donor agencies. Recently, the Executive Board of AAACU has agreed to officially endorse the membership of Tokyo University of Agriculture at the 15th Biennial Convention to be held in Chiangmai, Thailand in December 2002.

b. **Implementation of a Sandwich Program for the MS and PhD degrees in agriculture.** This scheme has proven to be resource-efficient while effectively addressing the relevance of research done by the student. Japanese students may take courses in one of SEARCA's University Consortium members or any of the members of the AAACU, then conduct their research in Japan to make sure that research projects address their country's concerns. Likewise, students from other Asian countries may take courses in Japan, but do their research projects in their respective countries. At SEARCA, an example of a sandwich program is the collaboration with the University of Gottingen (UG) in Germany, where Southeast Asian students take courses in Germany under a joint scholarship program of SEARCA and UG's Centre for Tropical and Subtropical Agriculture and Forestry (CeTSAF) for a period of one year, then return to their respective countries to do research for a period of six months, then return to Germany and spend another six months to finalize their research results, defend their thesis, and complete the requirements for graduation.

A more recent example is the first offering of the Asian-European Master of Science in Food Science and Technology (specializing in Agri-Food Industries Studies) organized by France's Ecole Nationale Superieure des Industries Agroalimentaires (ENSIA) of Montpellier, France, hosted by SEARCA and conducted in collaboration with the Department of Science and Technology (DOST) of the Philippines. It is an International Program that provides students with further knowledge in food science and technology with an aim of equipping them with the global approach of industrial food business aspects and to develop their methodology applied to an industrial topic. The duration of the program is 19 months consisting of nine months of coursework at SEARCA and ten months of thesis work carried out either in Southeast Asia or in Europe. The international faculty is composed of professors from Kasetsart University, Prince of Songkhla University, King Mongkut Institute of Technology at Ladkrabang, Suranaree University of Technology, all in Thailand; Universiti Putra Malaysia; and Universiti Kebangsaan Malaysia.

c. Implementation of Joint Projects.
Through networking, joint projects may also be implemented. One example of a joint project developed by a network is the University Consortium Distributed Learning Project, which allows the offering of an MS in Sustainable Resource Management on mixed mode of approaches such as on-line, distance, on-campus or face-to-face and off-campus. The degree program is jointly developed by the participating universities of the Consortium namely: University of British Columbia, Canada; University of Queensland, Australia; and Universiti Putra Malaysia. SEARCA, being the Secretariat, shares in the cost of course development by hiring and paying the honorarium of the expert involved in the course development, marketing the project, and facilitating the course development.

The above schemes are just a few of the best examples of strategies and approaches to enhance the internationalization of agriculture education in the region that may be adopted by Japanese universities in general and Nagoya University Graduate School of Bioagricultural Sciences in particular. There are many schemes and collaborative efforts that may be applied depending on the resources available, the readiness and interest of the institutions concerned, and the complementariness of the programs.

V. Concluding Remarks

Over its 36 years of existence, SEARCA has remained steadfastly committed to its mission of strengthening institutional capacity in sustainable agriculture for a food- secure Southeast Asia through human resource development, research, knowledge exchange, and policy support.

Its experience has proven that investment in human resource development is the way to sustainable development in the agricultural sector. This highlights the need for investments, not only in formal degree and short-term training programs, but also in R&D infrastructure and information sharing.

SEARCA's mandate may only be considered fulfilled as long as the Center continues to be relevant and credible, as it satisfies and anticipates developments in sustainable agriculture, and provides the options and opportunities that would show the way out of poverty to the farmers and fisherfolk in the region.

In this undertaking, the challenges are never ending and the problems are sometimes immense. But, as SEARCA has learned, so are the possibilities and solutions.

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Experiences and Prospects of AICAD About International Cooperation Including South-South for Agricultural and Human Development

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Abstract

This paper reports on experiences and prospects of the African Institute for Capacity Development (AICAD) on south-south cooperation in the field of agriculture during the pilot phase (August 2000-July 2002). Thirteen universities from East African countries participate in AICAD's activities. In response to water shortage, AICAD has conducted one regional training course on irrigation and water resources management to extension workers. As an immediate output of the course, the trainees formed "East Africa Irrigation Experts Network" with the aim of supporting regional efforts to promote sustainable agriculture. Furthermore, AICAD has five ongoing research projects in the field of agriculture, the aim of which is to improve traditional technologies for pest management and milk processing. Most Asian countries have achieved a remarkable agricultural development, and AICAD believes that Africa can benefit from their experiences and knowledge in agricultural and human development. With assistance from the ICCAE, AICAD expects to establish a consortium with Asian countries in the next phase (August 2002 to July 2007).

Key words: Sustainable agriculture, South-south cooperation, AICAD's experiences

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Introduction

Sustainable agriculture is a development concept in which agricultural natural resources (*ecological sustainability*), agricultural outputs and agricultural population (*social sustainability*) must all be sustained. It is inadequate to attempt achieving sustainable agriculture by only enhancing and protecting agricultural natural resources like organic farming technology. Agricultural output must increase, and for the increase to improve living standards of agricultural population, a fair national and international trade system must exist. However, the current North-controlled international trade system does not allow agricultural population from developing countries to benefit fully from their agricultural produce. As there is no place to conduct an integrated discussion between the North and South about sustainable agriculture at global level, it is doubtful if a real sustainable agriculture would ever be achieved (South Centre, 1997).

South-south cooperation is defined as cooperation among developing countries (also known as countries of the South). It involves inter-continental cooperation such as Asian-African, and intra-continental cooperation such as intra-African and intra-Asian.

Most developing countries have many similar agricultural development problems such as low agricultural outputs and productivity, weak bargaining power against unfair prices of agricultural produce and products at global level, and inadequate trained professionals and research facilities (South Commission, 1990).

There is a very strong relationship between sustainable agriculture and south-south cooperation. At a political level, south-south cooperation implies solidarity among developing countries to bargain against unfair prices of agricultural commodities in the international trade in a way that would protect the right of small farmers. Technologically, few developing countries have advanced research capacity including biotechnology, but many still lag behind, implying that south-south cooperation would facilitate sharing of knowledge and experiences. As opposed to developed countries, developing countries usually develop low technologies by improving traditional technologies. These technologies are often safe to the environment and appropriate to smallholder farming systems.

The African Institute for Capacity Development (AICAD) is an institute that promotes development of African region through enhancing south-south cooperation (AICAD, 2001). AICAD was established in August 2000 out of collaborative efforts by the government of Japan, Tanzania, Kenya and Uganda. The objective of this paper is to report on AICAD's experiences and prospects on intra-African and African-Asian cooperation in the field of agriculture during the first phase (August 2000 –July 2002).

AICAD's Experiences on South-South Cooperation

1. AICAD's participants

AICAD promotes collaboration, in various fields among universities, research institutions, government institutions, private sector, industries, non governmental organisations (NGOs) and community-based organisations. Currently, there are three East African countries participating in AICAD's activities, namely: Kenya, Tanzania and Uganda. The collaboration actively involves eight public universities working together in order to increase their capacity to tackle African problems. Five universities are located in Kenya (University of Nairobi, Moi University, Kenyatta University, Egerton University, and Jomo Kenyatta University of Agriculture and Technology); two in Tanzania (Sokoine University of Agriculture and University of Dar es Salaam); and one in Uganda (Makerere University) (Fig. 1). One year later, five more universities joined AICAD, namely: Maseno University in Kenya; Mzumbe University and Open University of Tanzania, both in Tanzania; and Mbarara University and Chiambo University, both in Uganda.

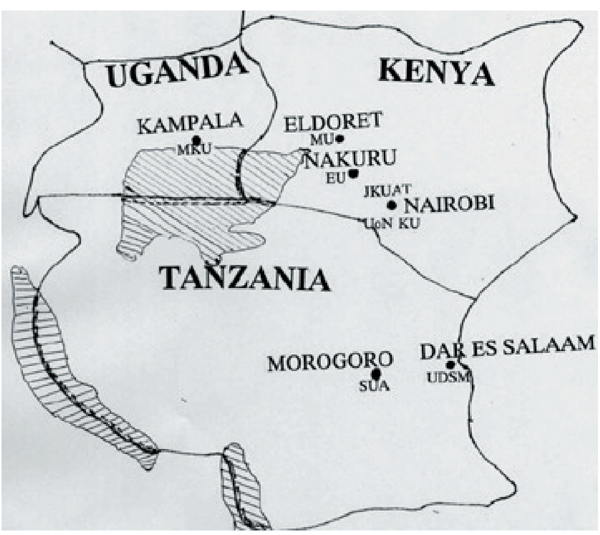

Fig1. Geographical location of AICAD's main eight participating universities sorted by country: **Kenya**: EU (Egerton University), JKUAT (Jomo Kenyatta University of Agriculture and Technology), KU (Kenyatta University), MU (Moi University), UoN (University of Nairobi). **Tanzania:** SUA (Sokoine University of Agriculture) and UDSM (University of Dar es salaam). **Uganda:** MKU (Makerere University)

2. AICAD's goal and main activities

AICAD aims at solving various issues of poverty in the African region by undertaking two major functions, namely: strengthening educational and research functions of African institutions, and accelerating human capacity development. AICAD integrates techno-creators, techno-disseminators and techno-end-users in order to facilitate effective sharing of valuable knowledge and technologies through demand-driven joint research, training and information networking (Fig. 2). The AICAD's ultimate target of the integration is to develop appropriate technologies for sustainable agricultural development of Africa (AICAD, 2002).

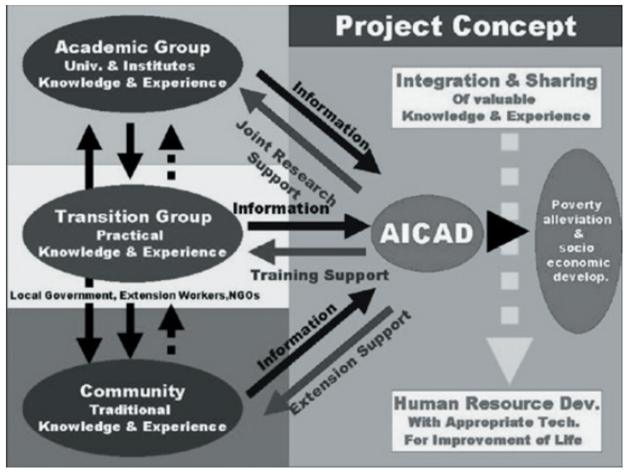

Fig 2. AICAD project concept: integration of academic, transition and community groups for sharing of valuable knowledge for development of appropriate agricultural technologies (Source: AICAD, 2002)

3. AICAD's experiences in research and training

AICAD conducts agricultural and non-agricultural research through three divisions, namely: Research and Development; Training and Extension; and Information Networking and Documentation. AICAD has five ongoing joint research projects in the field of agriculture, of which three are on disease and pest control, and two on milk preservation and processing. Many farmers use traditional agricultural technologies, which (though appropriate to the environment) result into low agricultural output. Thus, AICAD attempts to improve the exiting traditional agricultural technologies. The expected outcome of the research projects is to have improved traditional technologies for disease and pest control, and milk preservation and processing.

AICAD conducted a one-month regional training course on irrigation and water resources management to 30 extension workers working with farmers at grassroots. The course was conducted because water shortage is among the serious problems affecting rain-fed agriculture in Africa. AICAD identified lack of knowledge and skills on irrigation and water resources management as a major source of the problem. The training course mainly focused on appropriate rainwater harvesting and water-use-economy irrigation techniques (Fig. 3), water sources management, and integration of water use and crop husbandry practices. As an immediate output of the training course, the trainees formed an association called the "East Africa Irrigation Experts Network" with the aim of supporting regional efforts in poverty alleviation through sustainable agriculture.

