Proceedings of the JSPS International Seminar 2008

"Hybrid Rice and Transformation of Farming Systems"

22-24 November 2008

Kyushu University, Fukuoka, JAPAN

http://bbs1.agr.kyushu-u.ac.jp/tropic/Asia-Africa/index.html

Welcome Address

Prof. Dr. Atsushi Yoshimura
Dean of Faculty of Agriculture, Kyushu University

It is a great honor for me to extend, on behalf of all staffs and students of Faculty of Agriculture, Kyushu University, I would like to warmly welcome and thank you all for joining "Hybrid rice and Transformation of Farming Systems" an international seminar funded by Japan Society for Promotion of Science (JSPS), Asia-Africa Science Platform Program "Science of hybrid rice: breeding, cropping patterns and the environment".

This program is recognized as one of the international cooperation project which has been promoted in our University. Two and a half years have already passed from the starting of this program and we obtained useful results from the cooperative research.

Vietnam has developed the own hybrid rice seed production system using thermo-sensitive genetic male sterility (TGMS). This breeding system includes a seed multiplication of TGMS lines in mountain regions and the hybridization in Red River Delta, and facilitates new hybrid varieties of rice for local needs. The hybrid vigor can promote the productivity and their shorter growing period leads to open a new cropping system. We have developed a new hybrid variety (Viet Lai 20) in cooperation with Japanese specialists under JICA project in Hanoi Agricultural University. However, the hybrid rice production system affects the ecosystem because of the intensive cultivation and change of cropping pattern. In addition, the socio-economic changes in rural area may occur because of the high input and more benefit in farmers.

The overall goal of the project is to make a reasonable development of hybrid rice cultivation. The present program aims to establish a scientific background of hybrid rice production system, including studies on the genetics, breeding, cultivation, and the aspects of ecosystems and socio-economic impacts. The present program will contribute a practical technology and the development of rice production, as well as the sustainable development of agriculture.

I hope the seminar will be a good opportunity for researchers to exchange the opinions and promote further cooperation in agricultural development in Asia. Thank you very much.

INTERNATIONAL SEMINAR 2008
"Hybrid Rice and Transformation of Farming Systems"

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Program Schedule

November 22(Saturday) 17:00-19:00

Welcome Reception

Welcome Reception	**17:00-19:00**	*Kyushu University's Alumni Association "Faculty of Agriculture" Hall)*

November 23(Sunday) 9:50-13:30

Opening Ceremony and General Topics

Opening Ceremony		
	9:50-10:00	**Opening Speeches** Atsushi Yoshimura (Dean, Fac. Agriculture, Kyushu Univ.)
General Topics **Chair: Dr. Ogata**		
G-1	**10:00-10:35**	**Historical Review of Rice Breeding and the Future Prospects** Gurdev Singh Khush (Prof., Univ. California Davis)
G-2	**10:35-11:10**	**Economic Impact of Hybrid Rice in Vietnam: An Initial Assessment** Tran Duc Vien(Rector, Hanoi Univ. Agriculture)
	11:10-11:20	**Coffee Break**
G-3	**11:20-11:55**	**Currents Status F_1 of Hybrid Rice Seed Production in Vietnam** Nguyen Van Hoan (Assoc. Prof. Hanoi Univ. Agriculture)
G-4	**11:55-12:30**	**What's Wrong with Using Rice for Ethanol? The Power of Hybrid Rice.** Shoichi Ito（Prof., Fac. Agriculture, Kyushu Univ.）
	12:30-13:30	**Lunch**

November 23(Sunday) 13:30-16:30

Special Topics

Session 1: Breeding and Pest Management in Rice

Chair. Dr. Hoan and Dr. Yasui		
S1-1	**13:30-14:10**	**Genomics-Based Germplasm Enhancement and A New Paradigm in Rice Breeding** Masahiro Yano
S1-2	**14:10-14:30**	**Vietlai 50 - A New Super Hybrid Rice Variety Bred in Vietnam** Nguyen Van Hoan
S1-3	**14:30-14:50**	**Screening of Some Promising Rice Varieties (*Oryza sativa* L.) in ThaiNguyen Province, Vietnam.** Tran Ngoc Ngoan
S1-4	**15:10-15:30**	**Rice Planthoppers in Vietnam and Their Migration** Akira Otuka
S1-5	**15:30-15:50**	**Current Status of Insecticide Resistance and Virulence to Resistant Rice Varieties in Asian Rice Planthoppers** Masaya Matsumura
S1-6	**15:50-16:10**	**Management of Rice Planthoppers in Vietnam** Dinh van Thanh
S1-7	**16:10-16:30**	**Forward the Design Breeding of Resistance to Planthoppers in Rice** Hideshi Yasui

Session 2: Crop Science and Horticulture

Chair: Dr. Okubo		
S2-1	**13:30-14:00**	**Horticultural Development in Northern Upland Region of Vietnam** Ngo Xuan Binh
S2-2	**14:00-14:30**	**Hybrid Rice: Current Status in Thailand and Its Prospect on Transformation of Farming Systems** Lop Phavaphutanon
S2-3	**14:30-15:00**	**Development and Characterization of Bunching Onion (*Allium fistulosum*) Chromosome Addition Lines of Shallot (*A. cepa* Aggregatum group)** Masayoshi Shigyo
S2-4	**15:15-15:45**	**Affection of Magnesium and Mix of Silica & Humic on Photosynthetic and Agronomic Characters in F1 Hybrid Rice under Low N Fertilizer Condition** Pham Van Cuong
S2-5	**15:45-16:15**	**Hybrid Rice Cultivation Situation in the Northern Midland Region of Vietnam** Dang Quy Nhan

Session 3: Plant Protection and Environment

Chair: Dr. Kurosawa		
S3-1	**13:30-14:00**	**Temporal Changes of Inorganic-N Concentrations of Surface and Groundwater during a Rice Planting Period in Farming Villages of Northern Vietnam** Do Nguyen Hai
S3-2	**14:00-14:30**	**Rice Cultivation on Acid Sulphate Soils in the Plain of Reeds, Vietnam as Affected by Water Environment and Cropping Season.** Phan Thi Cong
S3-3	**14:30-15:00**	**Numerical Modeling of Nitrogen and Phosphorus Runoff in a Flat Low-lying Paddy Cultivated Area** Le Van Chinh
S3-4	**15:15-15:45**	**Heavy Metal Contamination of Soil in Wastewater-Irrigated Paddy Field in a Suburban Area of Hanoi, Vietnam** Nguyen Thi Lan Huong
S3-5	**15:45-16:15**	**Outbreaks of Insect Pests in the Tropics: A Case Study of the Coconut Beetle** Shun-Ichiro Takano

Session 4: Socio-Economic Issues

Chair: Dr. Yabe		
S4-1	**13:30-14:00**	**Hybrid Rice Production in Red River Delta, Vietnam** Nguyen Huu Ngoan
S4-2	**14:00-14:30**	**Efficiency of Rice Production in Selected Areas, the Mekong River Delta, Vietnam** Mai Van Nam
S4-3	**14:30-15:00**	**Structural Changes in Economic Efficiency of Rice Farming and Farm Household Economy: A Case of Lac Dao Commune, Van Lam, Hung Yen Province, The Northern Vietnam** Kazunari Tsuji
S4-4	**15:15-15:45**	**Development of Vegetable Marketing Channels in Vietnam- A Brief Consideration** Izumi Iwamoto
S4-5	**15:45-16:15**	**A Study on Farming System in Southeast Asia: Slash-and-burn Agriculture in the Mountainous Area of the Northern Lao PDR** Kazuhiko Hotta

November 24(Monday) 10:00-13:30

P & P Session

"Hybrid Rice in the Integrated Farming System"

Chair: Dr. Trun Duc Vien		
Opening address	**10:00-10:05**	Tran Duc Vien and Shinji Fukuda
P&P-1	**10:05-10:35**	**Current Situation of Integrated Farming Systems in Red River Delta, Vietnam** Vu Van Liet
P&P-2	**10:35-10:55**	**Population Structure of Rice Sheath Blight Pathogen, *Rhizoctonia solani* AG1-IA by rep-PCR and ITS Sequence in Red River Delta, Vietnam** Masaru Matsumoto
P&P-3	**10:55-11:15**	**Effects of Rice Cultivation on Water Quality and Diatom Species Composition in a Paddy Field at Hanoi University of Agriculture** Yohei Shimasaki
P&P-4	**11:30-11:50**	**Effect of Low Input of Chemical Fertilizer on Growth and Grain Yield in F_1 Hybrid and Inbred Rice (*Oryza Sativa* L.)** Takuya Araki
P&P-5	**11:50-12:10**	**Seasonal Change of Soil Nitrogen Components in Paddy Fields, Vietnam.** Yuki Mori
P&P-6	**12:10-12:30**	**Numerical Modelling on Nitrogen Balance in Integrated Farming Systems in Red River Delta, Vietnam—A Preliminary Model—** Shinji Fukuda
	12:30-13:30	**Lunch**

November 24(Monday) 13:30-14:45

General Discussion and Closing Remarks

General Discussion	**13:30-14:30**	*Main Conference Room*
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Farewell Party	**17:30-20:00**	*Restaurant "Faculty Club"*

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Session 1: Breeding and Pest Management in Rice

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General Topics

Historical Review of Rice Breeding and the Future Prospects

Gurdev S. Khush

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Abstract
Rice--humankind's most important food crop has been improved since its domestication about 8000 years ago. Constant human selection for improved traits has modified domesticated rice varieties from their wild progenitors so much, so that domesticated rices can no longer survive in the wild state. Thus primitive humans started the first rice breeding programs when they started to grow rice plants for their use. Scientific rice breeding which started in the early part of last century after the rediscovery of Mendel" laws of inheritance, can be divided into three phases: Selection phase (1901-1949) hybridization phase (1950-1960); green revolution phase (1960-2000). During the selection phase, rice breeding stations were established in most of rice growing countries of Asia. The breeding work was limited to purification of land races. Hybridization phase was initiated under the auspicious of FAO at CRRI, Cuttack, India. It was the first effort in international cooperation in rice breeding. The green revolution phase started with the establishment of IRRI in 1960. Improved varieties with high yield potential, shorter growth duration, resistance to biotic and abiotic stresses and superior grain quality developed by IRRI and Asian countries have had a major impact on rice production. Average yield of rice doubled from 2.0 to 4.0 tons per hectare between 1966 and 2000. World rice production increased from 257 to 600 million tons between 1966 and 2000. Most of the major rice producing countries became self-sufficient. However, population of rice consumers is continuing to increase and growth in rice production has slowed down. To reverse this trend we need rice varieties with higher yield potential and greater yield stability. Strategies for increasing the yield potential include; conventional hybridization and selection procedures, Ideotype breeding, hybrid breeding, wide hybridization and Genetic Engineering. Conventional and biotechnological approaches are being employed to develop varieties with durable resistance to diseases and insects and tolerance to abiotic stresses.
Key Words: selection, hybridization, green revolution, ideotype breeding, genetic engineering

Rice, mankind's most important food crop has been improved since its domestication about 8000 years ago. Constant human selection for improved traits has modified domesticated rice varieties from their wild progenitors so much so that domesticated rices can no longer survive in the wild state. The simple acts of reaping and sowing, for example, are selective. Primitive humans may not have known it, but they started the first rice breeding programs when they began to grow rice plants for their own use. Most farmers have a keen eye and sensitive feeling for plants. Millions of rice farmers have applied this keen insight and sensitivity for thousand of years to select better varieties.

Selection was first practiced on the variable and heterogeneous wild and semi-wild populations, which must have narrowed genetic variability. However, several mechanisms in primitive agriculture, such as the introduction of varieties from one region to another and occasional natural crosses between local and introduced varieties enhanced variability for further selection. Natural crosses between the domesticated crop and the weed complexes were another source of variability. The third source of variability was the varietal mixtures that primitive agriculturists grew as a protection against disease epidemics. Occasional intercrosses between component varieties gave still more variability. This conscious and unconscious selection by humans led to the development of over 150,000 land race varieties which were grown around the world till the dawn of scientific plant breeding after the rediscovery of Mendel's laws of inheritance (Khush 1987).

Scientific rice breeding can be divided into three phases; (1) selection phase, (2) hybridization phase, and (3) green revolution phase.

Selection phase (1901-1949)

The selection phase of rice breeding started in early part of last century when rice breeding stations were established in most of the rice growing countries in Asia (Table 1). Subsequently the number of rice breeding stations increased greatly in order to develop rice varieties for ecoregional adaptation. Early selection work was limited to purification of land races by removal of off-types in the varieties popular with farmers. The next step was purification of land races through single plant or mass selection to develop pure line varieties. Thus a large number of pure line varieties such as Ptb varieties at Rice Research Station Pattambi (now in Kerala), Co varieties at Paddy Breeding Station Coimbatore, and Adt varieties at Paddy Breeding Station at Adutturai, both in Tamil Nadu, were developed.

Table 1. First rice breeding stations established in different Asian countries.

Country	Place	Year of establishment
India*	Dacca	1911
Japan	Nishigahara	1903
Pakistan	Kalashahkaku	1926
Burma	Mandalay	1907
Sri Lanka	Batalagoda	?
Malaysia	Krian	1915
Indonesia	Bogor	1905
Philippines	Maligaya	1902
Thailand	Rangsit	1916
Cambodia	Battambang	1928
Vietnam	Phu My	1920
Laos	Salakom	1956

*United India

A limited amount of hybridization was carried out during this period. As an example variety Co 25 was developed during late 1920s from a cross between blast resistant variety Co 4 and a popular variety Korangu Samba (Parthasarathy 1972). Similarly, several varieties with regional adaptation in Indonesia were selected from a cross of Tjina and Latisail made in 1929 at Bogor (Van Der Meulen 1951). However most of the varieties developed before the second world war were pure line selections. Breeders concentrated on selecting long duration varieties for the monsoon season which occupied the largest land area. Their perception was that longer duration varieties were better yielders. Since no fertilizer was used, varieties with nitrogen responsiveness could not be developed. Breeder's effectiveness was limited by the variable conditions under which rice is grown, limited germplasm variability, inadequate research facilities, lack of trained personnel, and failure to recognize the importance of interdisciplinary approach to crop improvement. A review of trends in the area, production and yield of rice from 1934 to 1960 shows that moderate increase in production in major rice producing countries of Asia was primarily due to increase in area planted to rice but the change in yields was negligible (Table 2).