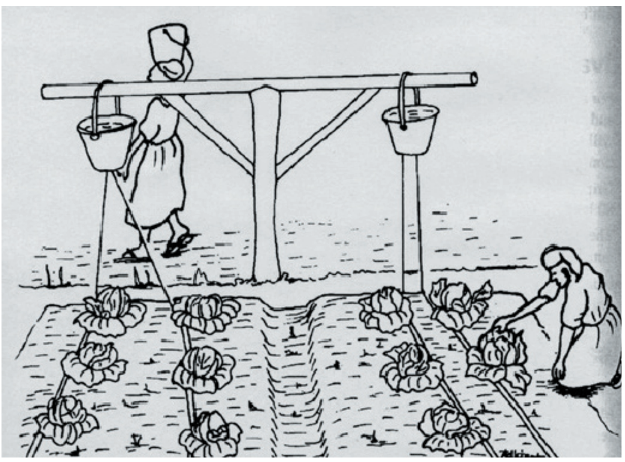

Fig 3. Application of a "bucket drip irrigation" technique for a water-use economy in a production of vegetables. (Source: International Institute of Rural Reconstruction (IIRR), 1998)

4. SUA's experiences in south-south cooperation

Although AICAD seems young, its participating universities have long experiences in south-south cooperation. For example, Sokoine University of Agriculture (SUA) in Tanzania collaborates in vegetable research and training with the Asian Vegetable Research and Development Center-Africa Regional Program (AVRDC-ARP), with main office in Arusha, Tanzania. AVRDC-ARP attempts to improve the existing tomato cultivars by using solanaceae germplasms from Asian countries. SUA serves as one of the major stations in the Eastern zone of Tanzania for multilocational evaluation of AVRDC-ARP's tomato new cultivars. As a result of this collaboration, two tomato cultivars have been released for commercial production, namely Tengeru 97® (indeterminate type) and Tanya® (determinate type) (AVRDC, 2002). Kalwani *et al*. (2002) recently reported that Tanya® was doing better than the traditional determinate tomato cultivars (Roma VF® and CAL J®).

5. General lessons learned from south-south cooperation

5.1.Demand-driven and participatory research

To develop a demand-driven technology, scientific researchers must look for farmers' needs. Although private companies are successful in developing demand-driven innovations, most researchers still do what they think is best for farmers. One of the main reasons is that researchers do not suffer the consequences of their innovations being rejected by farmers. Since researchers get their rewards from the government, farmers have little to influence demand-driven research.

Farmers' participation in research enables researchers to understand better about farmers' knowledge and experiences on a researchable area. This in turn enables researchers to integrate farmers' knowledge and experiences into a project. It has been reported that farmers' motivation and participation to research project implementation are increased when their knowledge and experiences are integrated in a research project. Although most researchers have currently started conducting demand-driven and participatory research, they often select progressive farmers, usually able to express themselves, and found in vicinal and easily accessible villages, and with good records of working with research projects (Chambers, 1983). Researchers hardly work with marginalized socio-economic classes of rural farmers. It is a big challenge for researchers to overcome this weakness with the current inaccessibility of many rural areas caused by bad roads, inadequate transport facilities and researchers' short of time in working with rural people. Additionally, it is difficult for researchers to work with destitute farmers who are habitually laggard, and shy and suspicious to outsiders.

5.2. Inter-disciplinary research

Many agricultural problems have multi-causatives, meaning that they cannot be successfully solved by a single discipline. Successful research projects on agricultural problems must integrate high quality professionals from different disciplines. However, the integration of disciplines in tackling problems is practically not so easy. What is currently called "integration of research disciplines" is merely grouping together of researchers from different disciplines with an assumption that they would work as a unit. In fact, the grouped researchers divide a research project into subtopics so that each researcher can individually deal with a subtopic according to his/her area of specialisation. Although not very certain, the researchers' tendency to disrepute and dislike other disciplines might probably be the cause of disintegration. This disintegration might partly originate from professional superiority complex and specialization. Successful inter-disciplinary research may require creation of a *new science.* One of the alternative approaches of the *new science* would be to establish a system where researchers from different disciplines work for one final outcome, for instance "improved living standards of coffee farmers in a given area". Their performance is then evaluated and rewarded based on the level of improvement of living standards of the coffee farmers. This would probably facilitate integration of sociologists, soil scientists, crop scientists, economists, politicians, etc.

5.3. Farmer-extenstionist-researcher (FER) linkage

Effective extension services are imperative for successful dissemination of research findings from researchers to farmers. In many developing countries, extension services do not work well, as a consequence of which good research findings often show little effect on agricultural production. Some of the major problems with extension services are inadequate extension workers and facilitation, especially transport and salaries. It has been reported that extension workers rarely provide technical assistance to farmers, and sometimes even when they live within the same village with farmers (Kirumira, 2002). Similarly, it has been noted that "experienced farmers" at Nzihi and Kidamali villages in Tanzania play more effective role in training other farmers on tomato production than extension workers (Kalwani *et al*. 2002). On the contrary, successful results of extension services are reported when extension workers are attached to NGOs and community development projects, where good transport services for fieldwork and allowance to supplement their small salaries are provided.

Many research projects attempt to strengthen the FER linkage through conducting farmers' forums, increasing number of farmers participating in joint research meetings and on-farm trials, and increasing number of researchers participating in extension meetings (TARP II, 2000). However strong it is, such FER linkage would collapse as soon as the projects phase out. Making an effective FER linkage under the existing government funding systems still remains a big challenge. It is therefore doubtful if training extension workers would have significant impact to agricultural development.

3. Advantages of African-Asian Cooperation to Africa

Science and technology (S&T) was a key issue in the North-South development dialogue. During the Vienna Conference on S&T for development in 1979, major policy and conceptual advances were made in the efforts to harness S&T to development, to promote the transfer of technology to developing countries, and to assist developing countries in their efforts to develop their own S&T capabilities. The recent ascendance of neo-liberal paradigm (where scientific knowledge and technologies are patented and commercialised) results into even greater difficulties and obstacles for developing countries in accessing to and benefiting from S&T from the North. So far, there is no place to discuss S&T issues in an integrated and sustained manner at the global level.

As a last alternative, developing countries need to tap an increasing range of opportunities for south-south cooperation in the domain of S&T. With exception of a few, many African countries still lag behind advanced technology; the major cause being the inadequate research facilities and trained professionals. On the contrary, some developing countries in Asia like Indonesia, the Philippines, Thailand and Malaysia have reached advanced levels of S&T, including biotechnology, and have shown major strides in development as evidenced by the "Green Revolution". This may offer an advantage to Africa for sharing agricultural development experiences and knowledge with such Asian countries through African-Asian cooperation.

The acquired new technologies from Asia would give good responses to African agriculture, which currently has low productivity due to lack of good technologies. Distance, slow communication and cost of travel have in the past hampered potential joint scientific research and technological development projects between Asian and African countries. However, Internet, E-mail and computer conferencing now enable interaction on a more speedy and regular basis, and hence make research and development programmes more feasible.

The rapidly decreasing assistance from the north (with future assistance being less predictable) calls for an immediate establishment of effective south-south cooperation as a sole alternative. In the absence of or reduced assistance from the north, stronger south-south cooperation would not only reduce dependence but also increase self-reliance spirit among developing countries. Under good enabling environment, self-reliance spirit is imperative for a self-initiated and self-controlled development of developing countries (Nyerere, 1990). Such type of development is sustainable since it is owned by the people.

4. Future Prospects of Asian-African Cooperation

Successful south-south cooperation requires complementation and relevance of programmes to each participant region's concerns, and mutual understanding and respect. Preliminary studies with SEARCA (Southeast Asian Regional Centre for Graduates Study and Research in Agriculture) have exposed that there are many areas of common interest between Africa and Southeast Asia. These include poverty alleviation, health and nutrition, education and training, food security, environmental and water resource management, and community development (Editha Cedicol, personal communication, 2002).

In addition, AICAD's visitation tour to Indonesia in October 2001 revealed that the country had many useful development experiences, including improved irrigation and rice production. During the visit, AICAD was offered training opportunities for Third-Country Training programmes implemented by the government of Indonesia (AICAD, 2002). With assistance from the International Cooperation Centre for Agricultural Education of Nagoya University, AICAD expects to establish a consortium with Asian countries in the field of agriculture during the second phase II. Furthermore, AICAD anticipates establishing consortia with other sub-Sahara African countries and international organisations during the third phase (August 2007 – July 2012) (Fig. 4). Its ultimate vision is to form a triangular cooperation consisting of South-South-North, an idea that was also stressed by the Second Tokyo International Conference on African Development (TICAD II, 1998).

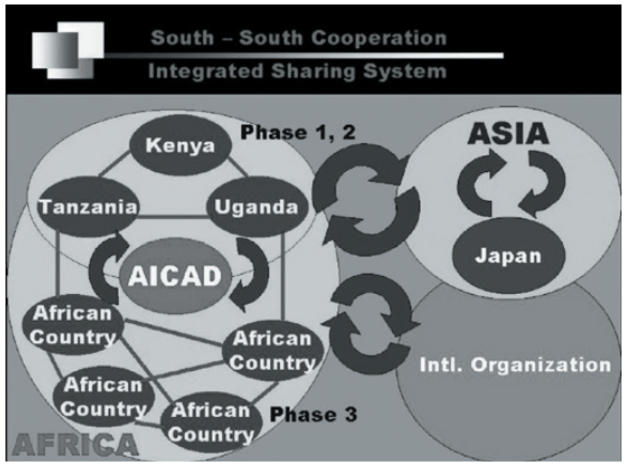

Fig 4. Ultimate vision of AICAD: promotion of South-South (Africa-Asian) and South-South –North (African-Asian-International organisation from the North) cooperation during the second and third phase respectively (Source: AICAD, 2002).

Conclusions and Recommendations

AICAD has successfully promoted the cooperation of 13 universities of Tanzania, Kenya and Uganda as a strategy to alleviate poverty through agricultural development. AICAD tries to improve agriculture through two approaches. The first approach involves improving traditional farming systems through collaborative research and training. In comparison to high technologies, improved traditional technologies are more appropriate to smallholder farmers, the environment, and the export market (which looks for eco-produce). The second approach is to promote exchange of knowledge and technologies through African-Asian cooperation. The reality behind this approach is that the "Green Revolution" in Asia occurred as a result of technological development (such as use of new cultivars, fertilizers and irrigation) combined with good agricultural policies and infrastructures (transport facilities, communication, etc.). The low productivity of African agriculture is principally due to lack of good technology. For this reason, AICAD believes that exchange of knowledge and technologies between Africa and Asia would give a considerable progress to African agriculture. But for this agricultural development to happen, Africa must make its agricultural environment more conducive in terms of agricultural policies, physical infrastructures and access to agricultural inputs. Furthermore, Africa must take serious measures on environmental protection and enhancement for the anticipated agricultural development to be sustainable.

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Human Development and Collaboration with Universities in Japan International Research Center for Agricultural Sciences (JIRCAS)

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1. Introduction

Global problems are increasingly impacting world food security. These include continued world population growth, deterioration of environments, and destruction of cultivated lands. The promotion of sustainable agriculture, forestry and fisheries to be in harmony with natural ecologies is a critical need. The demand for food is increasing in many developing countries due to both population increase and improved diets. At the same time, where agricultural and fisheries productivities have remained low, food supplies remain unstable and serious problems of hunger and poverty continue to persist. To address these critical needs, Japan International Research Center for Agricultural Sciences (JIRCAS) promotes research aimed at achieving a stable global food supply and ensuring sustainable agriculture, forestry and fisheries in harmony with the environment. It carries out interdisciplinary researches on biological and social aspects of agriculture, forestry and fisheries, and undertakes collaborative projects with institutions of developing countries as well as international organizations. JIRCAS is making many active contributions internationally to address the agricultural, forestry, fisheries, food and environmental problems of the world, with particular focus on developing regions.

Fig.1 Reorganization of JIRCAS into Independent Administrative Institution

course of the reorganization of the former Tropical Agriculture Research Center (TARC) founded on June 1, 1970. Effective April 1, 2001, JIRCAS operated as an independent administrative institution (IAI) (Fig.1).

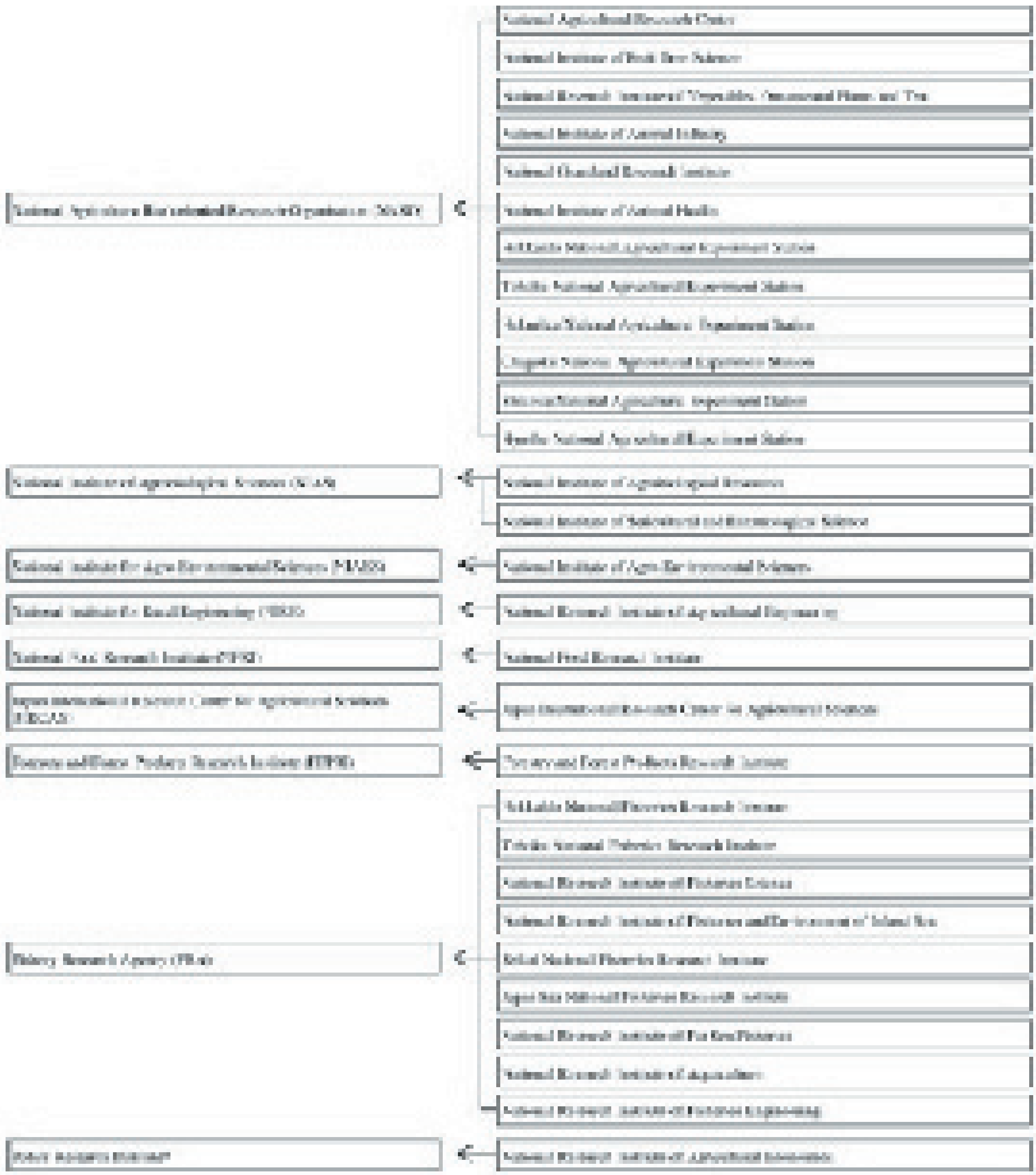
The IAI is a newly created public corporation established under the concept of separation of policy planning and implementing, as presented by the Administrative Reform Committee of the Japanese Government. Reorganized into IAIs are the national agricultural research institutes affiliated with Ministry of Agriculture, Forestry and Fisheries (MAFF) and the national research institutes affiliated with other ministries, investigation centers such as National Agricultural Chemicals Inspection Station and educational institutions such as National Farmers' Academy.

The characteristics of the IAI are defined in the General Law of Independent Administrative Institutions enacted in July 1999. The IAI is an independent organization separated from the national government. The government decides the objective (mid-term objective) that should be completed by each IAI within five years through their activities. The IAI then makes a mid-term plan to achieve mid-term objective. A mid-term plan is necessary to be acknowledged by the government. The IAI carries out its activities according to the mid-term plan. The government bears nearly 100% of the cost of the activities. The President of IAI can decide how to use the budget, establish organizational structures, recruit and promote researchers. The external evaluation committee organized by the national government evaluates the efficiency and effect of IAI activities.

The management, organization, treatment of employees under the IAI set-up is completely different from that of the former national research institutes. The IAI is expected to overcome rigidity, bureaucracy and inefficiency that are thought to have characterized a governmental organization. On the other hand, we are afraid that the establishment of IAIs causes a decline on agricultural research, which requires long-term investment in terms of time and resources, but is expected to yield a relatively low economical return.

In view of the IAI establishment and considering the circumstances of agriculture in Japan, 29 national agricultural research institutes have been reorganized into eight IAIs and one national institute (Fig.2).

In line with the reorganization, JIRCAS made a drastic change in its activities. This report will introduce some aspects of new JIRCAS activities concerning human resource development and cooperation with other organizations including universities.



*: National research institute, not IAI

Fig. 2. Reorganization of National agricultural research institutes into IAI

2. JIRCAS International Research Career Network (JIREC) - A project on the development of Japanese human resources for international collaborative agricultural research

(1) Objectives

Technology development in the modern era is a matter of competition and cooperation. It is evident that countries of the world are competing with each other in fields like biotechnology and other ultramodern technologies. At the same time however, it is recognized that international collaboration by combining and sharing the latest knowledge and information in these fields is indispensable for an efficient research program.

On the other hand, the world is presently faced with many problems on a global level in addition to the food and environmental problems, which are due to factors such as population increase. These problems must be grappled with and be solved by devising speedy and efficient technology development. For this purpose, the western as well as the developing countries are seeking a more prominent contribution from Japan. Therefore, Japan should prepare itself to make a far greater human contribution to international agricultural research.

As concerns get associated with international research, skills in conducting research in various fields, the ability to speak and communicate in foreign languages, adaptability to different cultures, living environments and lifestyles, and firm resolve to endure the hardships of international research are very important. Therefore, as a supporter of international research it is essential for Japan to foster and build up a pool of competent human resources to be tapped for international collaborative agricultural researches.

To achieve its purposes, the project “JIRCAS Research Career Network (JIREC),” which is operational from 2001 to 2004, has an ongoing survey of employed as well as retired researchers in order to identify competent human resources who possess the necessary dispositions and are interested to work for international collaborative agricultural researches. These researchers shall be advised of appropriate opportunities available to them for participation in international researches to utilize their expertise. In addition, the project shall make inquiry and analysis of the mechanisms and operational conditions in the implementation of international collaborative agricultural researches being conducted by international and national research institutes in foreign countries.

(2) Contents

This project is implemented by JIRCAS under the sponsorship of MAFF. There are two main activities of the project.

1) JIREC Database (JIREC-DB)

This activity involves the establishment of a database of Japanese aspirants to international research positions (including working and retired researchers of National Institutes, independent administrative institutions, prefectural agricultural institutes and other private institutes).

In FY2001, about 3,000 sheets of questionnaires were distributed to the national research institutes and IAIs affiliated to MAFF. A total of 878 researchers including post-doctoral researchers answered the questionnaire and registered with JIREC-DB. JIREC adopted almost the same format and survey questions among the basic items as those contained in the database questionnaire of Nagoya University International Cooperation Center for Agricultural Education (ICCAE), for the convenience of linking the two databases in the future.

Below is the summary of responses:

a. Age of respondents

Majority of the respondents (34%) are from the 30 to 39-age bracket, followed by those with ages ranging from 40 to 49 (32%), and finally, from 50 to 59 years of age (24%) (Fig.3).

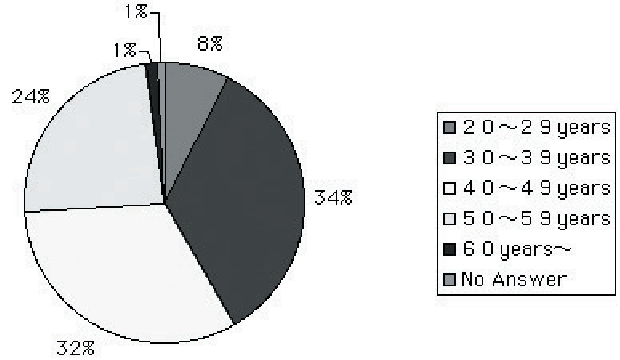


Fig.3 Age of respondents

b. Specialization of respondents

The respondents were asked to indicate their fields of expertise by selecting from among the 9 major agricultural fields listed in the questionnaire as follows: Agronomy, Agricultural Engineering, Forestry and Forest production, Animal Science and Veterinary Science, Fisheries, Agricultural Chemistry, Food Science, Agricultural Economics, Regional Agriculture. Those whose fields of specialization do not fall within any of the major fields listed have to indicate their fields under Others. Majority of the respondents indicated Agronomy as their field of specialization, followed by Agricultural Chemistry, and Animal science and Veterinary. The registered personnel of the DB covers almost all the fields of agricultural sciences (Fig.4).

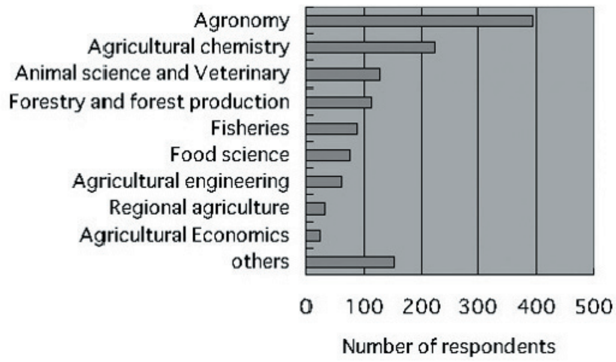


Fig.4. Fields of Specialization of respondents

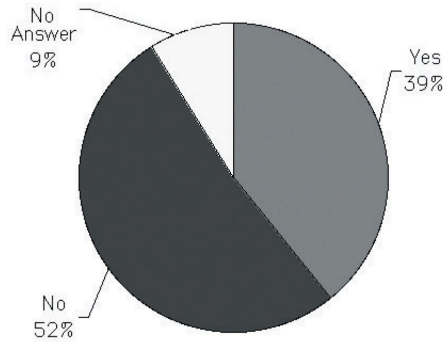


Fig.5 Experience of research in developing regions

c. Experience of research in developing regions

Thirty-nine percent (39%) (343 persons) of all the respondents have experiences in doing research activities in developing regions (Fig.5). On the frequency of being dispatched to developing regions, 140 persons indicated that they were dispatched only once, while 38 persons indicated five times (Fig.6). On the places where researchers are dispatched, majority (83) indicated Thailand. The second country indicated as most visited by a number of respondents for the conduct of research is People's Republic of China, while a third larger group indicated as having conducted researches in Malaysia (Table 1)

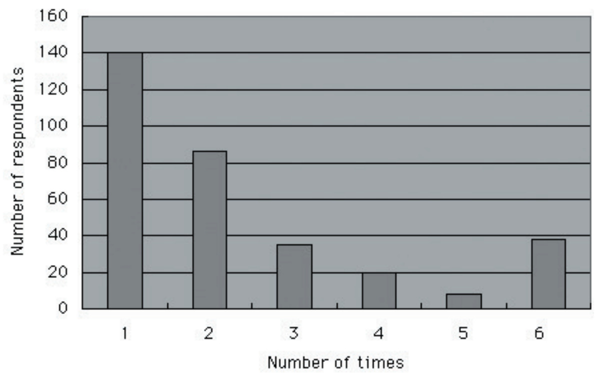


Fig.6 Number of times (experience of research in developing regions)

Table 1. International collaborative projects in JIRCAS (Comprehensive projects)

Time Frame	Project Title	Research Site
1 1996 - 2002	Comprehensive studies on the development of a sustainable agro-pastoral system in the sub-tropical zone of Brazil	Brazil
2 1997 - 2003	Development of sustainable production and utilization of major food resourcesin China	People's Republic of China
3 1997 - 2006	Comprehensive soybean research project in South America (multinational)	Paraguay, Brazil, Argentina
4 1998 - 2002	Evaluation and improvement of regional farming systems in Indonesia	Indonesia
5 1998 - 2002	Improving food security in West Africa through increased productivity in rainfed rice systems	Cote d'Ivoire
6 1999 - 2003	Development of new technologies and their practice for sustainable farming systems in the Mekong Delta (Phase Ⅱ)	Vietnam
7 2000 - 2004	Development of low-input technology for reducing postharvest losses of stables in Southeast Asia	Thailand
8 2000 - 2006	Development of agroforestry technology for conservation of tropical forest	Malaysia, Philippines
9 2001 - 2005	Studies on sustainable production systems of aquatic animals in brackish mangrove areas	Malaysia, Thailand
10 2002 - 2008	Increasing economic options in rainfed agriculture in Indochina through efficient use of water resources	Thailand, Laos

d. Experience of researchcollaboration with invited researchers from developing regions

Fifty-seven percent (501 persons) of all the respondents indicated that they have experience in research collaboration with invited researchers from developing regions (cooperative experiment, fieldwork, seminar etc.) (Fig.7).