Table 2. Annual growth in population, rice production, area, and yield in different countries of Asia, 1934-38 to 1956-60.

Country	Annual growth rate			
	Population	Rice production	Rice area	Rice yield
Japan	1.3	1.1	0.1	1.0
South Korea	1.8	0.5	-0.5	1.0
Taiwan	2.8	1.6	0.8	0.8
Burma	1.1	-0.6	-0.9	0.3
Cambodia	2.1	2.7	2.3	0.4
Sri Lanka	2.4	3.2	1.1	2.1
India	1.7	1.0	1.2	-0.2
Laos	2.5	2.5	1.8	0.7
Malaysia	2.3	2.0	0.9	1.1
Pakistan	1.2	0.8	1.0	-0.2
Philippines	2.1	2.1	2.0	0.1
Thailand	1.9	2.0	1.8	0.2

From Parthasarathy (1972)

Hybridization phase (1950-1960)

Immediately after World War II, the shortage of food supplies and the eminent threat of population increase directed world attention towards finding ways to increase the production of most important staple food of Asia. The establishment of the International Rice commission (IRC) in 1949 within the framework of FAO was the first effort in international cooperation in rice breeding (Parthasarathy 1972). The first meeting of the Working Party of IRC held at Rangoon in 1950 emphasized that the primary aim of rice improvement was increased yield. It was recognized that low yield was due to limitation of the varieties under cultivation, susceptibility to diseases and insects, long growth duration and lodging, and narrow adaptation. These observations pointed out the need for breeding for early maturity and lodging resistance.

The nucleus of international cooperation started with the cataloging of major rice varieties of the world, the establishment of centers for maintaining their seed stocks, and for exchange of seed. Two training courses on rice breeding were held at the Central Rice Research Institute (CRRI) at Cuttack, India. One or two trainees from most of the countries of tropical Asia participated in the courses held in 1952 and 1955. These courses focused on selection procedures, field plot techniques and principles of genetics and breeding. The IRC Working

Party on rice breeding held eight meetings from 1950-1959. There was consensus amongst participants that indica rices were not responsive to fertilizer. Thus indica-japonica hybridization program was initiated to transfer nitrogen responsiveness from japonica rices to indica rices. All the countries of tropical Asia participated in this program by sending seeds of their best varieties for crossing with japonica rices at CRRI. Japonica parents were early and flowered in 58-70 days at Cuttack, while indica varieties took 95-100 days.

F1 hybrids were grown at CRRI and F2 seeds were sent to collaborating countries for generation advancement and selection. This project had a very limited success because; (1) breeders knew little about the type of plants to select, (2) no country except India conducted experiments to determine response of final selections to different fertility levels as compared to indica parents, and (3) early yield evaluation was done on single plant basis where tall indica types crowded and outyielded shorter segregants. Only in India and Malaysia early maturing nonseasonal commercial varieties derived from this project were released for cultivation. In India ADT27 was recommended for early monsoon, short growing season (Kuruvai) in Tanjore Delta of Tamil Nadu. In Malaysia, Malinja and Mashuri were released for irrigated second crop season. Later on Mashuri spread widely in rainfed areas of Andhra Pradesh and Bihar states of India, Terai region of Nepal and became popular in Bangladesh and Myanmar during 1970s and 1980s.

Green revolution phase (1960-2000)

As mentioned in the previous sections little progress was made in increasing the yield potential of rice. 1960s was a decade of despair with regard to the world's ability to cope with the food-population balance, particularly in the tropics. The cultivated-land frontier was closing in most Asian countries, while population growth rates were accelerating owing to rapidly declining mortality rates resulting from advancements in modern medicine and health care. International organizations and concerned professionals were busy organizing seminars and conferences to raise awareness regarding ensuing food crisis and to mobilize global resources to tackle the problem on emergency basis. In a famous book entitled "Times of famine" published in 1967, Paddock brothers (Paddock and Paddock 1967) predicted, "Ten years from now, parts of the underdeveloped world will be suffering from famine. In 15 years, the famine will be catastrophic, and revolution and social turmoil and economic upheavals will sweep areas of Asia, Africa, and Latin America."

Thanks to the widespread adoption of "green revolution" technology, large scale famines and social and economic upheavals were averted. Between 1966 and 2000, the population of densely populated low income countries grew by 95% but rice production increased 135% from 257 million tons in 1966 to 600 million tons in 2000. In 2000 the average per capita food-grain availability was 20% higher than in 1966. The technological advance that led to the dramatic achievements in rice production over the 40 years was the development of high yielding varieties of rice with following traits (Khush 1999).

Yield potential

Increase in yield potential resulted from a reduction in plant height through incorporation of *sd1* gene for short stature. This led to improvements in harvest index (grain-straw ratio) as well as to increase in biomass production. Conventional varieties of rice are tall and leafy with weak stems and have a harvest index of 0.3, that is 30% grain and 70% straw. They can produce a total biomass of 10-12 tons. Thus their maximum yield potential is about 4 tons. When nitrogenous fertilizer is applied at rates exceeding 40 kg/ha, these varieties tiller profusely, grow excessively tall, lodge early, and yield less than under lower fertilizer inputs. The improved varieties on the other hand have a harvest index of 0.5. Because of short stature, they are lodging resistant and responsive to fertilizer inputs. Their biomass can be increased to 18-20 tons/ha. Thus their maximum yield potential is 9-10 tons/ha. This improvement in the harvest index was the single most important architectural change in the rice varieties (as well as wheat) that led to doubling of their yield potential (Khush 1995a).

Shorter growth duration

Most of the traditional varieties of rice grown in the tropics were photoperiod sensitive and took 150-200 days to mature. They were suitable for growing a single crop of rice during monsoon season in Asia. New varieties on the other hand, are photoperiod insensitive and can be planted at any time of the year. Moreover, their growth duration has been reduced to 110-115 days. The availability of short duration varieties has led to increased cropping intensity. Many farmers now grow two crops of rice where only one was grown before or even two crops of rice and another upland crop in between. IR36, the first high yielding short duration variety was accepted on a very wide scale and was grown to about 11 million hectares during 1980s. Most of the improved varieties now grown in Asia and elsewhere mature in 110-120 days.

Multiple disease and insect resistance

The varietal composition and cultural practices for rice have changed significantly during the green revolution era. Farmers have adopted improved cultural practices, such as application of more fertilizers and establishment of higher plant populations per unit area. Availability of short duration, photoperiod-insensitive varieties, coupled with the development of irrigation facilities, has enabled farmers in tropical Asia to grow successive crops of rice throughout the year. These conditions are conducive for the multiplication of disease and insect organisms. Several outbreaks of brown planthopper and viruses occurred during 1970s. Therefore major emphasis was put on incorporation of genes for disease and insect resistance into improved germplasm. In most of tropical and subtropical Asia, five diseases (blast, bacterial blight, sheath blight, tungro, and grassy stunt) and four insects (brown plant hopper, green leafhopper, stemborers, and gall midge) are of major importance. At IRRI major efforts were directed to develop germplasm with multiple resistances to diseases and insects. A large number of germplasm collections were screened and donors for resistance were identified (Khush 1977). Using these donors improved germplasm with resistance to four diseases and four insects was developed. First variety with multiple resistance, IR26 was released in 1973. Earlier IR varieties such as IR5, IR8, IR20, IR22, and IR24 were susceptible to most of the diseases and insects. All the IR varieties released subsequent to IR26 have multiple resistance. These varieties have as many as 20 parents in their ancestry which has helped restore genetic diversity on farmer’s fields. Large scale adoption of varieties with multiple resistance has prevented the occurrence of epidemics of diseases and insects

Grain quality

Grain quality of rice is evaluated relative to several consumer-oriented criteria (Khush 1995a). Most consumers in tropics and subtropics prefer long or medium long, slender, and translucent grains. Higher milling recovery is a universal requirement and is, to some extent, dependent on size, shape, and amount of chalkiness in grains. Cooking quality and palatability is another factor that is very important to consumers and is determined to some extent by the amylose content and gelatinization temperature of starch. In tropics and subtropics varieties with intermediate amylose and intermediate gelatinization temperature are preferred. Improvement of milling recovery and grain appearance received immediate attention. The early varieties, such as IR5 and IR8 have poor grain quality. They have bold and chalky grains of poor appearance that frequently break during milling. In addition they cook dry because of high amylose content and thus have poor consumer acceptance.

All the IR varieties released after IR5 and IR8 have slender and translucent grains and have good milling recovery. However, improvements in cooking quality were only achieved slowly primarily due to the fact that all the donors for disease and insect resistance used in the hybridization program had high amylose content and low gelatinization temperature. IR64 is the first IR variety, released in 1985, that has a desirable combination of intermediate amylose content and intermediate gelatinization temperature. It also has long slender and translucent grains with high milling recovery. In addition, cooked rice of IR64 is highly palatable. Not surprisingly, therefore, IR64 has been widely accepted as a high quality rice in tropical and subtropical Asia. It replaced IR36 during 1990s and has been planted to about 10 million hectares annually. Twenty-three years after its release it is still planted to large areas in India, Indonesia, Philippines, and Vietnam.

Tolerance to abiotic stresses

Large areas of land suitable for growing rice remain unplanted because of severe nutritional deficiencies and toxicities. A vast majority of rice soils have varying levels of alkalinity or salinity. Even well-managed rice lands suffer from mild nutritional deficiencies or toxicities. For example, zinc deficiency in rice soils is a common problem in many countries. Several improved varieties have moderate to high level of tolerance to several nutritional deficiencies and toxicities. IR36, for example, has a tolerance to salinity, alkalinity, peatiness, and iron and boron toxicities. It also tolerates zinc deficiency. Similarly IR42 has a broad spectrum of tolerance to many soil problems.

Use of IRRI's germplasm internationally

From the inception of IRRI's rice improvement program, the germplasm was shared with national rice improvement programs. Seeds of donor varieties, early generation breeding materials, fixed elite lines, and named varieties were sent to national program scientists at their request and through the International Network for Genetic Evaluation of Rice (INGER) nurseries. The seeds of breeding materials were sent to 87 countries irrespective of geographic location and ideology. IRRI even shouldered the cost of shipment. The materials were evaluated by local breeders for adaptation to their conditions. Some were released as varieties and others were used as parents in breeding program. Thus 328 IR breeding lines have been released as 643 varieties in 75 countries. Numerous IR varieties and breeding lines have been used as parents in breeding programs all over the world. During 1970s and up to 1980s many IR varieties and breeding lines were released directly by national breeding programs. However, as the national breeding programs became stronger, IR lines were used primarily as parents in local breeding programs. It is estimated that 60% of the world rice area is now planted to IRRI-bred varieties or their progenies.

Impact of the germplasm improvement program

The impact of germplasm improvement spearheaded by IRRI popularly described as green revolution has led not only to major increases in food production but also to improved socio-economic conditions and environmental sustainability.

Impact on food grain production

The gradual replacement of traditional varieties of rice by improved ones, together with associated improvement in farm management practices, has had a dramatic effect on the growth of rice production, particularly in Asia. Farmers harvest 5-7 tons of paddy rice per hectare from high yielding varieties as compared to 1-3 tons with traditional varieties. Since 1966, when the first high yielding variety of rice was released, the rice harvested area has increased only marginally, from 126 to 152 million hectares (18%), whereas the average yield has doubled from 2.0 to 4.0 tons per hectare. World rice production increased from 257 million tons in 1966 to 600 million tons in 2000 (133%). Area planted to rice, average yields, and total production in 12 Asian countries are shown in Figure 1. Every country has had a marginal increase in area but dramatic increases in average yields and total production (Khush and Virk 2005).

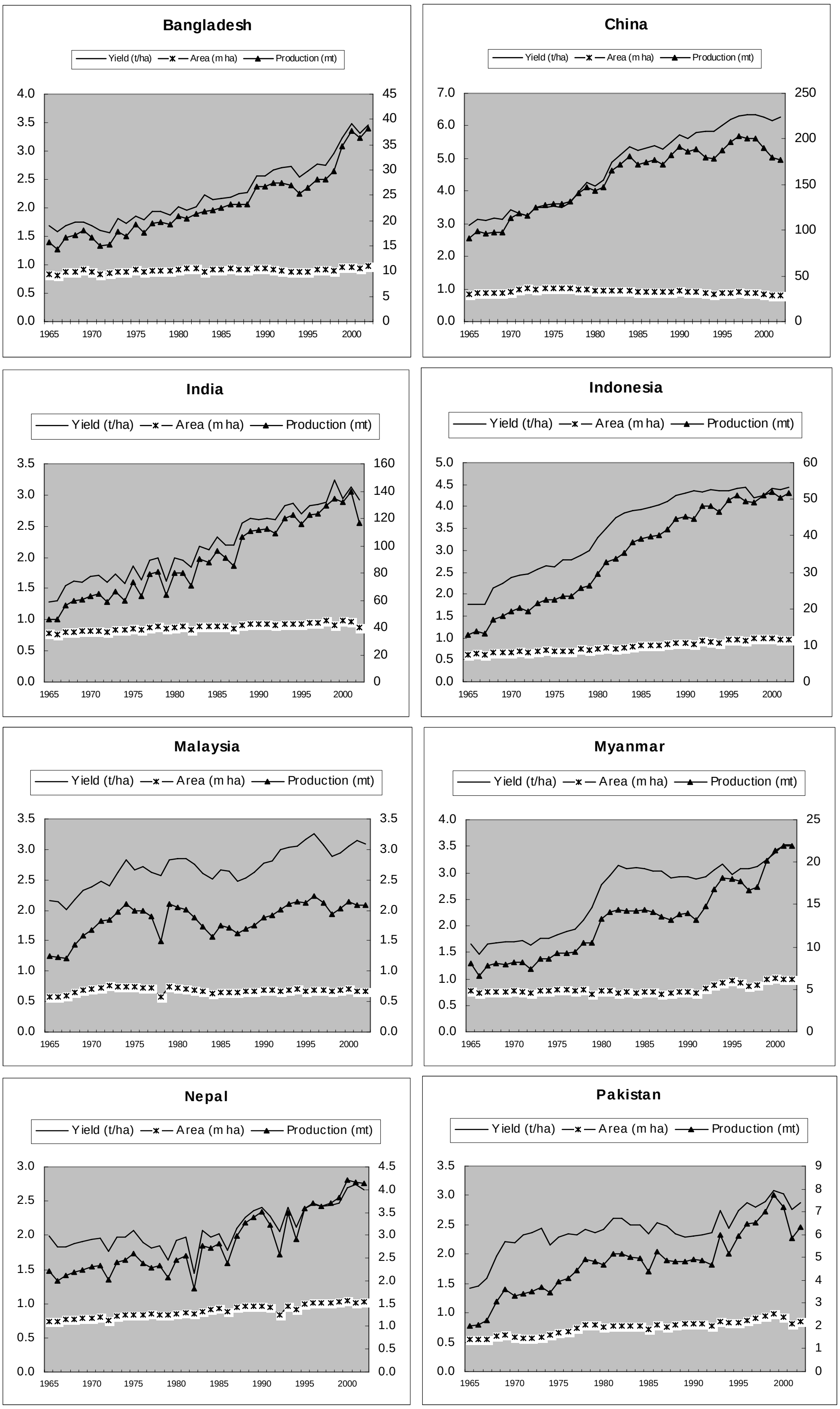

Fig. 1. Rice production (mt), Area (m ha) and Yield (t/ha) from 1965 to 2002 in major rice growing countries.