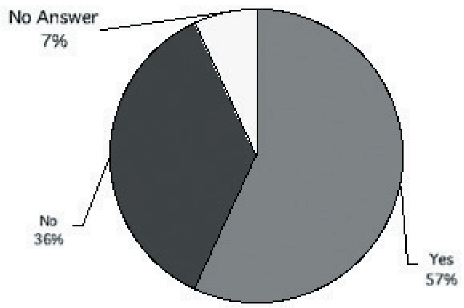


Fig.7 Experience of research collaboration with invited researchers from developing regions

e. The possibility of participation in international research collaboration

Seventy-one percent (71%) of the total respondents gave positive answers to question on possibility of participation in international research collaboration conducted in developing regions. Of this total, nine percent (83 persons) of all the respondents answered that they can participate in research activities in developing regions right away. Other positive answers include "If the conditions allow, I can" (47%), and "I can in the near future," (15%) (Fig.8). Twenty-two percent (22%) had a "No" answer, while 7% did not answer the question.

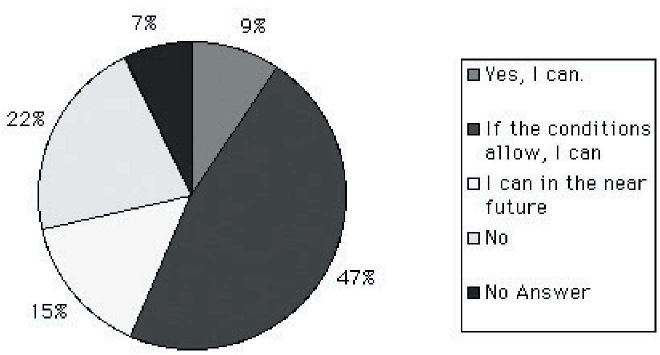


Fig.8. Participation in international research collaboration in developing regions

Sixteen percent (16%) (137 persons) of the total number of respondents indicated that they could accept researchers from developing regions into their laboratory right away. A total of 68% of all the respondents gave positive answers to the item on collaboration with invited researchers from developing regions (Fig.9).

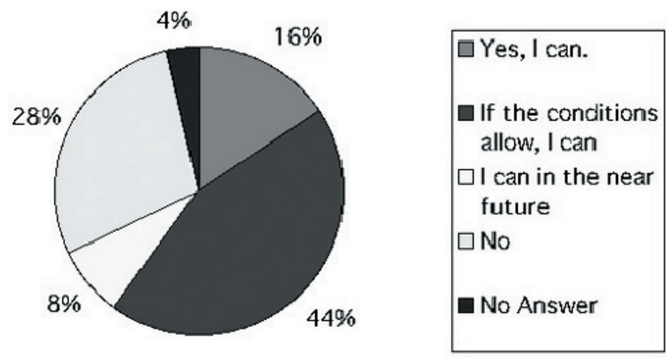


Fig.9. Participation in international research collaboration with invited researchers from developing regions

2) Collection and analysis of information

The purpose of this program is collection and analysis of information pertaining to operational mechanisms and enforcement of conditions for international collaborative agricultural researches, which are being carried out by foreign countries and by reputed international institutes participating with the CGIAR (Consultative Group on International Agricultural Research). Collection of information on employment opportunities in international agricultural research institutes is also being carried out through this project.

In 2001, JIRCAS dispatched its researchers to international agricultural research institutes such as the International Rice Research Institute (IRRI); Australian Center for International Agricultural Research (ACIAR), etc. and a funding agency for technical cooperation, the Asian Development Bank (ADB). The researchers interviewed the program managers in those institutes and gathered useful information for the formulation of international research collaboration strategies. The information collected was published the "JIREC Report," which shall be provided to researchers registered in JIREC DB.

(3) Future activities

From FY2002, we are expanding the target of JIREC-DB from researchers in national research institutes and IAIs to those in prefectural agricultural research institutes, as well as private research institutes. We have continued collecting and analyzing information about operational mechanisms of international agricultural research institutes. In 2002, we are planning to dispatch JIRCAS researchers to institutes engaged in research concerning Africa, which is one of the priority regions in JIRCAS research collaboration.

To establish a network of researchers who have interest in international research collaboration, it is necessary to provide appropriate information and opportunity to exchange opinion among the researchers registered in JIREC-DB. We consider possible activities to achieve this objective such as sending newsletters to registered researchers, constructing Internet forum, holding a workshop etc.

We believe that one of the most effective means to foster young researchers who wish to participate in research activities in developing regions is to establish an internship program. Through this program, we dispatch young researchers to the research collaboration sites in developing regions to carry out researches under the leadership of senior researchers. As mentioned, JIRCAS implements comprehensive international research projects in developing regions. JIRCAS believes that it can provide young researchers appropriate opportunities to experience research in developing regions through visit to the Center's research project sites.

3. Collaboration with universities and other institutes

As a result of reorganization into an IAI, JIRCAS got wider freedom to implement activities, but bearing in mind that the result of the research activities are strictly evaluated. Making research activities more efficient is an urgent task for JIRCAS. The Center aims not only to improve the research ability of individual researchers but also to develop an organizational structure that can promote research activities more effectively. Establishment of new methods of project management is also needed in order to utilize more efficiently the limited budget and human resources available to the Center.

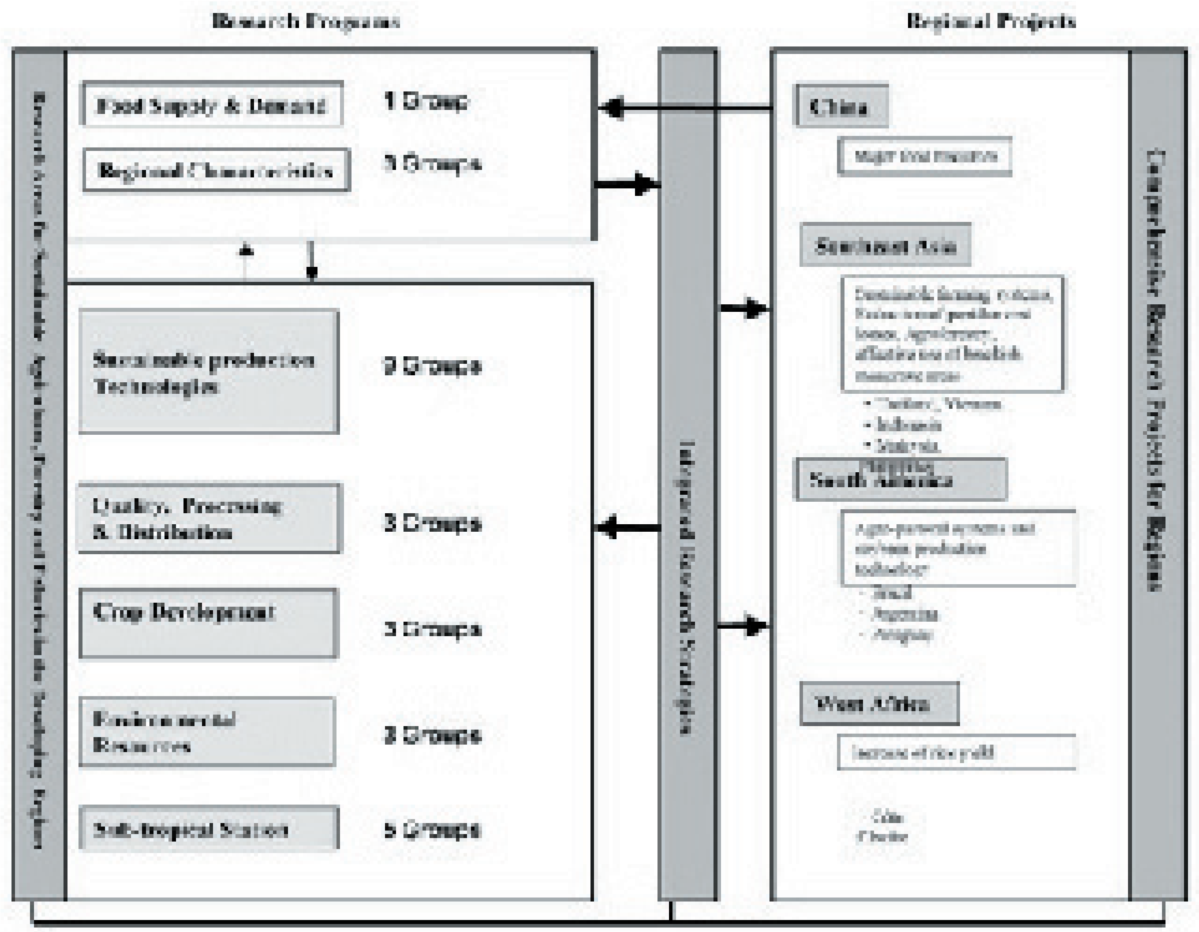


Fig.10 Research programs and regional projects of JIRCAS

(1) Organizational operation after the reorganization

In the organizational operation of JIRCAS, two components are important in order to increase the research ability of the whole institute. These are:

1) Human resource development through long-term research activities

2) Concentration of human resources to important short-term comprehensive research projects

Considering these two components, JIRCAS adopted matrix systems after the reorganization. Twenty-seven (27) research groups were established under seven research programs (Fig.10). These are as follows:

Research Program 1: Food Supply and Demand
(1): Food supply and demand

Research program 2: Regional Characteristics
(1) Information systems
(2) Regional trend
(3) Farming systems

Research program 3: Sustainable Production Technologies
(1) Crop management
(2) Plant nutrition and physiology
(3) Pest management
(4) Material cycling
(5) Animal production
(6) Feed production
(7) Animal health in tropical area
(8) Water resource management
(9) Aquaculture

Research program 4: Quality, Processing and Distribution
(1) Food quality
(2) Food distribution and processing
(3) Forestry resource management

Research program 5: Crop Development
(1) Genetic resource utilization
(2) Genetic engineering
(3) Breeding methodology

Research program 6: Environmental Resources
(1) Forestry
(2) Fishery resource management
(3) Coastal environment

Research program 7: Sub-tropical Station
(1) Stress tolerance crop
(2) Germplasm development
(3) Tropical fruits
(4) Integrated pest management
(5) Islands environment

Researchers implement research activities related to their major fields in each research group. Project teams were also organized to promote comprehensive research projects (Table 2). Most of the researchers participate as members of the project team that carries out Project researches under their respective groups. There are seven research divisions and one subtropical station in JIRCAS (Fig.11). Directors of research divisions are also designated as leaders of the comprehensive research projects. The Vice President supervises all the project teams. Research Coordinators are assigned to help the Vice President coordinate the projects.

The newly established Development Research Division gathers and analyzes information and data on the natural and social environments, economic aspects, and the agriculture, forestry and fisheries sectors of developing regions throughout the world. Using these data, the Division carries out research aimed at developing a global food security data collection system and a world food supply and demand forecasting model. Another activity of this division is the assessment of current farming system and the development of improved systems in representative priority regions. The division also carries out researches to identify the directions of technology development most likely to meet future needs, and contribute to the establishment of a comprehensive research strategy for JIRCAS.

In order to attract excellent researchers, recruitment is open to highly qualified personnel within and outside Japan through apply- and-review basic recruitment procedure.

Fig.11 Organization of JIRCAS

Table 2. International collaborative projects in JIRCAS (Comprehensive projects)

Time Frame	Project Title	Research Site
1 1996 - 2002	Comprehensive studies on the development of a sustainable agro-pastoral system in the sub-tropical zone of Brazil	Brazil
2 1997 - 2003	Development of sustainable production and utilization of major food resources in China	People's Republic of China
3 1997 - 2006	Comprehensive soybean research project in South America (multinational)	Paraguay, Brazil, Argentina
4 1998 - 2002	Evaluation and improvement of regional farming systems in Indonesia	Indonesia
5 1998 - 2002	Improving food security in West Africa through increased productivity in rainfed rice systems	Côte d'Ivoire
6 1999 - 2003	Development of new technologies and their practice for sustainable farming systems in the Mekong Delta (Phase Ⅱ)	Vietnam
7 2000 - 2004	Development of low-input technology for reducing postharvest losses of stables in Southeast Asia	Thailand
8 2000 - 2006	Development of agroforestry technology for conservation of tropical forest	Malaysia, Philippines
9 2001 - 2005	Studies on sustainable production systems of aquatic animals in brackish mangrove areas	Malaysia, Thailand
10 2002 - 2008	Increasing economic options in rainfed agriculture in Indochina through efficient use of water resources	Thailand, Laos

(2) Collaboration with universities and other institutes

JIRCAS endeavors to develop human resources and improve research capacity. Faced with budget and personnel limitation, JIRCAS aims to explore other collaborative schemes through stronger linkage with other institutes including universities and research institutes in developing regions in the near future.

a. Strengthening the linkage with universities and other institutes

After the reorganization of JIRCAS into an IAI, it became relatively easier to make collaboration with other institutes due to the deregulation of various governmental rules, which were applied to governmental organizations. For example, before the reorganization, prior approval of government was necessary to conclude research cooperation contracts with other institutes. Nowadays IAIs can make such decision for collaboration. To use the budget and human resources effectively, JIRCAS should strengthen its linkage with universities, other IAIs, JICA, international research institutes, advanced research institutes and the private sector. Sharing of facilities, personnel, information and budget to promote research activities in the field of agriculture in developing regions shall be explored with existing linkages.