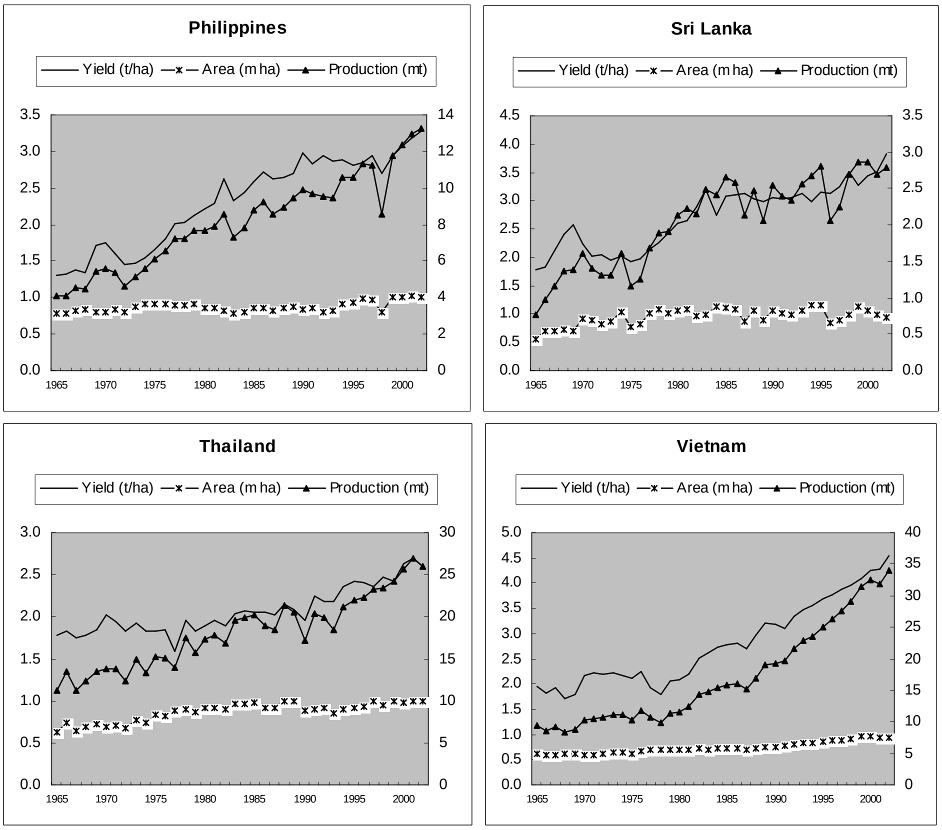

Fig. 1. Rice production (mt), Area (m ha) and Yield (t/ha) from 1965 to 2002 in major rice growing countries (continued).

Impact on food security

In many rice growing countries, the growth in rice production has outstripped the rise in population, leading to a substantial increase in cereal consumption and caloric intake per capita. During 1965-1990, the daily calorie supply in relation to the requirement improved from 81% to 120% in Indonesia, from 86% to 110% in China, from 82% to 99% in the Philippines, and from 89% to 94% in India (UNDP 1994). The increase in per capita availability of rice and decrease in the cost of production per ton of output contributed to a decline in the real price of rice, in both domestic and international markets. The unit cost of production is about 20-30% lower for high yielding varieties than for traditional varieties of rice (Yap 1991) and the price of rice adjusted for inflation is 40% lower than in mid 1960s (Figure 2). The decline in food prices has benefited the urban poor and rural landless, who are not directly involved in food production but who spend more than one half of their income on food grains. As net consumers of grain, small and marginal farmers, who are dominant rice producers in most Asian countries, have also benefited from the downward trend in real prices of rice.

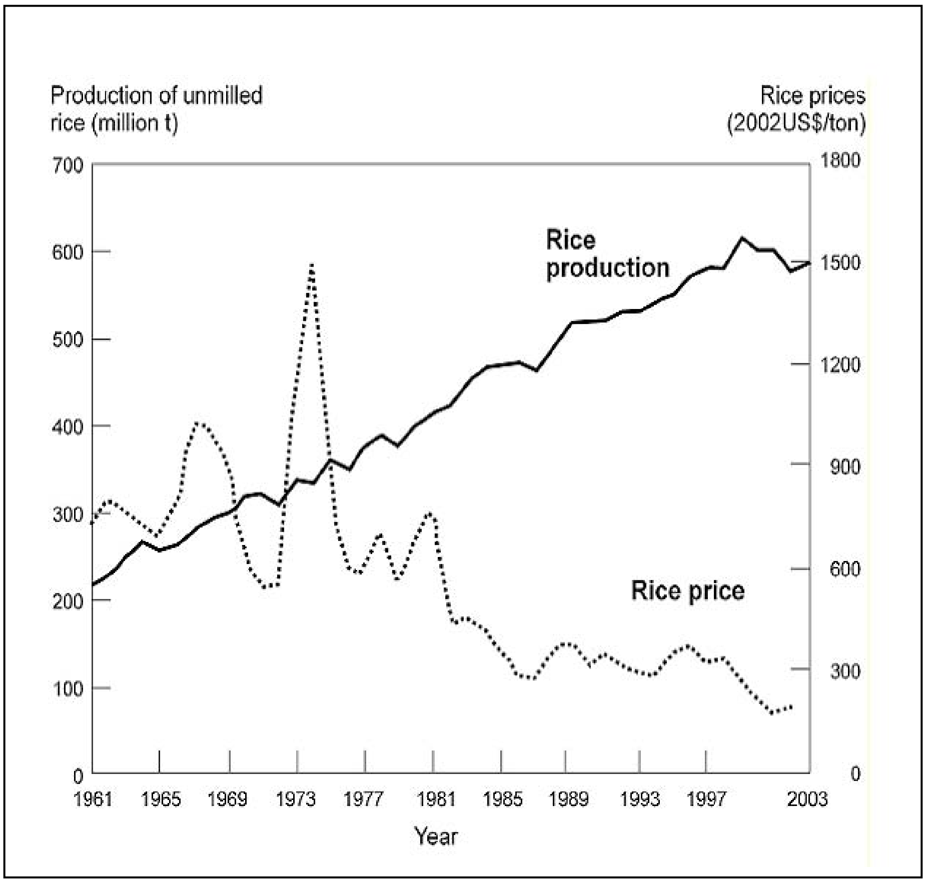

Fig. 2 Trends in world rice production and price (1961- 2003)

Impact on landless workers

The diffusion of high yielding varieties has also contributed to a growth in income for rural landless workers (Hyami et al. 1978, Hossain 1988). High-yielding varieties require more labor per unit of land because of increased intensive care in agricultural operations and harvesting of the larger output. The labor requirement has also increased because of the higher intensity of cropping, which has been made possible by the reduction in crop growth duration. As farm income increases, better-off farm households substitute leisure for family labor and hire more landless workers to do the work. The marketing of a larger volume of produce and an increased demand for non farm goods and services, resulting from higher farm income, have generated additional employment in rural trade, transport and construction activities. The economic miracle underway in Asia was triggered by the growth in agricultural income and its equitable distribution which helped expand the domestic market for non farm goods (Khush and Virk 2005).

Impact on environmental sustainability

In sharp contrast to rich countries where more of the environmental problems have been urban and industrial, the critical environmental problems in low-income developing countries are still rural, agricultural, and poverty based. More than half of the world's poor live on lands that are environmentally fragile and they rely on natural resources over which they have little control. Land-hungry farmers resort to cultivating unsuitable areas such as erosion-prone hillsides and semiarid areas where soil degradation is rapid, as in tropical forests, where crop yields on cleared soils drop sharply after just a few years.

The widespread adoption of high-yielding varieties has helped most Asian countries meet their growing food needs from productive lands, and thereby has reduced the pressure to open up more fragile lands for cultivation. If 1961 yields prevailed today, three times more land in China and two times more land in India would be needed to equal the 2000 rice harvest. If Asian countries attempted to produce a 2000 harvest at yield levels of 1960s, most of the forests, woodlands, pastures, and range lands would have disappeared and mountainsides would be eroded, with disastrous consequences for upper watershed and productive lowlands, the extinction of wildlife habitat, and the destruction of biodiversity. As an example, to produce the 2000 world rice production of 600 million tons at the yield levels of 1965, 135 million hectares more land would be required (Fig. 3).

The availability of rice varieties with multiple resistance to diseases and insects reduced the need for the application of insecticides and facilitated the adoption of integrated pest management (IPM) practices. Reduced insecticide use helps (1) enhance environmental quality, (2) improve human health in farming communities, (3) make safer food available, and (4) protect useful fauna and flora (Khush 1999).

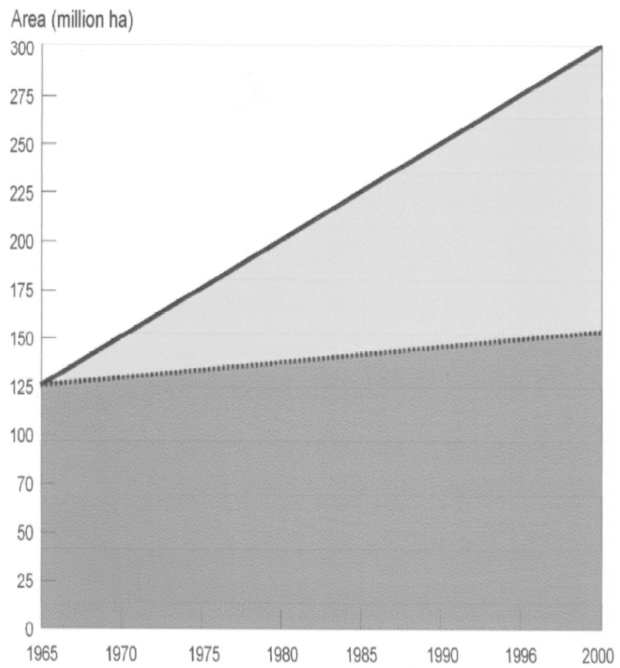

Fig. 3. Actual Area planted to rice and the additional area which would have been required to produce 2000 level of production at the yield level of 1965 .

Future challenges

In spite of major increases in food production, 800 million people in the world go to bed hungry every night and many suffer from micronutrient deficiencies. According to UN estimates, the world population will grow from 6.6 billion now to 8.5 billion in 2030. Most of this increase (93%) will take place in developing world whose share of population is projected to increase from 78% in 1995 to 83% in 2020. Since 97% of the rice is produced and consumed in developing countries, it is estimated rice production must increase by 30% to feed the rice consumers in 2030. This increased demand will have to be met from less land, with less water, less labor, and fewer chemicals. To meet this challenge we need rice varieties with higher yield potential, greater yield stability, and higher micronutrient cont

Increasing the yield potential

Various strategies for increasing the yield potential of rice are being employed. These include: (1) conventional hybridization and selection procedures, (2) ideotype breeding, (3) hybrid breeding, (4) wide hybridization, and (5) genetic engineering.

Conventional hybridization and selection procedures

Improvements in the yield potential of crops have been achieved through conventional hybridization and selection procedures. It is estimated that on the average about 1% increase has occurred per year in the yield potential of rice over a 35 year period since the development of first improved variety of rice IR8 (Peng et al. 2000). There is no reason to believe that such increase will not occur in the future if sufficient investment in research is made continuosly.

Ideotype breeding

Ideotype breeding aimed at modifying the plant architecture is a time tested strategy to achieve increases in yield potential. As discussed in an earlier section, breeding for short stature in rice resulted in doubling of yield potential. To increase the yield potential of rice further, a new plant type was conceptualized in 1990s. Modern short-statured rice varieties produce a large number of unproductive tillers and excessive leaf area which cause mutual shading and reduce canopy photosynthesis and sink size especially when they are grown under direct sowing conditions. To increase the yield potential of short-statured rice further, IRRI scientists proposed a new plant type (NPT) with the following characteristics (Khush 1995b).

- Low tillering
- No unproductive tillers
- 200-250 grains per panicle
- Dark green and erect leaves
- Vigorous and deep root system

Breeding efforts to develop NPT were initiated in early 1990s. The objective was to develop improved germplasm with about 15% higher yield potential than that of existing high yielding varieties. Genetic resources for developing NPT were identified and hybridization and selection undertaken. Numerous breeding lines with desired ideotype were developed and shared with national rice improvement (NARS) programs. Three NPT lines have been released in China, two in Indonesia, and one in Philippines. Other NARS are evaluating and further improving the NPT lines.

Hybrid breeding

Rice hybrids with a yield advantage of 10-15% are now widely grown in China. Rice hybrids adapted to tropics and subtropics have been developed at IRRI and by the NARS. Various strategies are being employed to raise the level of heterosis. Efforts are underway to identify heterotic groups within the indica germplasm. Most of the hybrids grown to date are based on cytoplasmic-genic male sterility system. Sterile cytoplasm imposes a yield penalty of up to 5% in hybrids. Therefore many hybrid rice breeding programs are developing hybrids based on alternative genetic male sterility systems based on thermo or photo sensitivity. These genetic male sterility systems also allow wider choice of male parents in hybrid seed production. A limited area is planted to such so called two line hybrids in China.

Wide hybridization

Crosses between crop cultivars and wild species, weedy races as well as intra-specific groups lead to widening of gene pools. Such gene pools are exploited for improving many traits including yield potential. Xiao et al. (1996) reported that some backcross derivatives from a cross between an Oryza rufipogon accession from Malaysia and cultivated rice outyielded the recurrent parent by as much as 18%. They identified two QTL from wild rice with major contribution to yield increase. These QTL have been transferred to modern short-statured varieties and yield evaluation is underway. Molecular marker assisted backcrossing is a useful approach for bringing alleles for yield improvment from wild and primitive germplasm.

Genetic engineering

Since protocols for rice transformation are well established (Christou et al. 1991) it is now possible to introduce single alien genes that can selectively modify yield determining processes. In several crop species incorporation of “stay green” trait or slower leaf senescence has been a major achievement of breeders in the past decade (Evans 1993). In some genotypes with slower senescence (stay green), the rubisco degradation is slower which results in longer duration of canopy photosynthesis and higher yields. The onset of senescence is controlled by a complement of external and internal factors. Plant hormones such as ethylene and abscisic acid promote senescence, while cytokinins are senescence antagonists. Therefore, over production of cytokinins can delay senescence. The *ipt* gene from Agrobacterium tumefaciens encoding an isopentenyl transferase (Akiyoshi et al. 1984) was fused with senescence specific promoter SAG12 (Gan and Amasino 1995) and introduced into tobacco plants. The leaf and floral senescence in transgenic plants was markedly delayed, biomass, and seed yield was increased but other aspects of plant growth and development were normal. This approach appears to have great potential in improving canopy photosynthesis and increasing the yield potential of rice.

Breeding for durable resistance

Diseases and insects take serious toll of crop production. According to FAO estimates, diseases, insects, and weeds cause as much as 25% yield losses annually in cereal crops. Similarly crop yields are reduced and fluctuate greatly as a result of biotic stresses such as drought, excess water (submergence), mineral deficiencies and toxicities, and abnormal temperatures. Plant breeders have been improving the crops to withstand these biotic and abiotic stresses to impart yield stability.

Diverse sources of resistance to major diseases and insects have been identified and rice varieties with multiple resistance to disease and insects have been developed. Recent breakthroughs in cellular and molecular biology have provided tools to develop more durably resistant cultivars and to overcome the problem of lack of donors for resistance to some diseases and insects such as sheath blight and stemborers.

Yellow stemborer is widespread pest in Asia and causes substantial crop losses. Improved rice cultivars are either susceptible to the insect or have only partial resistance. Codon optimized Bt gene was introduced into rice and the transgenic rice showed excellent levels of resistance in the laboratory as well as in the field (Datta et al. 1997). Bt rices have also been tested under field conditions in China (Tu et al. 2000) and showed excellent resistance. Besides Bt genes, other genes for insect resistance such as those for proteinase inhibitors, α-amylase inhibitors, and lectins are also beginning to receive attention.

Two of the most serious and widespread diseases in rice production are rice blast caused by the fungus Pyricularia oryzae and bacterial blight caused by Xanthomonas oryzae pv. oryzae. Development of durable resistance to these diseases is the focus of coordinated effort at IRRI using molecular marker technology. Efforts to develop markers closely linked to bacterial blight resistance genes have taken advantage of the availability of near isogenic lines having single genes for resistance. Segregating populations were used to confirm cosegregation between RFLP markers and genes for resistance. RFLP markers were converted into PCR based markers and using these PCR based markers in marker assisted selection (MAS), several genes for bacterial blight resistance were pyramided. Thus Xa4, xa5, xa13, and Xa21 were combined into same breeding lines (Huang et al. 1997). Pyramided lines showed a wider spectrum and higher level of resistance. Pyramided lines have been employed for moving genes into improved varieties grown in India (Singh et al. 2001). Xa21 has also been introduced into widely grown varieties through genetic engineering and transgenic lines are being evaluated under field conditions.

Breeding for abiotic stress tolerance

The progress in developing crop cultivars for tolerance to abiotic stresses has been slow because of lack of knowledge of mechanism of tolerance, poor understanding of inheritance of resistance or tolerance, low heritability and lack of efficient techniques for screening of germplasm. Only a few cultivars with varying degrees of tolerance to abiotic stresses have been developed. Rainfed rice is planted to 40 million hectares worldwide and vast rainfed areas suffer from drought at some stage of growth cycle. QTL for various component traits for drought tolerance have been identified and are being introduced into improved cultivars. Genetic engineering techniques hold great promise for developing drought tolerant cultivars. Datta et al. (2002) introduced Dreb1A gene in rice variety IR64 and transgenic plants showed good level of drought tolerance in greenhouse conditions. Large areas in river deltas of southeast and south Asia are submergence prone where water accumulates in fields after heavy rains for several days. Most rice varieties get killed after submergence of 3-4 days. However, rice variety FR13A can withstand submergence for up to 2 weeks. *Sub1* gene from FR13A has been bred into improved varieties such as Swarna (Neerja et al 2006), BR11, Samba Mahsuri grown in submergence prone areas and these varieties have greater yield stability. *Sub1* gene was also cloned recently (Xu et al 2006).

Tackling the hidden hunger

In addition to protein-energy malnutrition, deficiencies of minerals and vitamins affect a high proportion of world's poor. Deficiencies of iron (Fe), Zinc (Zn), and vitamin A are most acute amongst poor rice consumers. Rice has a low amount of Fe and Zn and is completely devoid of vitamin A. A research project to develop improved varieties of rice with higher level of micronutrients was initiated at IRRI in 1992. Considerable variation for both Fe and Zn was observed in rice germplasm. A comparison of Fe and Zn contents of selected varieties such as Jalmagna and Juchen with widely grown varieties such as IR36 and IR64 indicated that former have twice as much Fe and 50% more Zn. Rice varieties with high Fe and Zn contents are tall, unimproved and low yielding, and hence not suitable for modern agriculture. Efforts are underway to develop improved varieties with both high yield and higher levels of Fe and Zn. Crosses between these traditional varieties and high yielding varieties have produced progenies with high yield and high levels of these micronutrients. For example, an improved breeding line with short stature, IR 68144-3B 2-2-3 from a cross of high yielding variety IR 72 with tall traditional variety Zawa Bondy from India has high concentration of Fe in the grain, about 21 mg / kg in brown (i.e. unmilled) rice its yield potential is comparable to improved varieties.

β-Carotene, the precursor of vitamin A does not occur naturally in the rice endosperm. A genetic engineering project to introduce the biosynthetic pathway leading to production of β-carotene in rice endosperm was implemented by a team of Swiss and German scientists (Ye et al 2000). Two genes (*Psy* and *lcy*) from a plant (daffodil) and one (*crtI*) from a bacterium Erwinia uredovora were introduced into a rice variety Taipei 309. This resulted in the development of biosynthetic pathway leading to the development of beta-carotene in rice endosperm popularly called golden rice. Taipei 309 was used to introduce beta-carotene pathway genes as it is easy to transform. However, this variety is not cultivated due to its low yield and lack of adaptation to tropical and subtropical conditions. Subsequently new golden rice lines designated GR 1 and GR 2 in the background of two southern U.S. japonica type varieties Kaybonnet and Cocodrie respectively were developed by Syngenta. These US rice varieties are not adapted to the Asian rice growing conditions either Therefore, at IRRI efforts are underway to introgress the β-carotene loci from GR lines into popular Asian rice varieties, using marker aided backcrossing (MAB). Marker aided backcrossing for reconstituting various recurrent parents is in progress.

Future Prospects

Selections from lowly Oryza rufipogon made by primitive men and women as well as varieties developed by numerous farmers during eight thousand years and in the last century by breeders have fed and nurtured vast population in Asia and elsewhere from times immemorial . Rise of Asian civilizations depended upon availability of abundant supplies of this precious grain. Interruption in adequate supplies of rice resulted in devastating famines as exemplified by great Bengal famine of 1943 and even larger famine in China during 1950s.

Continued political stability in the developing world and welfare of humanity at large is contingent upon adequate supplies of world's most important source of calories. Any perturbations in supplies and price fluctuations can lead to food riots as happened in several countries in mid 2008 when rice prices doubled in the domestic markets of these countries. Therefore, we must ensure continued adequate supplies of rice in the future and redouble our efforts to develop rice varieties and management practices to produce 30% more rice by 2030. As mentioned in an earlier section we must raise the yield potential of rice, increase its durability to diseases and insects and tolerance to abiotic stresses. Low nitrogen use efficiency in rice production is a serious concern. Rice production consumes largest share of water used in agriculture. Dwindling water resources for agriculture is going to be a major constraint in future rice production. Therefore, major challenge for rice breeders is to develop varieties for higher nitrogen and water use efficiency. Fortunately, advances in rice genomics and breakthrough in molecular biology have provided tools and approaches to address these difficult problems of rice improvements. Cooperation between rice breeders and molecular biologists is essential to achieve these rice improvement objective

Yield potential of modern rice varieties is 10 tons per hectare. However, farmers harvest on the average only 5 tons per hectare. Agronomic practices must be fine-tuned to raise the average yields on farmer's fields.

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Economic Impact of Hybrid Rice in Vietnam: An Initial Assessment

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Abstract
This study was examined current situation of hybrid rice production in Vietnam and assess key impacts of hybrid rice production at national level and farmer level for recommend areas that need to be improved for future development of hybrid rice in Vietnam. The secondary data on commercial hybrid rice production and F1 hybrid seed production were collected from the Vietnamese government and other international organization. Primary data on rice production *viz*,. inputs, cost, output etc. of both hybrid and inbred rice was collected in a survey of 100 farm household in HaTay and NamDinh provinces in the Red River Delta. Trend analysis was used to show the pattern of development of hybrid rice production. The approach "with" and "without" comparison was made to examine the impact of hybrid rice at national and farm level. From result of household survey, two popular hybrid rice varieties (Nhi Uu 838 and TH3-3) and two popular inbred rice varieties (Bac Thom 7 and Khang Dan) were selected to evaluate likely impact of hybrid rice on farm households' income using food balance descriptive statistic method and partial budget analysis.
The result showed that hybrid rice has contributed to higher paddy output, hence better food security in Vietnam, especially in the North by providing an additional amount of almost 600,000 tons annually. Also, hybrid seed production has created more than 15,000 workdays yearly since 2001, which opens opportunities for rural employment. However, the analysis shows that hybrids have contributed very minimally to the improvement of paddy yield over the past 16 years. At farm level, hybrid rice contributed to less than a 3% additional gain in total farm household's paddy output in the Red River Delta. Both the larger amount of chemical fertilizer and higher seed cost, whereas lower price of hybrids contributes to a minimal positive impact of hybrid rice on farm household's income from rice. It was found the advantages that hybrid rice is shorter growth duration but more resistant to lodging than inbred rice, therefore future studies on the impact of hybrid rice should be concerned with specific ecological conditions.
Key Words: Hybrid rice, economic impact, national level, household income, Vietnam.

INTRODUCTION

Rice, the main staple food for most Vietnamese (except for some minority groups, such as H'mong), dominates Vietnam's agriculture with about 45% agricultural land devoted to rice production in 2007 (General Statistics Office (GSO), 2008). This sub-sector is a major source of income, employment, foreign exchange earnings, and an important contributor to the economic growth of the country.

Vietnam became a rice exporter in 1989, and is now recognized as the second biggest rice exporter in the world. However, not all of the regions in the country have achieved self-sufficiency in rice production, especially provinces in Northern Vietnam where the highest incidence of poverty is observed. While the Mekong river delta is the main basin of rice production in Vietnam, high marketing costs and demands for export have been obstacles for rice trade flow from South to North, hence this adversely affects the government's attempts to ensure food security in the country overall.

Table 1. Hybrid rice adoption in selected Asian countries

Country	Area cultivated (ha)			Hybrid rice as % of total area
	1997	2001	2003	
China	17,708,000	15,821,000	15,210,000	52
Vietnam	187,000	480,000	600,000	8
India	120,000	200,000	<200,000	<1
Philippines	500	90,000	107,000	3
Bangladesh	0	20,000	49,655	<1
Burma	0	10,000	unknown	-
Pakistan	0	0	Field trials	-

Source: GRAIN, 2005

Hybrid rice, proven to have 20% yield advantage over inbred rice in China (Yuan, 2004), was first introduced in Vietnam in 1991 with demonstrations in selected provinces in the North. Hybrid rice was then planted on a wide scale in the following year with an area of 1200 ha, and has now expanded to almost 600.000 ha in 2006 (Table 2), and is concentrated in the North. Given the fact that most of the sub-regions of the North are in rice-deficit situations (Nga, 2006), hybrid rice likely serves as one of the factors contributing to food security in the North of Vietnam.