In FY2001, JIRCAS dispatched five researchers from Japanese universities to developing regions to participate in JIRCAS research cooperation projects. Such number is small compared to the total number of dispatched researchers to the JIRCAS project of about 200 persons per year. Before the reorganization, university researchers rarely get engaged in JIRCAS projects. JIRCAS hopes that more and more university researchers participate in its researches. The possibility to dispatch postdoctoral researchers in universities, and graduate students to the research sites of JIRCAS international collaboration shall be explored. A system of contracting researches to other research institutes shall also be considered. Sharing of facilities has been arranged with JICA in some of JIRCAS' research projects. Adequate application of research results and its diffusion is expected through the close linkage with JICA and private sector. JICA's experience in handling technical cooperation projects is seen as a big help in strengthening JIRCAS capability. In promoting such linkage, especially with private sector, attention should be given to the basic policy of handling research results and information in order to avoid problems related to violation of intellectual property rights.

b. Participation of researchers in developing regions

More active participation of researchers from developing regions to JIRCAS projects should also be considered. Although JIRCAS projects are basically collaborative projects with developing regions, the conventional project management practice tend to forget the active participation of foreign counterpart researchers who have useful knowledge and experience about the region. To improve this situation, three schemes shall be implemented:

a) Coordinator scheme

Through this scheme, JIRCAS dispatches its researcher to a selected country in a developing region as a project coordinator. The coordinator makes project proposals to the research institutes in the region and forms the project team mainly composed of researchers in the region. In initial stage of the project, it is necessary for JIRCAS to dispatch the coordinator on a long-term basis. After the research activity takes off, the JIRCAS coordinator visits the research site on a short-term basis, i.e., once or twice a year for discussion with counterpart researchers and evaluation of the research plan and result. It is expected that efficiency on the use of resources is maximized with the utilization of minimum research manpower of JIRCAS by entrusting most of the actual research activities to researchers in the developing regions.

b) Multilateral cooperation scheme

This is similar to the "Coordinator scheme". The difference is in the number of counterpart countries. In coordinator scheme, one country in a developing region participates in the project, which is carried out under a bilateral agreement. In the multilateral scheme, more than two countries in developing regions participate in the research. Therefore, the management of the project would be more complex than that of the coordinator scheme. JIRCAS has already established some offices in developing regions, namely: Bangkok in Thailand, Beijing in P. R. China, and Londrina in Brazil. In addition to the research coordinator from JIRCAS, these offices will be expected to work as core centers of multilateral research cooperation whenever JIRCAS decides implement the multilateral cooperation scheme.

c) Invitation scheme

One of the important activities of JIRCAS is the invitation program for foreign researchers from developing regions. Every year, JIRCAS invites about 100 researchers from developing regions under various invitation programs such as counterpart researcher invitation, research manager invitation and JIRCAS fellowship programs. Graduates are also being considered for involvement in these invitation programs for research projects. This scheme is best illustrated as follows: First, JIRCAS invites researchers from developing regions to participate in the training program to study advanced research methods in Japan. Upon completion of the program, the participants are requested to make research proposals on agriculture focused on their respective countries. After evaluation of the research proposals, a group of researchers are selected from among the invited researchers to carry out a project on a research theme in their countries to be funded by JIRCAS, which contributes to JIRCAS objectives of achieving a stable global food supply and ensuring sustainable development of agriculture (Fig.12).

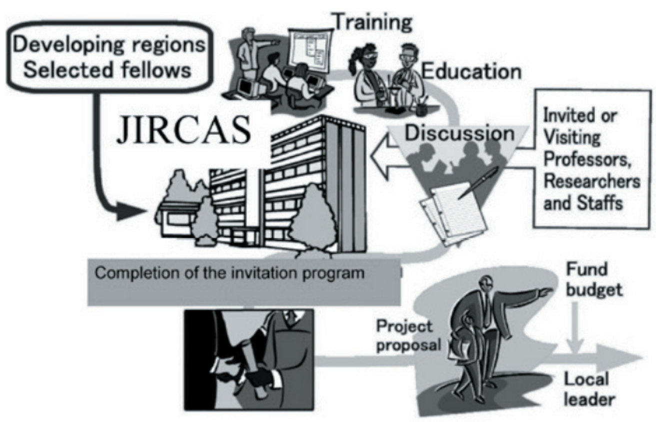


Fig.12 The concept of invitation method

The Coordinator scheme, multi-lateral cooperation scheme and invitation scheme have the following advantages:

1) Reduction in travel expenses of Japanese researchers, and therefore, savings on the budget allocation
2) Promotion of research that suits the environment and social condition of the developing regions, and establishment of appropriate technologies.
3) Decrease the problem of dispatched Japanese researchers encountering difficulty due to change of living circumstances.

In the management of research projects, there should be clear delineation of roles and sharing of responsibilities between JIRCAS and counterpart institutes. Appropriate research personnel in the regions are also selected to manage the project efficiently. The experiences of other international research institutes, which already adopted similar methods, like ACIAR and ESCAP CAPSA (Center for Alleviation of Poverty through Secondary Crops Development in Asia and the pacific) will be useful to establish new project management Policy. Collection of data in the regions also considers the advantage of JIRCAS as an information center for research activities in the developing regions.

4. Conclusions

Human resource development and collaboration with universities play important roles in the promotion of JIRCAS activities. JIRCAS could become more responsive to technological needs from developing regions, especially through close cooperation with university and its personnel.

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Evaluation of ODA to Build and Strengthen International Cooperation: Towards Constructing an International Framework of Evaluation for International Cooperation

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Abstract

This paper claims that building international framework for evaluation needs to be recognized as a critical and urgent agenda to promote the effectiveness and efficiency of international cooperation. Most of efforts during evaluation activities are concentrated within an aid agency, not among aid agencies and recipient countries. There is a lack of connection between the efforts of aid agencies. This situation reduces the effectiveness of evaluation efforts and international cooperation. To remedy this situation, two possible future efforts are recommended: 1) building a network centered on evaluation, and 2) establishment of an evaluation archive for knowledge sharing. One possibility for achieving the above mentioned idea is the utilization of existing universities' networks and their capabilities in knowledge accumulation.

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Introduction

The High-level Meeting of DAC (The Development Assistance Committee) of OECD (The Organization of Economic Cooperation and Development) adopted the resolution: “Toward the 21st Century: The Contribution of Development Cooperation (DAC New Strategy)” in May 1996. With the adoption of The New Development Strategy, which, for the first time, provided the development goals in numerical term, evaluation became more important than before in the field of international cooperation. The new development goals have played an important role to convert the conception from the inputs of cooperation, which is represented by the ratio of Official Development Assistance (ODA) to GDP, to the results of cooperation. As this new concept gains acceptance in aid communities, each aid agency is obliged to develop concrete policies and implementation strategies by stressing their results. This concept also affected the development of ideas of sector-wide approach and poverty reduction strategy paper, which are key concepts in international development. Following the New Development Strategy, the Millennium Assembly of the United Nations, which was held in September 2000, adopted the Millennium Development Goals. This means that seeking the results of international cooperation, which correspond to the development goals defined by developing countries, requires the establishment of recognition of common goals among donors and recipient countries. As a consequence, results of evaluation, which confirm the performance, study the process, and clarify the cause and effect relation of international cooperation, have to be shared among donors and recipient countries to perform in order to accomplish the development goals.

Evaluation provides international cooperation activities with various possibilities. The evaluation is an assessment, as systematic and objective as possible, of an ongoing or completed project, program or policy, in terms of its design, implementation and results.

The aim is to determine the relevance and fulfillment of objectives, efficiency, effectiveness, impact and sustainability (OECD-DAC 2001). If an evaluation is credible and useful, it enables to incorporate the lessons learned into the decision-making process of recipients and donors.

Therefore, many aid agencies have started to make efforts to integrate evaluation into the various aspects of international cooperation activities so as to maximize the advantages of evaluation. In this case, evaluation performs two important functions: 1) as a management tool for creating ideas, and 2) as a learning tool for all interested parties. More concretely, evaluation is used as an effective tool to improve the policy structure that is composed of policy, program, and project, by assessing their relevance and value, with influence from people concerned. In this case, evaluation provides opportunities to build and strengthen international cooperation by accumulating the results of evaluation as resources of knowledge and experiences. While each aid agency's respective efforts in promoting evaluation are progressive, the effect is rather small. Therefore, it is important, for more effective evaluation, to integrate various efforts in accumulating and utilizing the results of evaluation by aid agencies in order to maximize the contribution of evaluation. In other words, accumulation of the results of evaluation has to be conducted not only at the state level but also at the international level.

This paper claims that building international framework for evaluation needs to be recognized as a critical and urgent agenda to promote the effectiveness and efficiency of international cooperation. The first section examines an effort of Japan International Cooperation Agency (JICA) as an example of promoting evaluation activities by accumulating the evaluation results at the state level. Following this, the second section clarifies agendas of promoting international evaluation activities stimulated by the experiences of JICA. Finally, the third section provides some implications to build international framework for more effective evaluation that eventually leads to more effective international cooperation.

1. Aid Agency's Efforts: A Case of JICA

In order to show the significant role of evaluation in aid agencies, this section examines the efforts of JICA in shaping evaluation structures. JICA is one of Japan's two aid agencies, which executes technical cooperation and grant capital cooperation activities. In FY 2000 JICA conducted over 800 training courses of technical cooperation in Japan and overseas. The number of participants reached 16,990. The total number of experts dispatched overseas is 15,138. JICA conducted over 250 technical cooperation projects, and over 250 feasibility and master planning studies. Furthermore, JICA conducted a number of project identification and formulation activities to support the above-mentioned activities. In addition, JICA conducted over 300 grant capital projects mainly on the development of social sectors by providing facilities and equipment. In terms of organization structure, JICA has International Training Centers in Japan and overseas offices outside of Japan. JICA operates technical cooperation activities all over the world.

In recent years, the environment that surrounds JICA has become severe. Discussions on ODA have been conducted in the National Diet more often than before. The ODA budget was cut in FY 2002, which affected JICA's budget. The Diet approved an administrative evaluation bill in July 2001 that became effective in April 2002. Consequently, clarifying the purpose of aid activities and its verification has become an important task for aid agencies. One of the effective ways to pursue this direction is to advance "country and issue oriented approach". Importantly, JICA views evaluation as a crucial element to promote this approach, so that it proceeds by establishing an operational system that stresses on evaluation functions as a component of its management process.

Table 1 shows the current JICA evaluation structure. JICA's evaluation activities are classified into two categories by the level of objectives for evaluation, namely: project evaluation, and program/policy evaluation. Project evaluation mainly focuses on individual projects and their operations, which are performed mainly by the modality of activities. Project evaluation is conducted in the form of ex-ante, mid-term, terminal and ex-post evaluation in the context of

Table 1. JICA's Evaluation Structure.

Type of Evaluation	Objectives	Responsible Department	Nature of Evaluation
Project	Ex-ante	Regional/Sector Dept.	Self-Evaluation
	Mid-term	Regional/Sector Dept.	Self-evaluation
	Terminal	Regional/Sector Dept.	Self-evaluation
	Ex-post	Overseas Office	External evaluation
Program/Policy	Country evaluation Sector evaluation Thematic	Evaluation Office	Internal/ External

project implementation. The ex-ante, mid-term, and terminal evaluations are conducted by respective responsible operation departments, namely: regional and sector departments; while the ex-post evaluation, by overseas offices. The character of project evaluation is categorized as self-evaluation. On the other hand, program evaluation consists of country, sector, and thematic evaluations focusing mainly on policy structure. The nature of these evaluations is categorized as ineternal/external evaluation.

The staffs in the Office of Evaluation, as well as external evaluators who are independent from directly responsible departments, conduct the evaluation.

It is clear that the aid agencies are required to perform their activities effectively and efficiently. However, in the actual situation, it is not so easy to demonstrate effectiveness and efficiency in international cooperation activities. In 1999 JICA's Office of Evaluation conducted a survey on utilization of evaluation results. It was found that utilization of evaluation results is poor. More importantly, the study showed that there had not been a clear methodology on measurement of accomplishments and verification on effectiveness of activities (JICA 2001b).

The JICA's Office of Evaluation took this issue seriously and took actions to improve the situation by setting up the following processes; 1) establishing an evaluation policy, 2) building an system from ex-ante to ex-post evaluation, 3) studying and establishing evaluation methodologies, 4) strengthening external evaluation, 5) promoting feedback of the evaluation results, and 6) disclosing evaluation results.

In JICA, evaluation is now an integrated component of project activities, eventually providing a framework of project activities. However, the progress of integrating evaluation with JICA's activities is not faster than expected even if steady progress has been seen, especially that it is necessary to work more at the policy and program levels. There is a need to develop an evaluation methodology to conduct policy and program evaluation by synthesizing various modalities of aid activities

For this purpose, JICA recently conducted a thematic evaluation of its cooperation in the field of infectious disease control in the Philippines. In this evaluation, a program defined the policy structure of aid conducted by JICA. This evaluation approach promoted discussion on JICA's activities as integrated activities in the context of the Philippines' policy structure on infectious disease control, and proposes further approaches concerning JICA's cooperation policy in the future. It also provided the evaluation methodology of the program as well as aid coordination with other donors in this study with USAID. This evaluation shows a new approach, which is more focused on policy structure, and increase in the effectiveness of evaluation. On the other hand, this approach is required to integrate evaluation with the recipient country's policy structure and those of other donors' aid policy structures.

JICA is also currently making efforts to increase external evaluations. One example is the evaluation study conducted by Nagoya University under the JICA contract. The evaluation study examined how the technical cooperation projects in agriculture, forestry and fisheries conducted by JICA in Nepal impacted on farmers at the community level. In particular, the study focused on impacts on poverty and gender issues, as well as the changes in the life of residents. The study had two purposes: 1) to research on new evaluation procedures from the viewpoint of poverty and gender; and 2) to apply the new methods produced as a result of such research to actual cooperation projects of JICA in Nepal in the past. The Joint Study Committee that conducted the evaluation study was composed of representatives from the Graduate School of International Development, the Graduate School of Bio-agricultural Sciences, and the International Cooperation Center for Agricultural Education. This study provided useful evaluation experiences and knowledge by utilizing the university's academic resources and showed that universities are one of prominent organizations to provide excellent evaluators based on accumulated research and study experiences.

2. Agenda for Promoting International Evaluation Activities

In the previous section, the efforts of an aid agency in promoting evaluation and maximizing its advantages were examined by using JICA as a case. This kind of effort is also predominant in other aid agencies. One example is the World Bank's distance education for training evaluators in order to increase the number of evaluators in developing countries. In order to clearly define the result of international cooperation increasing the number of evaluators is an indispensable task. The number of joint evaluations by aid agencies is increasing nowadays, and provides very prominent opportunity, where aid agencies bring their own experiences for future collaboration in their programming and operation. On the other hand, developing countries make efforts to introduce evaluation system such as performance measurement. Universities are also involved in evaluation works of ODA by utilizing their academic resources. The increase of evaluation activities in various organizations can be seen in the various fields of international cooperation.

Considering these situations, it is important to integrate various efforts of aid agencies for more effective evaluation. In fact, although each agency's efforts are progressive, it is not possible without integrating the efforts of each aid agency to maximize them. As mentioned earlier, the current policies and strategies of aid agencies to developing countries seek the common results, which correspond to the development goals the developing country defines. This means that seeking the results of international cooperation emphasizes establishing recognition of common goals among donors and recipient countries. Consequently, results of evaluation, which confirm the performance, study the process, and clarify the cause and effect relation of international cooperation, have to be shared among donors and recipient countries to utilize for accomplishing the development goals.

What is necessary to accomplish this? The following are issues to be discussed: 1) establishment of effective evaluation methodology; 2) generalization of knowledge based on evaluation results; 3) collaboration work of evaluation among aid agencies and recipient countries; and 4) promotion of stakeholders' participation in evaluation activities.

One of the important issues is to share knowledge on effective evaluation methodologies. Various agencies apply evaluation methodologies based on their own policies and strategies, or guidelines of evaluation. Some agencies stressed project evaluation while others, program evaluation. Most of evaluation defines targets together with indicators. However, they do not always share them with other evaluation. Even in the same field of cooperation activities, different evaluation methodologies are observed. Although utilization of different methodologies is not undesirable, sharing ideas of methodologies makes more effective execution of evaluation, especially in program evaluation, where policy issues of the recipient country is involved and other activities of aid agencies affect the result to be evaluated. In particular, the evaluation on capacity building needs to consider the contribution of other aid agencies because each agency often shares activities each other.

Furthermore, conceptualization and generalization of evaluation results are necessary in order to share the knowledge created by evaluation. In conceptualization and generalization of the results of evaluation, evaluation methodologies, purpose of activities, and assumption of activities are clarified, and a series of evaluation results are analyzed in a comprehensive manner. Through these procedures, the results of evaluation conducted in the past are firmly converted to and accumulated as knowledge, and are then disseminated to the peoples concerned. The comparison of results of various evaluations provides the best practices and appropriate way of thinking in international cooperation.

Collaboration work of evaluation among aid agencies and recipient countries is indispensable in the era of aid coordination. There is a change in aid coordination. In fact, in many developing countries, poverty reduction strategy papers are under formulation and sector-wide approaches are introduced in various sectors so that evaluations conducted by one aid agency have not always provided substantial results. The development of these approaches depends on the capability of recipient countries. Therefore, it is desirable that most of aid agencies, which participate in the development of these approaches, conduct evaluation jointly by allowing greater involvement of the recipient country for more useful evaluation results. Basic education is one of the sectors where joint evaluation is indispensable to access policy and program, due to the involvement of various aid agencies.

Finally, promotion of stakeholders' participation in evaluation activities is an important issue to address in order to make evaluation more effective. As discussed before, stressing on the evaluation at the program and policy levels requires more involvement of stakeholders of recipient countries, especially when focused on poverty as a development issue.

3. International Frameworks for Effective Evaluation

Based on discussions on aid agency's efforts in evaluation and agenda for international evaluation activities, it is understood that in order to make evaluation more effective for international cooperation, it is necessary to improve evaluation not only within an aid agency but also among aid agencies. It is also indispensable to improve policy structure both of recipient country and aid agencies.

However, it was observed that most of efforts during evaluation activities are concentrated within an aid agency, not among aid agencies and recipient countries. There is a lack of connection between the efforts of aid agencies. Therefore, it is necessary to increase a linkage among aid agencies for more coordinated evaluation efforts. On the other hand, the establishment of this kind of bond stimulates the efforts of aid agencies' evaluation works.

In conclusion and to facilitate this situation, two possible future efforts are recommended for more effective evaluation activities: 1) building a network centered on evaluation, and 2) establishment of an evaluation archive for knowledge sharing. Firstly, as discussed in the first section, the success of establishing an effective evaluation methodology, generalization of knowledge based on evaluation results, collaboration of evaluation work among aid agencies and recipient countries, and promotion of stakeholders' participation into evaluation activities fairly depend on the interchange of ideas and knowledge of people who are involved in international cooperation. Therefore, the creation of vehicle for interchange of ideas and knowledge, that is, the establishment of networks, is indispensable.

Secondly, accessibility is also an important issue in order to increase sharing experiences and knowledge based on evaluation results. In the past, this kind of issue is difficult to solve, but nowadays, a knowledge base created by utilizing the developed information and communication technology enables increased accessibility without the restriction of time, distance or place. The knowledge base accumulates explicit knowledge created by evaluation results. Therefore, it is possible to share more easily these information by creating an evaluation archives of knowledge on evaluation.

One possibility for achieving the above mentioned idea is the utilization of existing universities' networks and their capabilities in knowledge accumulation. As I introduced in JICA's case, there is an increase in the involvement of universities into evaluation activities. When evaluation is focused on policy /program and become more complex, this tendency is accelerated because universities can accumulate academic resources, and provide appropriate evaluators. Furthermore, the experience of evaluation can integrated into various academic activities and can be utilized in academic discussions through academic exchange. This accumulation of knowledge on these kinds of activities increases the possibility of utilization of evaluation results.

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Role of International Cooperation Center for Agricultural Education (ICCAE) in Capacity Building for Sustainable Agriculture

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Abstract

The International Cooperation Center for Agricultural Education (ICCAE) was established in April 1999 and is one of the five centers for international cooperation established in Japan, but the only one dedicated to agriculture. In pursuit of its vision of becoming a leading center for international cooperation in agriculture education, the Center's Project Development Division implements activities towards the conduct of evaluation studies, development of agricultural projects and technologies, training of human resources, and creation of scientific solutions to address problems related to agriculture and environmental issues through international cooperation. The other division, which is in charge of Network Development, endeavors to develop and coordinate a human resource database for teachers and researchers in domestic universities, research institutes, and high schools in the field of agricultural sciences in order to achieve effective international cooperation in agricultural education. In addition, it establishes well-working consortia and cooperative networks between and among international and/or domestic organizations. Over the past years, ICCAE has been involved in projects such as the development of higher education in agricultural universities in Cambodia and Namibia, and the African Institute for Capacity Development (AICAD). The Center's collaboration with the Japanese International Cooperation Agency (JICA) is also crucial in the human resource development of countries in Africa. The activities promote the project's goal to strengthen practical education and research in the universities to assist in the alleviation of poverty in each developing country. ICCAE continuously explores ways to enhance linkages with international institutions to promote cooperation in the area of agriculture. Establishment of linkages has been found to be very effective and efficient way of ensuring cooperation in Asia and Africa. The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) and ICCAE look forward to further collaboration in the project with Royal University of Agriculture in Cambodia.

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Introduction

This paper is composed of two parts. The first part introduces the function of ICCAE in international cooperation in developing countries. The second part presents the Center's experience in implementing curriculum development assistance to the Royal University of Agriculture in Cambodia as one of the component activities of ICCAE in higher education.

I. The ICCAE: Its functions and Activities

The ICCAE was established in Nagoya University in April 1999. Its vision is to be a leading center for international cooperation in agricultural education. ICCAE is one of the five centers for international cooperation established in Japan, but is the only one dedicated to agriculture (Table 1). Its missions are 1) to contribute to human resource development for solving agricultural issues in developing countries as the national center; 2) to coordinate international cooperation projects with institutions as an international center; 3) to establish human resource databases and managing methods for effective international cooperation; and 4) to conduct research in agricultural cooperation projects for the well-being of people in developing countries. Within three years since its establishment, ICCAE aimed to be the national center for human resource development to address agricultural issues in developing countries through international cooperation in agricultural research and education. Having achieved its first target on time in 2002, ICCAE is now working towards achieving its goal of acquiring the status as an International Center for human resource development in Japan within two years.

Table 1. International Cooperation Centers established

Centers	Year of Establishment
Center for the Study of International Cooperation in Education (CICE), Hiroshima University	1997
International Cooperation Center for Agricultural Education (ICCAE), Nagoya University	1999
International Research Center for Medical Education (IRCME), the University of Tokyo	2000
International Cooperation Center for Engineering Education Development (ICCEED), Toyahashi University of Technology	2001
Center for Asian Legal Exchange (CALE), Nagoya University	2002

To realize the Center's missions, ICCAE consists of two divisions that take charge of several functions including field survey, project development, project evaluation, human resource database, network development, and training with four permanent staff (two professors and two associate professors). A Director heads the Center.

The Division of Project Development 1) surveys, analyzes and evaluates the needs, requests, and projects of developing countries that focus on international cooperation in agriculture and agricultural education to improve agriculture and rural life; 2) develops agricultural projects and technologies to meet the field and rural life needs of developing countries, considering traditional agricultural practices and environmental issues; 3) cooperates in human resource development at any level of education; and 4) creates scientific solutions for addressing agricultural problems in the field through international cooperation.

The Division of Network Development 1) develops a human resource database for teachers and researchers in domestic universities, research institutes, and high schools in the field of agricultural sciences; 2) researches and develops methods for coordinating use of the database in order to achieve effective international cooperation in agricultural education; and 3) establishes well-working consortia and cooperative networks between and among international and/or domestic organizations.

The ICCAE has two posts for Visiting Fellows in order to conduct joint research or cooperation on the projects in ICCAE. One of these positions is for Japanese scientists or professionals under one year contract. The other is for foreign scientists or professionals for a period of three to twelve months. ICCAE usually invites three foreigners with three to five month-stay a year.

The main activities of ICCAE in international cooperation are summarized in Tables 2 and 3.