Table 2. Hybrid rice area in Vietnam, 1992-2006 (ha)

Year	Total	Spring season	Summer season	Rate of adoption
1992	11094	1156	9938	0.17
1993	34648	17025	17623	0.53
1994	60100	45400	14700	0.91
1995	73500	39600	33900	1.09
1996	127700	60400	77300	1.82
1997	187800	110800	77000	2.65
1998	200000	120000	80000	2.72
1999	233000	127000	106000	3.04
2000	435508	227615	207893	5.68
2001	480000	300000	180000	6.41
2002	500000	300000	200000	6.68
2003	600000	350000	250000	8.06
2004	577000	350000	222104	8.09
2005	601944	350000	251944	8.21
2006	584000	346000	238000	7.97

Source: Department of Plant Cultivation statistics, MARD

To promote hybrid rice production, Vietnam's government has spent a large amount of money importing hybrid seed, on R&D for hybrid rice production, and on subsidizing hybrid rice seed production. However, an evaluation of the likely impact of hybrid rice on the national, as well farm level, has not yet been conducted. In view of this, this study attempts to provide preliminary results on the likely impact of hybrid rice, focusing on the economic aspects. Specifically, the study aims to:

Provide an overview on hybrid rice production in Vietnam;

Assess key impacts of hybrid rice production at national and farm level; and

Recommend areas that need to be improved for future development of hybrid rice in Vietnam.

Hybrid rice production and adoption in selected Asian countries

China:

Hybrid rice was first successfully developed in China in the 1970s. In 2003, an area of 15,210 ha was devoted to hybrid rice in the country, accounting for about 52% of the total rice area of the country (Table 1) and more than 90% of the total hybrid rice area planted in Asia. Average hybrid rice yield in China was recorded at 7 tons/ha in 2004 (Yuan, 2004b), 1.4 tons higher than inbred rice yield. China has developed super hybrid rice since 1996, which attained yields of 12 tons/ha in the period 2001-2005 (Yuan, 2004b). Hybrid rice is expected to attain yields of 13 tons/ha in the country in the future. However, the rate of hybrid rice adoption has decreased steadily (at low pace) because of changing demand. According to David (2005), Chinese's income levels have increased, consumers demand for good quality rice has increased, while hybrid rice varieties have not been able to meet this demand.

Bangladesh

Hybrid rice research was initiated at the Bangladesh Rice Research Institute (BRRI) in 1983 but only for academic purposes. The government encouraged private sector companies to import hybrid rice seeds and try them with farmers. Some private seed companies imported rice hybrids and evaluated them through on-farm trials during 1997-98 *boro* season (winter rice). In 2001, about 20,000 ha was devoted to hybrid rice production in the country, this figure was report at 49,655 ha in 2003, making up less than 1% of the total rice area of Bangladesh (Table 1). Husain (2001) shows that grain yields of hybrids were 14% higher than that of high yield varieties. Constraints to hybrid rice adoption in Bangladesh included external dependence and higher cost of seed, higher need for management skills, input intensity, higher incidence of pest and diseases, inadequate yield gains and lower head-rice recovery. Stickiness of cooked rice and its relatively inferior quality in terms of taste were also considered as other constraints for hybrid rice adoption.

India

Research on hybrid rice was initiated in India in the 1980s with imported materials from China, which was then shown to be not adaptable to local conditions. With support from FAO and UNDP, India has developed its research network in hybrid rice since the early 1990s. The private sector actively participates in hybrid rice production, especially seed production. However farmer's adoption of hybrids in the country is still at a low level. In 2003, the area devoted to hybrid rice was about 200,000 ha, less than 1% of total country's rice area. Therefore, emphasis is now given to creating awareness among farmers, especially in the states of Uttar Pradesh, Maharashtra, and Karnataka. In India, hybrid rice area has been reduced and is now mostly confined to "small areas where there are government and seed industry on-farm demonstration programs" (Grain, 2005).

Myanmar

Myanmar started research on hybrid rice in 1997 and released its hybrid seeds. Hybrid rice activities in Myanmar are being pursued by both the public and private sectors. The private sector is primarily dominated by Chinese seed companies, which are involved mainly in the dissemination of Chinese-bred hybrids. In 2001, the area cultivated in hybrid rice was about 10,000 ha (Table 1). Yield advantage of hybrid was shown to be about 12%-48% over inbred varieties through experimental trials done by IRRI and the Mandalay Division in 2003. IR58025A and IR68897A are among the 15 IRRI-developed lines being maintained at CARI. These two lines have been selected for large-scale use in the development of rice hybrids.

Philippines

The Philippines became the fourth country to engage in hybrid rice and released its first hybrid seedling in 1993. The development and use of hybrid rice technology as a major approach for further increasing rice productivity has drawn attention from the government. A Hybrid Rice Commercialization Program (HRCP) initiated in 2001, is the centerpiece strategy of the governments' Ginintuang Masaganang Ani (GMA) program to attain rice self-sufficiency in the country. The HRCP targets 135 hectares in 2002, 200,000 ha in 2003 and 300,000 ha in 2004 (PhilRice, 2005).

According to the Philippine government statistics, hybrid rice varieties in the previous 12 seasons from 2001-2007 have recorded a yield advantage of 33% over those of inbred certified seeds. The adoption of hybrid seeds by farmers has been slow, moving from about 5% in 2004 to 11% of total rice area in 2005 (David, 2006). The Philippine government has subsidized hybrid seed heavily (SEARCA, 2005). This creates problems for the dissemination of hybrid rice as it depends on the government's budget, especially in times of financial crisis and budget deficits, as has been the case over the past several years.

Hybrid rice in Vietnam

Research in hybrid rice

Research in hybrid rice was initiated in the late 1970s at Vietnam's Institute of Agricultural Science. Since 1983, CLRRI and IRRI have been in collaboration to develop hybrid rice technology for farmers in the Mekong River Delta provinces. Experimental results show that hybrid rice outyeilded inbred rice by 18-45% (Luat et al, 1994). At present, institutions involved in hybrid rice research are the Hybrid Rice Research Center, Hanoi University of Agriculture, Cuu Long Rice Research Institute, and the Agricultural Genetic Institute. Vietnamese scientists have selected and produced parental lines with novel characteristics for rice production in the country, such as 103S, T1S-96, T4S, T23S, T70S, T100, AMS27S (Tram, 2007). These lines are used to produce Vietnamese F1 seed such as VL20, VL24, TH3-3, TH3-4, HYT83, and HYT92.

F1 seed production

Vietnam first released F1 seed in 1992, which was produced in a limited area of less than 200 ha (Fig. 1). With very low yield (on average of 302kg/ha), total F1 seed amount released in 1992 was recorded at about 52 tons. F1 seed area declined slightly during 1992-1995, but then recovered and expanded quickly after that, reaching 1920 ha in 2006. There has also been significant improvement in productivity, which was recorded at 2.2 tons/ha in 2006, 7 times higher than in 1992. The main production areas of hybrid seed are provinces in the north, such as Thanh Hoa, Hai Phong, Ha Nam, and Nam Dinh. In 2005, an area of 820 ha was devoted to Vietnamese seeds, accounting for about 60% of the total hybrid seed area in the country. The rest was planted in Chinese hybrid varieties. This suggests that Vietnamese hybrid rice seeds are accepted and preferred by growers.

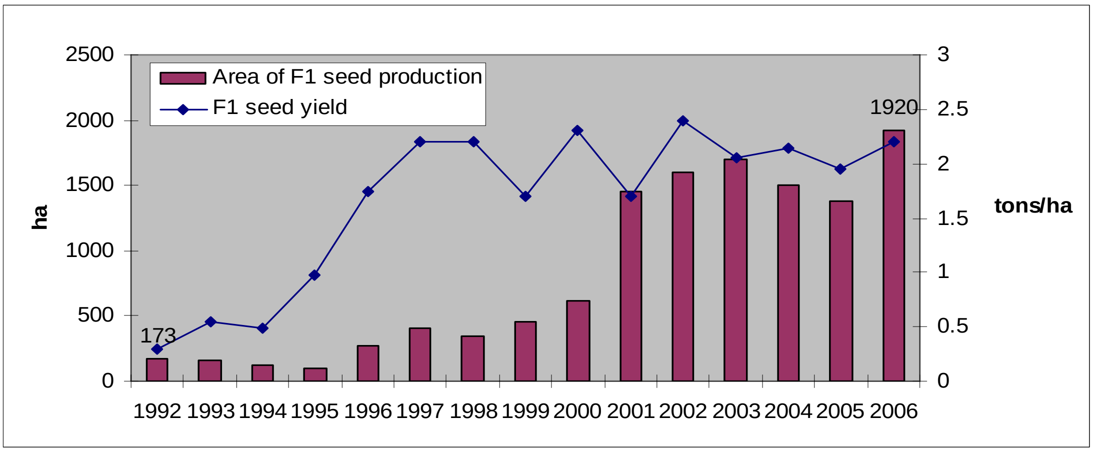

Figure 1. Trend in F1 hybrid seed area and yield, Vietnam, 1992-2006
Source: MARD's statistics

Domestic supply of F1 seed, however, has not been able to meet the demand, which grew quickly due to the rapid expansion of hybrid rice production in the country (Fig. 2). Vietnam has had to import F1 seed (mainly from China). In 1998, the imported quantity of seed was 4,106 tons, this figure tripled to 13,316 tons in 2006 (Fig. 2). On average, total domestically produced seeds meet 18.54% demand. In 2008, it was reported that the F1 seed area dropped to 1200 ha (NNVN, 2008).

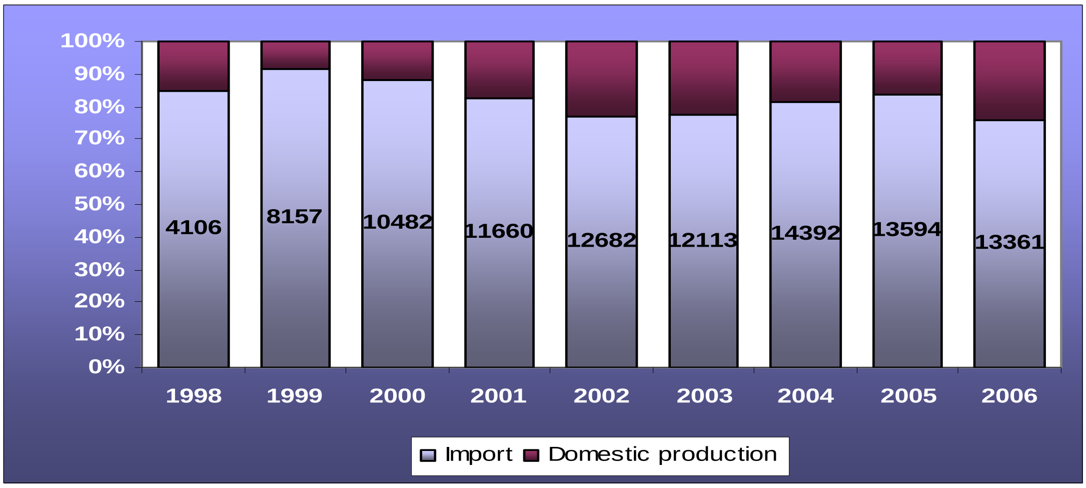

Figure 2. F1 hybrid rice production and import, Vietnam, 1998-2006
Sources: MARD and Vietnam Custom

Hybrid rice adoption in Vietnam

In 1992, the total area devoted to hybrid rice was recorded at 11,094 ha (Table 2), accounting for 0.17% of the total rice production area. Up until now, hybrid rice is planted in about 40of the 64 provinces in the country. The Red River Delta (RRD) takes the lead in hybrid rice production with a 51.25% share in 2000 (Table 3). This rate declined to 36% in 2006. The North Central Coast has become the region with the highest adoption rate in the country recently, recorded at 38.23% in 2006.

Table 3. Hybrid rice area in different ecological areas of Vietnam, selected years.

Region	2000		2006	
	Area (ha)	%	Area (ha)	%
North Central Coast	109500	25.21	135000	22.93
Red River Delta	225400	51.25	214000	36.41
North Central Coast	99500	21.75	225000	38.23
Central Highland and South Central Coast	7800	1.79	14000	2.43
Total	442200	100.00	588000	100.00

Source: Division of Cultivation statistics, MARD

In the Red River Delta, Ninh Binh province had largest hybrid rice area, at 94,800 ha in 2000, but this area declined to 84,000 ha in 2006. Other provinces that experienced declines in hybrid rice adoption are Ha Nam, Hai Duong, Thai Binh, Ha Noi, Vinh Phuc. Other provinces have expanded the area of hybrid rice. For example Hung Yen has an annual growth rate of hybrid area posting at 14%, and the increase in area is 7.35% in Bac Ninh. However, hybrid adoption in the RRD has declined at rate of 1.07% during the period 2000-2006 (Table 4). Possible reasons are (i) Removal of price subsidy; (ii) Unstable source of seed; (iii) There is some inbred rice with comparable yield, such as Q5, Khang Dan; and (iv) Farmers moved to varieties with medium yield but high quality and value, such as Bac Thom 7.

Table 4. Trend in hybrid adoption area in provinces in the Red River delta, selected years **(ha)**

Province \ Year	2000	2006	Average growth rate 2000-2006 (%)
Ninh Binh	94800	84000	-2.00
Nam Dinh	34300	36000	0.81
Hai Phong	23800	24400	0.42
Thai Binh	25600	18200	-5.53
Vinh Phuc	15800	15000	-0.86
Ha Tay	6700	8000	3.00
Hung Yen	3550	7800	14.02
Bac Ninh	4900	7500	7.35
Ha Noi	6400	4500	-5.70
Hai Duong	3200	1500	-11.86
Ha Nam	2600	900	-16.21
RRD	221650	207800	-1.07

Farmers in the South have started growing larger areas of hybrids recently. Arize B-TE1 (India originated) have been introduced in the South recently and shown its advantages over inbred rice in terms of yield and resistance to unfavorable soil conditions. Farmers in the South, (i.e. Binh Dinh, Quang Nam, Kien Giang) are becoming more convinced in the use of hybrid rice.

METHODOLOGY

Study area and data collection

Secondary data on hybrid seed and hybrid rice production in Vietnam and some Asian countries were collected from the Department of Plant Cultivation, Ministr of Agriculture and Rural Development (MARD), IRRI web page, FAO, India hybrid rice webpage, GRAIN publications. A case study on hybrids at farm level was done in Nam Dinh and Ha Tay in spring 2007 and summer 2006 crop seasons. Primary data on rice production (inputs, cost, output, etc.) of both hybrids and inbred was collected in a survey of 100 farm households in the two provinces.

Analytical tools

Vietnam's hybrid rice development is briefly described in terms of seed and hybrid rice areas, productivity, volume of production, and its share of total output. Trend analysis with the aid of tables, graphs, and geometric growth rate were used to show the pattern of development.

To examine the impact of hybrid rice technology at national and farm levels in Vietnam, the approach "with" and "without" comparison was made. The simple descriptive statistic method was used with Paache indices. This study also made use of food balance sheet computation method described in Que and Thao (2004). Partial budget analysis was used to evaluate likely impact of hybrid rice on farm households' income. Hybrid rice is expected to have positive impact on total rice output of household, but lower price might contribute to insignificant change in gross output value. Also, fertilizer cost for hybrid rice is expected to be higher than that of inbreds.

There are a number of hybrid and inbred varieties grown at the survey site, hence the most popular varieties are chosen for the analysis. Hybrid rice here refers to Nhi uu 838 and TH3-3, inbred rice refers to Bac Thom 7 and Khang Dan.

3. RESULT AND DISCUSSION

Impact of hybrid rice in Vietnam

3.1. At national level

Production of F1 seed creates more employment in rural areas

Table 5. Estimates of employment created by F1 hybrid seed production in Vietnam, 1992-2006

Year	F1 seed area (ha)	Total additional employment created(workdays)	Year	F1 seed area (ha)	Total additional employment created(workdays)
1992	173	17300	2000	620	62000
1993	154	15400	2001	1450	145000
1994	123	12300	2002	1600	160000
1995	101	10100	2003	1700	170000
1996	267	26700	2004	1500	150000
1997	410	41000	2005	1380	138000
1998	340	34000	2006	1920	192000
1999	455	45500			
Total					*1219300*

Sources: Computed on the basis of GSO, MARD data

According to the latest survey on F1 seed production in Truc Ninh district, Nam Dinh province in April 2008, total labor required for 1 ha of F1 seed production is approximately 400 workdays. Compared with total labor required for 1 ha of inbred rice production in the

North, which was estimated at about 300 workdays/ha, production of F1 seed creates about 100 workdays/ha[1]. Hence, total number of workdays created by F1 seed production has increased with area expansion. Table 5 shows that F1 hybrid production has created more than 15,000 workdays yearly since 2001. In 2007, a workday in seed production was paid with around VND 49,000 (Tung, 2008), almost the same with average wage rate in the survey sites. This is an opportunity for unemployed labor in rural areas, especially women and old farmers. F1 seed production created about 1.2 million workdays in the period 1992-2006.

Production of hybrid rice contributes to higher overall paddy yield of the country

Table 6. Trend in productivity of hybrid and inbred paddy, Vietnam, 1992-2006 **(tons/ha)**

Year	Overall productivity	Hybrid yield	Inbred Yield
1992	3.33	6.22	3.33
1993	3.48	6.75	3.46
1994	3.57	5.84	3.54
1995	3.69	6.14	3.66
1996	3.77	5.85	3.73
1997	3.88	6.35	3.81
1998	3.96	6.50	3.89
1999	4.10	6.47	4.03
2000	4.24	6.45	4.11
2001	4.29	6.44	4.14
2002	4.55	6.30	4.42
2003	4.63	6.30	4.49
2004	5.03	6.08	4.92
2005	4.89	6.15	4.78
2006	4.89	6.32	4.77

Sources: Computed on the basic of GSO and MARD data

During the period 1992-2006, overall paddy yield of the country increased from 3.33 tons/ha to 4.89 tons/ha (Table 6) , as a result of yield improvement and changes in area structure devoted of both hybrids and inbreds. Table 7 shows that the major source of overall paddy yield improvement in the period is attributed to increase in paddy yield of hybrid and inbred rice. For instance, total yield change is 1.56 tons/ha (during the period 1992-2006, of which 1.33 tons/ha is resulted from improvement in hybrid and inbred yield and the rest is attributed to area structural changes).

Table 7. Factors contributing to overall paddy yield improvement, Vietnam, 1992-2006

	Change	
	Absolute (tons/ha)	Percentage (%)
Overall paddy increase	1.56	146.70
Contribution of yield increased	1.33	137.44
Contribution of area structure	0.22	106.74

Sources: Computed on the basic of GSO and MARD data

Table 6 shows that there was a minimal improvement in hybrid paddy yield in the period 1992-2006 (0.1% annually), while inbred paddy yield grew at rate of 2.4% annually. Even

[1] This figure is a little bit lower than stated in FAO (2004), which was 400-500 workdays/ha required for F1 seed production in the North Vietnam.

though Vietnam experienced a high adoption rate of hybrid as compared to other Asian countries (8% recently), this change in area structure contributes much less than yield improvement. Hence, hybrid rice has contributed very little to overall paddy yield improvement of Vietnam since 1992.

Production of hybrid rice contributes to higher total paddy output of the country

Despite of much lower rate in productivity improvement as compared with inbreds during the period 1992-2006, hybrids are still advantageous over inbreds in terms of yields (6.32 tons/ha vs. 4.66 tons/ha in 2006, Table 6). With higher yield and expanding area of hybrids, total paddy output of the country has been at higher level as compared with case of no hybrids. Table 8 shows that if no hybrids were planted, total paddy output of the country would be 21.56 million tons instead of 21.59 million tons in 1992. With hybrid rice, additional output was estimated at 906,000 tons in 2007. On average, hybrid rice brought an additional quantity of 589,800 tons of paddy annually during the period 1992-2006, or 2.1% paddy output compared with case of no hybrids.

Production of hybrid rice contributes to higher level of food security

According to the socioeconomic survey of MARD in 2001, annual per capita rice consumption was 178 kg[2]. Gains in total output contributes to higher level of food security, as it makes higher quantity of rice supply, hence quantity of rice available for human consumption. Table 8 presents estimates for the number of people that could be fed with additional rice gained from hybrid rice production.

Table 8. Impact of hybrids to total paddy output and food security, Vietnam, 1992-2005

Year	Total paddy output ('000 tons)	Total paddy output if no hybrids ('000 tons)	Changes in paddy output (000 tons)	Changes in paddy output (%)	Change in rice quantity ('000 tons)	No of people fed with additional rice gained from hybrids (person)
1992	21590.4	21558.9	31.5	0.15	18.04	101359
1993	22836.5	22723.2	113.3	0.50	64.92	364697
1994	23528.2	23390.7	137.5	0.59	78.75	442394
1995	24963.7	24782.0	181.7	0.73	104.10	584805
1996	26396.6	26126.9	269.7	1.03	154.51	868048
1997	27523.9	27048.6	475.3	1.76	272.27	1529621
1998	29145.5	28624.3	521.2	1.82	298.57	1677364
1999	31393.8	30826.5	567.3	1.84	324.97	1825694
2000	32529.5	31513.1	1016.4	3.23	582.28	3271209
2001	32108.4	31009.3	1099.1	3.54	629.63	3537221
2002	34063.5	33133.3	930.2	2.81	532.89	2993771
2003	34474.98	33392.8	1082.2	3.24	619.97	3482967
2004	35867.8	35217.0	650.8	1.85	372.85	2094664
2005	35832.9	35012.2	820.7	2.34	470.17	2641410
2006	35826.8	34929.4	897.4	2.57	514.11	2888261
Average (92-06)	29872.17	29285.89	586.28	2.00	335.87	1886899

Sources: Computed on the basic of GSO and MARD data

[2] which included both home and outside consumption, and different rice-made products such as noodle, cakes, etc.

In 1992, about 18.04 tons rice gained from hybrids which could feed 101,359 people in a year. This figure increased to approximately 2.9 million people in 2006. On average, gains in hybrids production could ensure food security for 1.88 million people annually. This is approximately the population of 1-3 provinces in North East, North West, North Central Coast, or the Central Highlands. Given the fact that these regions are rice-deficit, hybrid rice production is a big opportunity for improving food security in these regions.

Hybrid rice has drawn resources from the country

To develop hybrid rice, the government has spent money on seed importation and seed production subsidy: seed price subsidy, technical trainings, research and development. During the period 1998-2006, the average import quantity of seed was recorded at 11,172 tons yearly, valued at 14.5 million USD. Annual spending on hybrid seed imports were 1.55% of total earnings from rice exports (Table 9).

Table 9. Foreign exchange spent on seed importation, Vietnam, 1998-2006

Year	Total spending on F1 hybrid seed		
	Value (mil.USD)	Compared with previous year (%)	As percentage of rice export earnings (%)
1998	5.42		0.54
1999	10.60	195.65	1.02
2000	14.15	133.45	2.12
2001	16.21	114.53	2.44
2002	14.33	88.42	1.98
2003	11.75	81.99	1.49
2004	18.85	160.46	2.19
2005	21.61	114.64	1.54
2006	17.37	80.36	1.38
Total	130.3		
Average	14.5	115.67	1.55

Sources: Sources: Computed on the basic of GSO and MARD data

Vietnam spent a total of 130.3 million USD importing seed during the period 1998-2006. According to the Department of Agriculture (2005), total budget spent for the extension program and R&D in hybrid rice production from 1993-2005 is recorded at 82.4 billion VND (approximately 5.5 million USD). Some provinces spent more for their hybrid rice program (Thanh Hoa, Nam Dinh).

The hybrid rice development program in Vietnam has received support from MARD and local governments in various forms. However, hybrid rice area has not shown increased development and even the hybrid seed area has declined to 1200 ha in 2008 (NNVN, 2008). As a result, a larger quantity of seed is imported and larger amounts of foreign exchange are required.

3.2. At farm level: case in the Red River Delta

Hybrid rice is expected to improve total rice output of farm households. Its impact on a household's income is uncertain as lower price may leverage yield advantages.

Profile of surveyed farm households and varieties adopted

The average size of a farm household is about 5 people and 3 of them are in the labor force (Table 10). The respondents have an average of 8.34 years of education. On average, each household has 0.38 ha devoted to rice production.
The majority of farm households planted both hybrids and non-hybrids (more than two-thirds). Hybrid varieties are Nhi uu 838 , Nhi uu 63, D uu 527, TH3-3. Inbred varieties are Khang Dan, Bac Thom 7, and Nep 97.

Table 10. Socio-economic and demographic characteristics of farm households

Criteria	Unit	Quantity
Number of surveyed households (hh)	hh	100
Average size/hh	Person	4.57
Average number of labors	Person	2.76
Household head's age	Year	49.32
Years of household head's education	Year	8.34
Average rice area/household	Ha	0.38
HH with more than 50% income from agriculture.	hh	68

Sources: Calculated on the basis of surveyed data

Fertilizer application

Table 11 shows that hybrid rice consumed Nitrogen much more than inbred in both seasons. In spring 2007, total Nitrogen for 1 ha of hybrid rice was estimated at 116.7 kg/ha, 29 kg higher than inbred. The difference is bigger in summer 2006. Farmers applied P_2O_5 for hybrids at a higher rate than for inbreds in spring, but less than for inbreds in the summer. For K_2O, it was found that farmers applied less for hybrids. In spring 2007, a hectare of hybrid rice was treated with 45.05 kg K_2O, while this figure is 54.48kg for inbred rice. However, it is correct that farmers spent more on chemical fertilizers for hybrids than for inbreds with the difference being about 30 kg /ha (Table 11)

Table 11. Chemical fertilizer application for hybrid and inbred rice by surveyed farm households **(kg/ha)**

Fertilizer	Spring 2007				Summer 2006			
	Hybrid	Inbred	Difference		Hybrid	Inbred	Difference	
	(1)	(2)	(3) = (1)-(2)	(4)= (1)/(2)	(5)	(6)	(7)= (5)-(6)	(8)= (5)/(6)
Nitrogen	116.89	87.88	29.01	33.02	163.21	97.12	66.08	68.04
P_2O_5	55.23	45.38	9.85	21.70	56.93	74.80	-17.87	-23.89
K_2O	48.05	54.48	-6.43	-11.79	37.66	48.98	-11.32	-23.11
N+P+K	220.18	187.74	32.44	17.28	257.79	220.90	36.89	16.70

Source: Calculated on the basis of surveyed data

Impact of hybrid to total paddy output of farm households

In spring 2007, the average yield of paddy was estimated at 6.39 tons/ha and 6.19 tons/ha for hybrid and inbred respectively, which is quite high for inbred. Paddy yield in the summer was about one ton lower than in the spring (Table 12). With about 65% and 34% of the total rice area planted to hybrids in the spring and summer crop seasons respectively, total paddy output was estimated at an average of 2.43 tons in spring season and 2.12 tons in summer season. Assuming that no hybrid rice was planted, total paddy output would be 2.38tons and 1.98 tons in the spring and summer seasons, respectively. Changes in total paddy output due to hybrid adoption was minimal, which brought about 49 kg for household in spring crop season (Table 12), accounting for only a 2.1% increase. The reason for the low contribution of hybrids is because farmers in the survey site have attained high yield from inbreds.

Table 12. Impact of hybrid rice on total output of farm households

Indicators	Unit	Spring	Summer
Yield	kg/ha		
Hybrid	kg/ha	6391.53	5389.35
Inbred	kg/ha	6194.17	5166.02
Share of hybrid in total hh's rice area	%	65	34
Total output /farm household	kg	2430.86	2015.43
Total output/farm household if no hybrids	kg	2381.53	1986.23
Additional output gained	kg	49.32	29.19
As percentage	%	2.07	1.47

Source: Calculated on the basis of surveyed data

Impact of hybrid to household's income from rice production

Assuming inbred rice is now replaced with hybrids, will farmers become better-off? Table 13 shows that if one ha of inbred is replaced, total estimated increase in income is 27.82 USD and 15.27 USD in spring and summer seasons respectively. It is likely that the positive impact of hybrids on farm household's income is insignificant. A simple calculation shows that by replacing inbreds with hybrids, a typical farm household with total rice area of 0.38 ha would gain about 10.7 USD and 5.9 USD VND in spring and summer, respectively.