Table 2. Main activities of ICCAE

Project	Activities
Project for Capacity Building of the Faculty of Agriculture and Natural Resources, University of Nambia (JICA, 2002-present)	Conducted preliminary survey; trained 3 teaching staff; dispatched 1 long-term and 3 short-term experts.
African Institute for Capacity Development (AICAD) Phase 2 (JICA, 2000-present)	Conducted preliminary survey; participated as member of the JICA support committee; dispatched a long-term research advisor and short-term experts.
Collaboration with Royal University of Agriculture, Cambodia, in Higher Education and Capacity Building (ICCAE, 2000-present)	Hosted 5 visiting fellows from RUA; implemented curriculum development assistance; supported the establishment of the master's course.
External Evaluation of JICA Agricultural Projects in Nepal (JICA, 1999-2000)	Conducted joint evaluation with the Graduate Schools of International Development and of Bioagricultural Sciences, Nagoya University.
External Evaluation on the SG 2000 Program (Sasakawa Africa Association, 2001-2002)	Evaluated SG 2000 Program in 9 African countries.
Database of Human Resource in Agricultural Cooperation (ICCAE, 1999-present)	Developed the database registering more than 2500 human resources.

Table 3. Training by ICCAE

Training Courses	Activities
Group Training Course; GIS (Geographic Information System) Technology for Sustainable Management of Natural Resources and Agricultural Products (JICA, 2000-present)	Trained 6 research fellows in agricultural sciences for 5 weeks a year.
JICA Rice Research Techniques Course (JICA, 1999-present)	Trained 6~7 research fellows once a year.
Group Training Course in Bioindustries (JICA, Japan Bioindustry Association, 1999-present)	Trained 10 research fellows once a year.

II. Curriculum Development and Capacity Building for Royal University of Agriculture (RUA)

The development of a new curriculum and capacity building for Royal University of Agriculture (RUA), Cambodia, are cited as one of the representative activities of ICCAE in higher education.

RUA was founded in 1964 during the Prince Norodom Sihanouk regime as one of the nine (9) national universities and had been playing a key role in offering agricultural higher education in Cambodia. Statistically, 200 students graduated from the RUA from 1965 to 1975. Unfortunately, RUA was completely closed and converted into an ammunition factory during Pol Pot's regime from 1975 to 1978 (APIP 2000; MAFF 1999).

Designing new and appropriate curricula has been recognized as one of the most important issues for RUA (APIP 2000; MAFF 1999). It took as long as eleven years to complete the new curricula after the former Soviet Union withdrew from Cambodia in 1990 because little effort had been directed to curriculum development before 1999.

Russian lecturers designed the former curricula when the former Soviet Union supported the university from 1985 to 1990 (MAFF 1999). In 1990, when the former Soviet Union support suddenly withdrew from Cambodia, the university (Institute of Agricultural Technology at that time) faced a lot of problems, especially the replacements of the teachers. In order to alleviate the urgent needs, the young graduates from the Institute were appointed as teachers notwithstanding their lack of teaching and research experience. The newly appointed lecturers continued using the curricula designed by the Russian lectures, although the Khmer was used as the medium of instruction. The former curricula were used until the first semester of the academic year 2000-2001, although there were some changes introduced by French non-governmental organizations (NGOs) such as Groupe de Recherche et d'Echanges Technologiques (GRET) and Veterinaires Sans Frontieres (VSF) (MAFF 1999).

The ICCAE has been assisting RUA in developing the new curricula since 2000. The RUA and ICCAE jointly studied higher educational systems and curricula of other universities throughout the world. The ICCAE staff visited RUA to study the status of RUA and the higher education in Cambodia in February and June of 2000. The Center then invited an RUA staff as an ICCAE Visiting Fellow for the joint study from August to October 2000. ICCAE proposed a number of recommendations concerning the new curricula and educational system. The RUA accepted the recommendations with few modifications, and completed the new curricula and educational system in 2001, which were then introduced in the second semester of the academic year 2000-2001.

As a starting point for discussion on curriculum development, the first draft of "Academic Catalog for Undergraduates" was used, which included the curricula and educational system. This first draft was provided by RUA with assistance from a French project called Programme d'Appui a la Formation Agricole et Agronomique au Royaume du Cambodge (PAFAARC) as suggested from a project of the National Action Plan for Agricultural Higher Education by the Food and Agriculture Organization of the United Nation (FAO) (MAFF 1999).

New Curriculum

The main points of curriculum reform were as follows:

1) The term of school attendance was shortened from four and a half years to four years;

2) The hour-based curriculum was changed to a credit-based system;

3) The number of credits required for a BS degree was reduced from 170 (hours converted into credits) to 144 credits;

4) Electives were introduced for the first time, and the status of English and French courses were changed from compulsory to elective; and

5) The list of subjects was changed completely.

The additional major changes included the development of a mission statement for the university and a policy for the instructional program together with a manual describing the processes from admission to graduation. There were, however, some recommendations that could not be realized in a short time, such as strengthening practical subjects, and shifting thesis supervision from extramural to intramural persons, which must be matched with human resource development.

Introduction of the credit system into the new curriculum was the chief objective of RUA in the curriculum revision. The credit system, which is convenient for indicating the outcome and substance of education, is widely adopted by higher education institutions around the world.

RUA received a number of advantages by introducing the credit system such as:

1) Credits clearly show the quality and the quantity of academic achievement;

2) Students are able to study at their own pace as full-time or part-time students, so that some students may simultaneously have a job;

3) Students are able to take leave of absence from school and to return to school later while retaining their credits; and

4) A credit transfer system can exist.

Credits must reflect the quality of education and assure a university degree. It is clear that the credit system needs to be universal. The university has a responsibility to ensure the quality of education. However, RUA students are not really satisfied with the quality of education because of insufficient practical activities, a shortage of human resources, a lack of textbooks and teaching materials, and inadequacy of educational facilities and equipment. In RUA, the quality of credits is limited mainly to the quality of the education. Improvement in the quality of education is vital to ensure accreditation. The impact of the introduction of credit-based curricula will be limited unless the quality of education is improved.

Establishment of master's course

RUA is the only university that achieved curriculum development among the nine national universities in Cambodia. It is expected as the forerunner of reforming the higher education system and consequently gaining approval to establish the master's course of graduate school. ICCAE started the joint study on the education system, management of the graduate school, and the master's course curriculum with RUA by inviting the Dean of RUA as Visiting Fellow from 2001 to 2002. As a result of this study, RUA opened the master's course of graduate school in October 2002. ICCAE also trained the RUA staff in administration aspects in cooperation with the administrative office of Nagoya University.

The key issues for RUA to live up to the expectations of the government, society, and students from now on are as follows:

1) **Capacity building of staff.** It is very important to provide quality higher education to students. The number of staff who has the degree is one of the indicators to analyze the quality of staff. There are only 6 and 13 permanent lecturers having PhD and MS Degrees, respectively, out of 106, and 6 and 12 contract lecturers having PhD and MS Degrees, respectively, out of 47 in RUA. It is therefore, urgent for RUA to pursue the dispatch of staff to overseas universities or institutions for degrees. The number of MS degree holders in RUA is expected to increase as RUA opened the master's course in 2002. Without improvement in the quality of education, the capacity building of lecturers will not be realized even if the number of MS degree holders will have increased.

2) **Strengthening of practical activities.** In reality, classes at RUA are mainly conducted as oral lessons, and few practical activities such as laboratory training and farm practice are carried out, even after the introduction of the new curricula. The balance between theory and practice should be considered in the curricula of RUA. Although fairly large portions of time are allocated to practical activities both in the former and the new curricula of RUA, few practices are implemented because of insufficient lecturer ability and a shortage of facilities and equipment. Practical activities in RUA curricula are set by repartitioning a subject into oral lessons and practical work with some set proportion of time allocated to each. In this system, it is easy to convert the time for practical work into oral lessons. This system may cause the insufficiency of practical work. The development of the capability to conduct practical activities, from the aspect of the human resources and the system, is one of the most urgent problems facing RUA.

3) **Development of quality textbooks**. The shortage of teaching materials, including textbooks, is one of the major issues concerning the education at RUA. The shortage of recent textbooks and reference materials hinder progress in the renewal or updating of course content. Development of textbooks and an enhancement of library services are needed to upgrade educational standards. However, the most important issue is the enthusiasm of lecturers to constantly improve the education in their classes. Lecturers need to be motivated to collect new information within their fields. The point of education at university level should not only be just the transfer of knowledge, but also the development of intellectual capability. Training programs for teaching techniques are also necessary as well as the willingness of lecturers to improve their teaching.

The ICCAE contributed in the human resource development of RUA by assisting an RUA staff to be a PhD student of the United Graduate School of Agricultural Sciences, Ehime University under the supervision of Professor S. Hayakawa at Kagawa University. Two RUA staffs are now studying as MS and PhD students, respectively, in Plant Genetics & Breeding Laboratory and Socioeconomic Science of Food Production Laboratory of the Graduate School of Bioagricultural Sciences (GSBS), Nagoya University. The Animal Genetics Laboratory of GSBS is going to conduct biodiversity study of wild animals with RUA in 2002 and 2003. GSBS and ICCAE will continue to support RUA in capacity building.

The ICCAE is exploring the enhancement of linkages with international institutions to promote international cooperation in the agricultural area. It has been proven to be very effective and efficient way in dealing with agriculture concerns in Asia and Africa. SEARCA and ICCAE are now exploring collaboration in the Asia and RUA projects.

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Summary, Highlights of Discussion and Closing Statement

Sustainable Agricultural System in Asia: Student Development Towards Global Standard

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Introduction

This paper presents highlights of the general discussion on Student Development Towards Global Standard, a subtopic under the theme of the Satellite Forum on *Sustainable Agricultural System in Asia* held on 21 June 2002 at Nagoya University, Japan. I wish to express my appreciation to Professor Tetsuko Watanabe and Professor Akira Yamauchi who served as assistant moderators in this session.

The satellite forum had two objectives: *first*, to discuss sustainable agricultural production systems and biotechnology in Asia, with special emphasis on research and resource development; and *second*, to document the contribution of Nagoya University in general, and the Graduate School of Bioagricultural Sciences in particular, in research and identification of sustainable agricultural production systems. We wanted to recognize and discuss the school's accomplishments in terms of international collaborative programs as it continues to find ways to establish an active international academic consortium.

The purpose of the general discussion was to learn and share various experiences and teachings on how to improve our education so that our graduates would play more important roles in the international community in the agricultural sciences or related fields. The general discussion was composed of three parts: *first*, a summary of the three sessions, including research achievements, their consequence in education in the field of sustainability in agricultural sciences, and the future direction of research and education in agriculture; *second*, an overview of the goals of the university in research and education for agricultural sustainability in view of the establishment of an academic consortium; and *third*, suggestions and recommendations for strengthening the human resources development programs in education and research in Japanese universities in general, and at the Nagoya University Graduate School of Bioagricultural Sciences, in particular.

Highlights of Discussion

As a backdrop of this discussion, I must state that our national university currently faces a drastic change to a parastatal institution. The Japan International Research Center for Agricultural Sciences (JIRCAS) is now under this category of institution. In view of this recent development, the Japanese universities face the challenge of how to further enhance their research and education programs in order to be globally competitive.

1) Achievements, consequences and future directions in research and education in sustainable agriculture

Professor Yamauchi presented a summary of the five paper presentations as follows:

In the cultivation of rainfed lowland rice, Dr. Shu Fukai stressed the importance of thoroughly characterizing the environment where crops are grown. He cited that among the several traits considered important for crop production is drought resistance. Research agenda has been totally different during the time of the Green Revolution when basic studies in laboratories can be directly applied to the field. But after that, there is a need for a paradigm shift. There is an urgent need to consider sustainability now that high-output studies have been conducted. Thus, in order to study sustainability, the accomplishments of different fields of science must be integrated toward the creation of a new science.

Dr. Jose R. Pardales Jr. highlighted the unlimited potential of root crops, a very neglected less economically important crop. He emphasized the prospects of root crops for use as food and industrial material. He mentioned that research on these crops must consider the social science aspects, including technology transfer from the researcher to the end user. He stressed that extension workers, researchers, and students, are important components of the research that must be working together to help provide solutions to food security problems.

Dr. Sri Nugroho Marsoem emphasized the importance of forest management and the value of wood and non-wood forest products. Exploring the full potential of these forest resources for food and income while aiming for forest sustainability is a big challenge. One area that needs to be further enhanced is the linkage of agricultural production and forestry management. Efforts to introduce agro-forestry as an alternative to sustainable forest development have increased, although many institutions still put little attention to this field. Marsoem stressed that networking of educational institutions in Asia for stronger cooperation is surely a welcome initiative.

Dr. Inkee Paik gave a very good example of the application of basic science to practice. Plant scientists consider nitrogen phosphorous as a nutrient; however, in this case as presented by Dr. Paik, nitrogen phosphrous can be a pollutant. By controlling diets, nitrogen phosphorous can control or prevent a serious problem on pollution caused by animal and livestock production in relation to environmental issues.

Dr. Osamu Ito talked about farming system and management of technology under diverse agro-ecosystems. In his paper, he clearly showed that, in order to attain sustainability, there must be a science that covers the various disciplines of soil science, crop science, forestry, aquatic science, and animal science.