Table 13. Partial budget analysis for the replacement of inbred with hybrid rice *(applied for 1 ha)*

Changes	Spring crop	Summer crop
Positive effects		
Total additional income (USD)	1,482.83	1,228.78
Reduced cost(USD)	451.23	448.52
Total additional income and reduced cost(USD)	1,934.07	1,677.29
Negative effects		
Reduced income(USD)	1,548.54	1,224.51
Additional cost(USD)	357.70	437.52
Total reduced income and additional cost(USD)	1,906.24	1,662.03
Change in net income	27.82	15.27

Note: exchange rate is 15,000 VND: 1 USD

Source: Calculated on the basis of surveyed data

Reasons for hybrid rice adoption

Figure 3 shows that yield advantage is the reason for the majority of farmers to plant hybrid rice (79% of respondents). This is somewhat inconsistent because hybrid rice did not show a significant higher yield in the above analysis. However, it should be noted that there is a difference in the yield in lodging areas, where farmers planted almost no inbred rice because of the low resistance to lodging conditions. The study also has missed the analysis of how different types of soil influence the yield.

About one-third reported that hybrids are less susceptible to insects and more resistant to lodging. Shorter life time (which opens opportunity to have cash crop in winter), better rice cooking quality, and better selling price were rewarded to Vietnamese hybrid rice. It was reported that the price of TH3-3 was higher than some inbreds, such as Khang Dan, Q5.

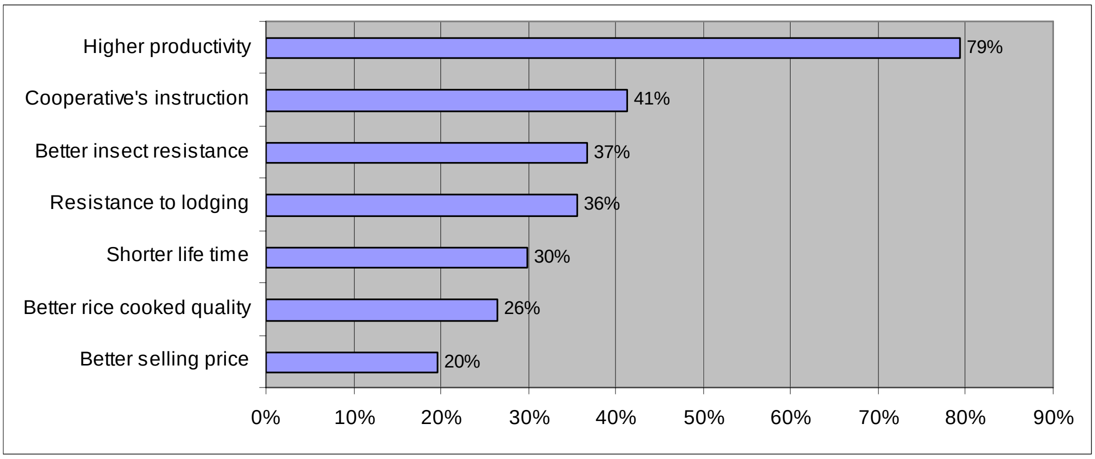

Figure 3. Reasons for adoption of hybrid rice by farmers in Nam Dinh and Ha Tay
Sources: Computed from surveyed data

Production distribution

About one half of a farm household's total paddy output is sold after drying. For hybrid rice, farmers kept 50% of the total output for home consumption (36.33%), and to store it to sell later (12%). It was observed that farmers kept a smaller percentage of inbred paddy output for home consumption (29.08%). However, there is no difference in the pattern of using rice for food between inbred and hybrid. Farmers used 23.55% and 24.76% of total hybrid and total inbred outputs for food consumption, respectively (Table 14). This may help to change some people's thinking that hybrid rice is just used for animal feed. While 12.78% of hybrid output was used for feeding animals, about 4.27% of total inbred produces was used for the same purpose.

Table 14. Production distribution in spring 2007 crop season **(%)**

Purpose	Hybrid	Inbred
Total	100	100
1. Sold after drying	50.03	63.06
2. Home consumption	36.33	29.08
Food	23.55	24.76
Seed	0.00	0.06
Feed	12.78	4.27
Other	1.19	0.74
3. Store to sell later	12.12	5.27
4. Other	2.71	9.54

Source: Calculated on the basis of surveyed data

Constraints to hybrid rice adoption in Vietnam

The availability of quality seed at a reasonable price is a crucial factor behind the large-scale adoption of hybrid technology for any crop. China's success in the large-scale adoption of hybrid rice can also be attributed to the efficient hybrid seed production and distribution system. In Vietnam, hybrid rice production has scaled up at a slow rate recently due to problems of hybrid seed and grain quality.

Unstable supply of hybrid seed

With almost 80% of seed imported from China, Vietnamese farmers are dependent on seed supply from outside in terms of quantity, quality, variety and price. A tightening of the supply from China would result in excess demand in domestic market and price would go up, the case that happened in the winter-spring crop 2005 and summer crop season 2008. It was reported that the price of Chinese hybrid seed in 2008 was more than doubled the previous year, and many farmers in RRD were not able to buy TH3-3 or VL-20 seed.

The dependence on the seed source may be partly attributed to the low capacity of domestic seed production and distribution system, possible causes are:

Many seed companies prefer to import seed instead of produce and market the domestically produced seed because it is more profitable and less risky.

Limited capacity to enlarge hybrid seed areas. Aside from that, seed companies take advantage of the government's subsidy by reporting incorrectly their capacity of production or higher seed area planted.

Limited knowledge on hybrid seed production is also a problem. Aside from risks caused by unfavorable climate, poor synchronization of the parental lines has resulted in low (even zero) yield, and this is mostly due to limited knowledge of technical assistants and seed growers.

Dependence of parental seeds imported from China, as Vietnam is not able to supply the required parental seeds for production.

Seed quality

Quality control is vital to the widespread adoption of hybrid rice. Quality control is done throughout the entire process of seed production (including nucleus, breeder, foundation and certified seed production of both parental lines and F_1 hybrids). Seed quality standards are met by the intensive elimination of off-types (from seeding to harvesting) and careful handling during harvesting, threshing, drying, cleaning, processing, bagging and labeling (Virmani et al, 2002).

Lower quality of domestically produced seed also results from the weak capacity of seed producers. It was reported that in a quality test for hybrid seed in 2008, 46 out of 219 samples of hybrid rice seed did not meet the quality standards (Nguyen, 2008).

The weak performance of seed quality control system in Vietnam has been mentioned. Seed quality is not ensured especially in times of tight supply and excess demand when traders could make profits by importing and selling poor quality seed. Poor quality seeds result in low yield and economic loss for rice farmers; hence it discourages farmers from adopting the hybrids. It has happened that several seed companies sold seed to farmers with quality differing from that reported on the label. Other more recent cases happened in Binh Dinh province, two cooperatives in An Nhon districts provided farmers with seed stored from previous season. Poor storage caused low seed quality and very low germination rate. In Hung (2007), it was reported that only 84.9% of imported seed in 2006 was quality seed , and 74.4% of imported seed was certified to meet the requirement of purity.

Farmers prefer imported seed to domestically produced seed

The psychology that imported goods are better than domestic ones probably applies in this case. In 2006, seed produced by cooperatives in Vu Ban district was sold at 12,000 VND/kg but farmers still bought imported seed (China) at about 20,000 VND/kg. Farmers believed that imported seeds were better than domestically produced seeds in terms of discoloration, grain size uniformity, presence of off-types, and germination rate (Tung, 2008). However in many cases, they were not aware that they had bought the domestically produced seeds in imported labels. The fact is that imported seed companies buy seed produced in Vietnam and pack in it in sacks with their labels on it. Weaker demand for domestically produced seed has contributed to the slow rate of seed production in Vietnam.

Lack of parental lines and lack of good varieties for summer crop season

Vietnam has only been able to produce parental lines for F1 seed production recently, but it has not yet been able to produce the quantity required. Lack of parental lines contributes to more dependence on imported seed. This, coupled with seed companies' preferences for importing over producing seed themselves, has hindered the expansion of F1 seed production in Vietnam.

Hybrid rice is susceptible to blast disease during the summer season, and this is especially true of Chinese varieties. That is one of the reasons hybrid rice is not preferred during the summer season. Some of 2-lines hybrids of Vietnam have advantages of shorter maturation time and less susceptibility to blast disease, but are not adaptable to a wide range of conditions.

Grain quality and awareness of public and key leaders

Grain quality is one of major factors limiting the adoption of hybrid rice in most of the Asian countries (Dat, 2002). Most of the widely adopted Chinese varieties in Vietnam, such as Nhi uu, Bac uu, D uu, were reported to be of lower quality than inbreds, but they are still being used for food. Recently, Vietnamese hybrid rice (TH3-3, VL20, HYT 83, and HYT 92) has been appreciated for its better cooking quality and higher yield than some inbreds, but these varieties are not adaptable to a wide range of conditions.

Whether hybrid rice should be developed in Vietnam or not, and at what scale is a controversial topic among government leaders and scientists. Some view that the government's investment in hybrid rice development program is not effective and efficient, the quality of hybrids is low, or hybrids have high susceptibility to diseases.These views are a result of the fact that great efforts (budget, human resources) have been put into hybrid rice development in the past 16 years, but hybrid rice adoption is still at a low rate and Vietnam depends much on Chinese seed production.

4. CONCLUSION AND FUTURE OUTLOOK

Conclusion

Hybrid rice has contributed to higher paddy output, hence better food security in Vietnam, especially in the North by providing an additional amount of almost 600,000 tons annually. This amount is good for about 1.89 million people (2.5% of total population) every year. This extra amount creates better accessibility to food for the poor consumers. Without hybrid rice technology, it would require about 138,000 ha more to produce the same quantity, which is not feasible because some previously agricultural land has been built up and is used for other purposes[3]. Hybrid seed production opens opportunities for rural employment. However, the analysis shows that hybrids have contributed very minimally to the improvement of paddy yield over the past 16 years.

At farm level, hybrid rice in the Red River Delta was not found to have a yield advantage (15-20%) over inbred rice as expected. As a result, hybrid rice contributed to less than a 3% additional gain in total farm household's paddy output. The lower price of hybrids contributes to a minimal positive impact of hybrid rice on farm household's income from rice. Future studies on the impact of hybrid rice should be concerned with specific ecological conditions for rice.

Future outlook

With a decrease in rice area, hybrid seed area, and also the slow trend in hybrid rice adoption recently, MARD has paid special attention to the promotion of hybrid rice and to maintaining the area devoted to rice. The Prime Minister required the Ministry of Resources and Environment to review and report on the current status of agricultural land in the country, especially rice area (Decree 391/QĐ-TTg dated April, 2008). Besides this, MARD encourages enterprises/companies (with more than 100 ha of rice seed) to produce hybrid seed to avoid the need to import a large quantity of seed. The Department of Plant Cultivation (MARD) proposed to increase spending from 1.5-3 times higher for extension projects in hybrid rice production, focusing on seed (NNVN, 2008). The focus on hybrid rice should be extended to the southern and central part of Vietnam, especially to the south central coast where hybrids have an advantage over inbreds in their better resistance to unfavorable conditions. For the target of MARD – to be self-sufficient in hybrid seed for 70% hybrid rice area in 2010- more efforts should be initiated to enlarge seed production areas.

The continued support of the government will be needed for the development of hybrid rice in the country. The major issues that still need to be addressed include: the lack of hybrids with good quality, the advantage of yield and adaptability to various ecological conditions, the absence of a strong private rice seed industry (in terms of producing and willingness to market the domestic seed); inadequately trained labor for R&D; problems with genetic purity and flowering synchronization in hybrid seed production; the limited number and experience of seed growers; inadequate equipment for research and seed production; small and fragmented F1 seed production areas; and the limited awareness of the general public and key leaders to the potential of hybrid rice technology.

Hybrid rice development has brought about changes in paddy productivity and total output of the country, and other positive impacts. Meanwhile, it has been the target of much spending

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[3] In period 2001-2005, more than 366,000 ha of agricultural land were transferred to non-agricultural purposes (KTNT, 2008).

from the government. The question of whether the hybrid development program is effective and efficient, and hence should be continued, is still unresolved.

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Currents Status F_1 of Hybrid Rice Seed Production in Vietnam

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Key word: Hybrid rice seed, two-line system, three line system

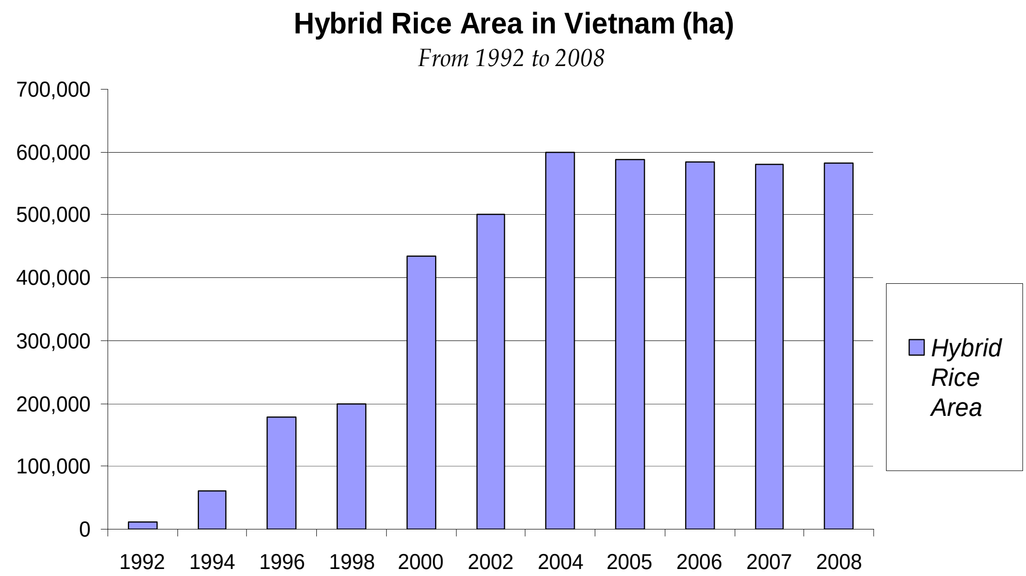
Abstract:

Hybrid rice seed production in Vietnam has been beginning from 1994. It can be divided in three periods: (1) from 1994 to 1998, Introducing hybrid rice seed production technology from China with three line system, using cytoplasmic male sterility (CMS) line as female parent. (2) 1999 – 2004: Forming Vietnamese technology of hybrid rice seed production and (3) 2005 – 2008: Developing and releasing hybrid rice seed technology in large scale; focusing on two line system using TGMS lines as female parent for F_1 varieties bred in Vietnam such as Vietlai20, Vietlai24, TH3-3, TH3-4, Vietlai50. In the end of 2007, the domestic hybrid rice seed production supplied seed for more than 40% of hybrid rice area.