Based on the five paper presentations, Dr. Yamauchi concluded that there seemed to be an agreement on the importance of an interdisciplinary research in looking at the concerns for sustainable agriculture. And this would require not just the convening of soil scientists, crop scientists, breeders, and others to form a team of researchers but the creation of a new field of science that integrates all those fields of discipline. It is recognized that this is a difficult task because of the diverse academic backgrounds and experiences of the players involved; however, there is a need to start from the level of education, which requires the development of an integrated curriculum aimed at developing the mental faculty and skills of the student towards providing solutions to problems and concerns for sustainable agriculture in a more holistic point of view.

2) Goals of the university in research and education

Dr. Takabe summarized the next batch of paper presentations as follows:

Dr. Steven C. Huber shared his experience in producing a transgenic plant with an increased level of cartinine. Such an interesting work, he mentioned, shows that the university can truly function as an “architect of the new century” by assembling teams and providing the seed money to initiate programs and conduct fundamental research for applied problems that impact agriculture. So far, whether for the environment or to increase plant productivity, the focus of biotechnology is just on the gene level. Using the up-regulated gene, salt tolerant or more salt tolerant transgenic plants that make plant productivity a little bit higher than that of non-transgenic plant. Dr. Huber said that these achievements are partially successful, and pointed out that there must be more studies on protein levels and enzyme interferal localization in the enzyme degradation. He stressed that to fully understand the regulation of carbon metabolism, it is important to carry out efficient biotechnology.

Dr. Tatsuo Omata talked about the control of nitrogen uptake in a simulation and plant productivity. He mentioned problems caused by nitrates in the environment and in the plant body, which are becoming serious problems, even in Japan. Nitrates are used for agriculture, but extra nitrates are getting into drinking water and into the body. Nitrates converted to toxic nitrates are not good for health. Dr. Omata stressed the importance of finding ways on how to regulate the nitrate uptake system. He suggested two ways: one is to regulate the nitrate transporter gene, and the other is to just accumulate nitrates only in the root, not in the leaf, as in the case of the spinach. He said that spinach accumulates a lot of nitrates; therefore, eating spinach leaves in a salad might be dangerous. He emphasized the importance of basic research in order to successfully carry out genetic engineering.

In the field of food production and biotechnology for food production, Dr. Tsuneo Yamane presented interesting findings of the research on enzyme engineering of lipids. One of these findings is the effectiveness of phosphatidylserine, or PS for AAMI or age-associated memory impairment, which is wonderful news for middle and old-aged persons in the future.

Dr. Jeng-de Su discussed the protective role of antioxidant compounds in oxidative stress, which occurs in the human body. He expressed that there maybe a lot of new dietary antioxidants that can be found in the future and if the pathway to produce such antioxidants is clarified, this can be applied to biotechnology.

In Thailand, the general public has a positive attitude toward GMO (genetically modified organisms) based on the report of Dr. Tipvadee Attathom. Most of the Thais accept GMO since it is permitted. However, he saw the need to compare the toxicity of chemical pesticides to GMO and transgenic plants. This is also an issue in Japan where the people fear the effects of GMO on humans. This attitude might be partly due to the inability of the scientists to disseminate the right information about GMOs. Biotechnology is viewed as a very important and powerful tool for sustainable agricultural systems in Asia. Dr. Tipvadee expressed that there is a need to collaborate in this aspect.

3) Suggestions and recommendations for strengthening human resource development programs for sustainable agriculture

The papers in Session 3 mostly dealt with sharing of experiences of different institutions and presented suggestions and recommendations toward the strengthening of human resource development programs in education and research for sustainable agriculture.

Dr. Norihiro Tsukagoshi gave a perspective of the international collaloration for education and research at Nagoya University especially focused on the achievements of the Graduate School of Bioagricultural Sciences. He pointed out that one way to improve the educational learning experience is to create the conditions and provide opportunities for such experience in order to attract bright and competent students from both the developing and developed countries to come to Nagoya University to study. He noted the imbalance in the number of students from developing and developed countries and suggested an improvement of working conditions of staff who provide assistance in academic and foreign relations services in order to expedite and accommodate requests and monitoring of student programs.

Dr. Supat Attathom pointed out the university's role in developing technology in the advent of globalization, which is providing newer conditions such as global standard, new rules on safety, ethics and the like. She discussed the relation between the development of technology and the development of science and stressed the importance of striking a good balance between the two. How to connect research and education in with the actual needs in developing countries poses a big challenge that need to be addressed.

Dr. Villareal. talked about the role of SEAMEO SEARCA in human development in Southeast Asia. As he mentioned, SEARCA's experiences have proven that investment in human resource development is vital to the well-being of the agricultural sector. He pointed out the need for investment, not only in degree and training programs, but also in research and development, infrastructure, and information sharing.

Mr. Mosgoya shared the experiences and prospects of AICAD, whose mission is to foster south-south collaboration as supported by developed countries, such as Japan. He pointed out that south-south cooperation, as well as north-south cooperation, could provide an important role for human development, especially in low technology and in the building and spreading of a self-support sphere. He stressed the importance of establishing an effective farmer-researcher- extension linkage.

Mr. Sugino introduced new aspects of the new JIRCAS structure and activities, especially concerning human resource development cooperation with other organizations, including universities. Such information should provide directions on how national universities should revise or modify their activities, including cooperation with other institutions.

The culture of evaluation as exemplified in the evaluation system of ODA, according to Dr. Koichi Miyoshi, was introduced to Japan by other developed countries, such as the United States. He pointed out that external evaluation has an important function, such as providing management tools for creating and learning for all interested organizations. He also indicated that universities are expected to participate in these kinds of evaluation activities, and showed the achievements of evaluation activities in international work.

Dr. Tetsuo Matsumoto introduced the mission, functions and activities of ICCAE at Nagoya University, which is one of the core centers serving in the field of agricultural sciences, engineering, research and education. He emphasized the important role that ICCAE has to play in research and education and encouraged the graduate schools and other interested institutions whose mandates are similar to those of ICCAE to collaborate with the Center for their activities. ICCAE continues to explore possible linkages with international institutions to promote international cooperation in agriculture. It pursues the strengthening of existing collaborations to efficiently and effectively carry out activities in Asian and African regions. The case study of ICCAE's ODA in Cambodia is an example of collaboration between ICCAE and JICA. SEARCA and ICCAE are now looking for collaboration in its project to assist the Royal University of Agriculture in Cambodia.

General Recommendations

After lengthy discussions and exchange of ideas during the open forum, the following were the general recommendations set forth by the participants in the forum:

1. It would be best for JICA to consider reclassifying or reengineering the evaluation and approval process in awarding grants for a project at the institution level and select only those that are ready to go into research to shorten the process and eliminate too much competition, sometimes for just a single grant. In this case, alumni groups or institutions that may be interested in conducting the research may have better chances of winning the grant.

2. Results of discussion in this forum should be considered when evaluating the present curriculum in the context of Asia.

3. Higher education institutions should take the following roles in the promotion of sustainable agriculture:

   a. Continuously generate knowledge;

   b. Develop and produce high-quality manpower at the undergraduate and graduate level, or in non-degree training programs equipped with the proper skills to undertake researches and projects that promote sustainable agriculture;

   c. Continuously perform advocacy work on environment and natural resource conservation, seeing to it that the core philosophy is sustainable agriculture.

4. Higher education institutions should be able to assist weaker universities to gain the concept of sustainable agriculture and biological equilibrium through discourse of agriculture and related sciences in conferences, symposia, training programs and curriculum development projects.

5. The following strategies are recommended for adoption in strengthening agricultural R & D in Asia:

   a. Forging of strategic alliances with partners for complementation of programs and activities;

   b. Implementation of a sandwich program- a very important innovation in education;

   c. Implementation of joint projects in as many areas as possible.

6. Institutions must remember three very important elements of collaboration:

   a. Common interest to enrich the knowledge of staff;

   b. Willingness to share resources;

   c. A mechanism to stipulate such a relationship so that activities will succeed.

7. Since the environment that surrounds the university is becoming more complex, the following factors need to be considered:

   a. The discipline issue, whether it is interdisciplinary issues, and academic versus practical issues;

   b. The various roles of the public and the private sector, the non-state sector; the universities, research organizations, aid agencies, and other stakeholders.

   c. The issue of globalization versus localization;

   d. A concrete framework and system to set the direction of the University, which may consist of three things, namely: a network, a knowledge creation system, and a knowledge accumulation system.

   e. Utilization of various resources in the creation of a new field of science

   f. Management framework to consider any change in rules

8. Universities must provide activities that would

allow exposure of students to other countries and gain experience on how things are done in other countries. The example of Japanese students going to Thailand, and vice-versa for immersion in the farm or to do extension work in a community, and at the same time learn the culture of the people in the host country is good model. The spirit of collaboration can also be found in this model because of the sharing of resources as demonstrated by both host universities taking care of the living expenses of the students whenever it is their turn to host the foreign students.

9. In organizing conferences on topics pertaining to agriculture in Asia, organizers should see to it that a balance of views would be obtained by ensuring that participants come from different disciplines so there would be a better understanding of what Asia needs for the development of agriculture within the region.

10. It would be beneficial to developing countries if JICA, JIRCAS and other funding agencies in Japan could consider supporting researches and re-entry programs/projects of fellows who graduate from Japanese universities to be conducted when they go back to their respective countries. These researchers or re-entry programs should address problems confronting the home countries of the fellows. The reason why most developing countries suffer from brain drain of technical people is oftentimes because of the absence of opportunity for fellows to establish follow-up researches in their own countries because of financial constraints. As a result, most of them go to developed countries in order to pursue their research interests. Since Japan is a very powerful country in Asia, Japanese funding agencies may wish to consider supporting foreign student alumni of Japanese universities to establish research in respective countries.

11. To prepare the students to face the challenges of globalization, universities must come up with a program that would hone the skills of the Japanese as well as other Asian students, especially the research students, to learn to speak and write their research reports and thesis in English. It is advisable to do comprehensive literature search on related topics during the initial three months of the student's stay in a foreign university, thus exposing oneself to new findings while gradually learning to write his or her thoughts and ideas in English.

12. The establishment of academic and alumni societies in each country such as the one in Thailand would be a good strategy for both development and linkages.

13. The small farmers who comprise about 60% of total farm families in the world have been left out from the mainstream of the agricultural development process. Because these small farmers always practice the traditional farming, they are usually not interested to adopt the modern technology in farming because of lack of information on the benefits of modern technology, or they may lack the capital to apply new technologies in the farm. It is therefore recommended that information on new technologies be extended to the field level to educate the small farmers, and some development programs be made available for the benefit of these small farmers

14. There is an urgent need for a new integrated field of science that would provide the students and faculty the knowledge and skills for integrated agricultural development that can functionally link agriculture crop production and livestock industry, forestry, and other sciences. This new field of science should allow an interdisciplinary team to teach and do research on sustainable agricultural system grounded on the principles of sustainable agriculture development, as well as expose the students to practical experiences in sustainable agriculture in Asia.

15. Universities should encourage an academic exchange program that would allow students to do relevant research in their own countries on problems specific to their respective countries and their advisers to see how they are going about in their researches. The student exchange program implemented by University of Queensland in Australia, and the one by Kasetsart University, Thailand with Ethiopia are good examples. The faculty adviser also needs to see and monitor the research of the student, although local faculty supervisors are assigned.

16. It would be advantageous to the students

and university faculty if JIRCAS would disseminate information on the guidelines, procedures and requirements to enable the students to avail of opportunities to do visit or do research with the JIRCAS foreign scientists in the specific research sites of JIRCAS projects. In this way, students get exposed to problems associated with the different agricultural systems in different countries which could serve as very good inputs to the improvement of their own researches when they go back to their respective universities.

17. Since universities are one of the eligible institutions to participate in contract-based projects with JICA, Japanese universities are encouraged to avail of this opportunity by submitting proposals to JICA.

18. Universities can certainly play a role in providing the venue for scientists from different disciplines to work closely together, and for the training of students who have an appreciation for very fundamental and applied aspects of science.

Closing Statement

In his closing remarks, Dr. Shohei Yamaki stressed that the main questions and important points in relation to sustainability in agricultural science, the role of universities, and the future direction of education and research programs presented by the different resource persons and participants in the forum are valuable contributions that should be documented. The proceedings of the forum should be able to reflect all the points raised, the highlights of discussions, and recommendations made. This publication should be able to provide initially the direction towards organizing an academic consortium in the field of agricultural science. Dr. Yamaki expressed confidence that the universities, together with the students and faculty, will certainly play an important role in the international communities of agricultural science in the near future.

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