The process of hybrid rice seed production in Vietnam has three categories, including: Super parent seed → elite parent seed → certified hybrid seed. Both the governmental seed companies, join stock companies and private sectors have joined in a national project of hybrid rice seed production and this project will satisfy more than 60% F_1 seed for total hybrid rice area by 2010.

1. Outlook of Hybrid Rice Production in Vietnam

Area: Hybrid rice development was initiated in the year 1992. The area rapidly develops in the period 1998 – 2004 and reach to 600,000 hectares in 2004. From 2005 to 2008 Hybrid rice area is stabile around 580,000 hectares. Hybrid rice is planted in both spring and autumn season of which 60% of the total area of hybrid rice is planted in the Spring season. The adopted ecological regional areas of hybrid rice are located in the North, central highland and part of Southern of Vietnam.



The varieties:

Releasing of the hybrid rice varieties is divided in two periods: The first period was the year of 1992 to 2002. At that time all of varieties area imported from China. Situation chance much after the year of 2004 to 2008: most of the released varieties are bred in Vietnam such as Vietlai20 (first national variety), Vietlai50 (super hybrid rice variety), Vietlai24 (bacterial leaf blight resistance variety).

Table 1. Hybrid Rice Varieties Release in Vietnam

Name	Year	Breeding Country	Growing duration	Season
Shan you 63	1992	China	140	Spring
Bo you 64	1994	China	120	Autumn
Shan you Q99	1995	China	135	Spring
Jink you Q99	1996	China	105	Autumn
II you 63	1998	China	140	Spring
II you 838	2000	China	140	Spring
D you 527	2002	China	135	Spring
Trang nong 15	2002	China	140	Autumn
HYT 83	2004	Vietnam	140	Spring
Vietlai 20	2004	Vietnam	95	Autumn
TH 3-3	2005	Vietnam	130	Spring
Vietlai 24	2007	Vietnam	90	Autumn
TH 3-4	2008	Vietnam	135	Spring
BTE-1	2008	India	105	Dry season
Vietlai 50	2008	Vietnam	105	Autumn

The yield:

Average yield of hybrid rice in large scale is range from 30.0% to 44.7% higher than inbred pure line varieties. Seven years later (2000 – 2007) the yield of hybrid rice is stabilize and rounding 6.40 to 6.60 tons per hectare.

Table 2. Hybrid Rice Yield in Vietnam

Year	Hybrid Rice yield (ton.ha-1)	Inbred Rice yield (ton.ha-1)	Comparing with Inbred Rice
1992	5.77	4.20	137.4%
1994	5.84	4.30	135.8%
1996	5.85	4.41	132.7%
1998	6.54	4.52	144.7%
2000	6.44	4.63	139.1%
2002	6.36	4.74	134.2%
2004	6.35	4.76	133.4%
2005	6.50	4.83	134.6%
2006	6.32	4.86	130.0%
2007	6.58	4.91	134.0%

2. Hybrid rice seed production

The yield:

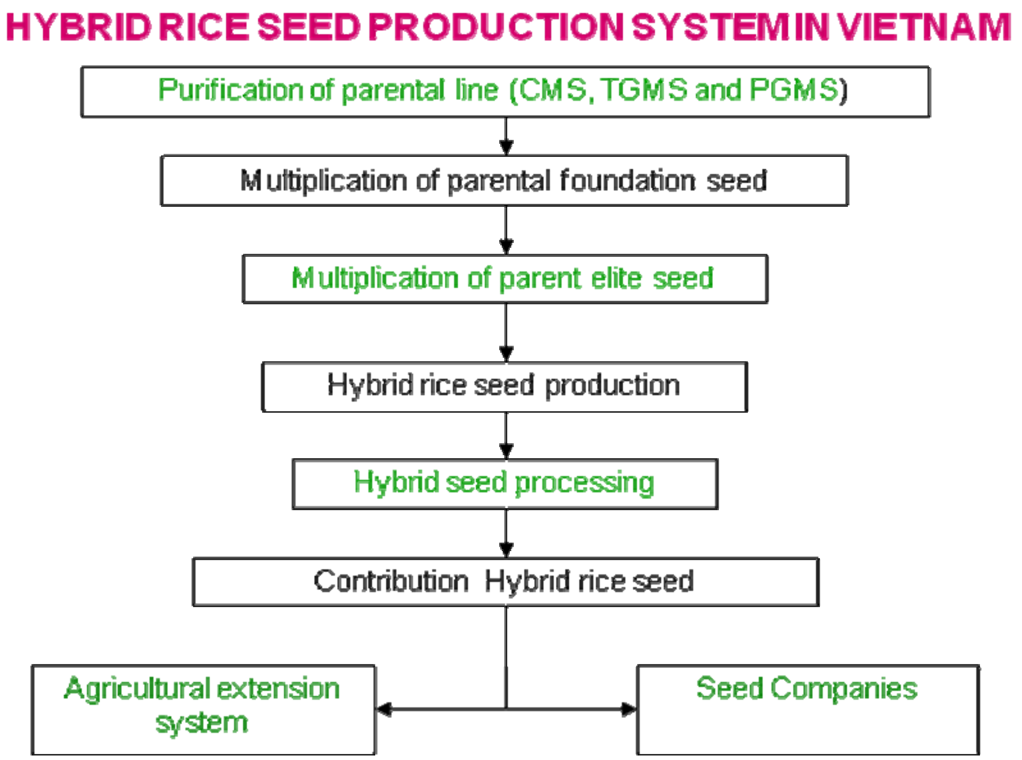
The average yield in seed production were below 1.0 tons per hectare (1993 – 1995) , 2.0 tons per hectare (1996 – 1997) and more than 2.1 tons per hectare in the period 1998 – 2007. The highest of yield was recorded in 2007 (4300kg ha^{-1}) in Vietnamese variety Vietlai20 in Haiphong.

Table 3. Yield of hybrid rice seed production ($kg.ha^{-1}$)

Year	Average	Highest
1994	484	1510
1996	1751	2600
1998	2200	2800
2000	2300	3500
2002	2400	3800
2004	2420	3900
2005	2100	4100
2006	2200	4200
2007	2510	4300

The system

The below is hybrid seed production management system in Vietnam



The Technology

Table 4 is showing main elements of hybrid rice seed technology carrying on variety II you 838 (the imported variety from China) and Vietlai20 (the variety bred in Vietnam). The big differentiation recognize on synchronization of flowering, GA_3 application and supplementary pollination. GA_3 spraying on II you 838 is 250gr per hectare when only 90gr per hectare on Vietlai20. This differenciation bring expenditure of GA_3 application on Vietlai20 is 160gr lower than application on II you 838.

Table 4. Elements of hybrid rice seed production technology in Vietnam

Elements		Varieties		
		II you 838		Vietlai 20
1	Time of sowing	Spring		Autumn
2	Male & female ratio	2:12-2:14		2:16-2:18
3	Isolation	50 m and 21 days		50 m and 21 days
4	Synchronization	+21 days to female		-6 days to female
5	Rouging	Stages: Tillering, before heading and harvesting		
6	GA3 Spraying	250 gr ha-1		90 gr ha-1
7	Supplementary pollination	By rope		By stiring
8	Seed control	Field inspection before harvest		
9	Processing and labeling	1 kg		1 kg
10	Seed Testing	Seed vigor, germination, 1000-weight grain		

The Economy

Table 5 shows economic effect carrying for the farmer when made production of hybrid rice seed of variety Vietlai50. Very high income bring for the farmer when the yield of hybrid rice seed is 3.0 tons per hectare: There are 21 millions VND and 3.23 millions VND on hybrid rice seed production and conventional rice production respectively.

Table 5. Economic effect of hybrid rice seed production of Vietlai50 variety (red river delta)

Elements	Seed production Vietlai 50 variety (1000 VND)	Conventional rice production (1000 VND)
Fertilizer	**5,270**	**7,230**
Labor	**13,500**	**8,310**
GA3	**840**	**0**
Chemical	**810**	**550**
irrigation	**1,680**	**1,680**
Total Expenditure	**23,100**	**17,770**
Total Income	**45,000**	**21**
Economic effect	**21,900**	**3,230**

3. Future prospect

- Increase quantity of hybrid rice seed production in Vietnam, decrease that of import deed.

- Purifying parental seed that focus on national two line hybrid rice varieties.
- Improving hybrid rice seed technology to:
    - Yield of F1 seed production: more than 3000 kg ha^{-1}
    - Decreasing price of F1 seed to 1 USD per kg.
    - Specialization of hybrid rice seed production as a profession in crop production.
- Increase the amount of hybrid rice seed production in country from 25% (2006) to 60% (2010)

What's Wrong with Using Rice for Ethanol?
The Power of Hybrid Rice

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Abstract

Use of grains for producing ethanol appears to be unethical. The general public opinions are against using grains for ethanol, this is because that ethanol production using food would push up the food prices further more. Recalling the situation for the farmers in the world in the past that they have suffered from low prices of agricultural products, the price hikes in agricultural products during the recent years are the first experience in years of low prices.

The subsidies for ethanol in the U.S. boosted corn prices as oil prices went up. Because grains are substitute with one another to a certain extent, increases in prices of one crop soon push up prices of the other grains. However, agricultural products are fundamentally different from oil. Agricultural commodities can be produced practically everywhere in the world and they are subject to be spoiled eventually, whereas oil is produced only in limited areas in the world and it does not get spoiled even if it is left alone for a long time.

Therefore, agricultural products have a fate to be overproduced and plunged market prices in the long run. Besides, per capita rice consumption in the world has been declining. If there are no expansion of demand for rice, it gets easily over-produced. Accordingly, it is important to develop new markets for rice. The new markets can be for producing ethanol using rice as well as feeding rice for livestock. This way, the rice prices would be kept higher than supposed to be, and this should benefit the rice farmers.

There are some arguments that high food prices would harm the poor. It might be so in the short run. However, the financial benefits for the farmers from the high agricultural prices should eventually expand to the poor in the long-run.

Producing rice in lower costs using the hybrid rice should have a strong potential for boosting rural economy in Asian countries. Rice production has to be diversified into high quality rice for direct human consumption with high prices and the processed for those including ethanol with low prices. This way, Asian agriculture, which is centered in rice production, should survive for the future.

Key Words: Global, rice prices, bio-energy, rice supply/demand

I. Introduction

Whether food should be used for energy or not is a major and sensitive issue, while the global price hikes of grains as well as soybeans and other agricultural products are calming down since July 2008. Riots over the high food prices have been reported from many developing countries during the last two years. Poor people at poverty line, in particular, are at risk for life with the high food prices.

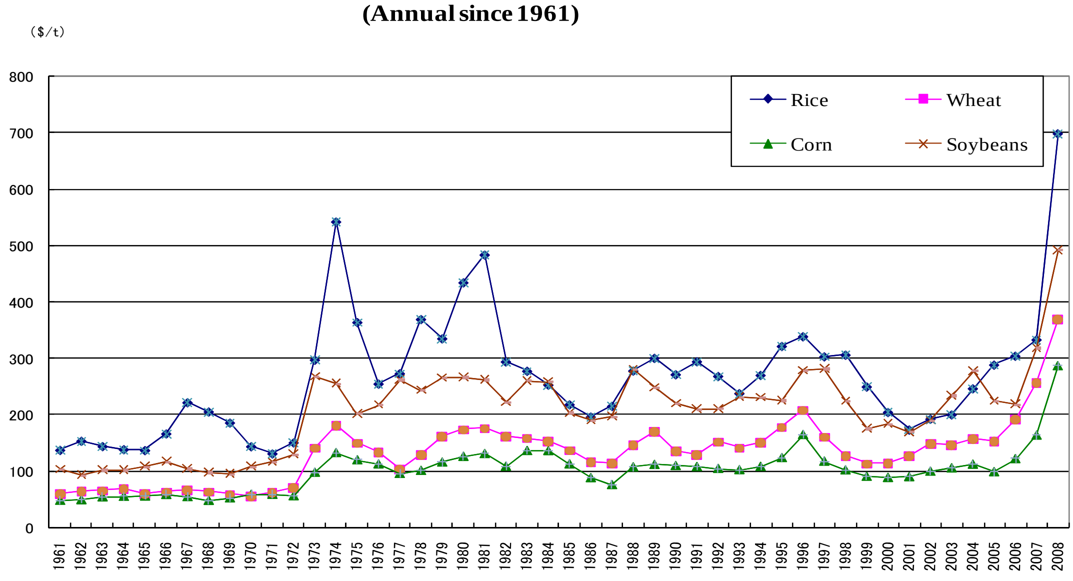
Those rising prices of grains and soybeans originated the rising oil prices and the announcement of the U.S. government for subsidizing the ethanol production. The enormous amount of corn is being used for ethanol in the U.S. Accordingly, as speculative investments for oil led the oil prices higher and higher towards the early July 2008, the corn market prices also began to rise. Certainly, corn prices for livestock feeding and other uses also surged.

In this paper, it is attempted to theoretically rationalize use of grains and oil crops to produce ethanol and other bio-energy for the global benefits as well as the agricultural producers in both developed and developing countries. To do this, price movement mechanism among the oil and crops is reviewed, first, then, farm incomes, production potentials for rice in the world are argued for promoting use of rice, especially hybrid rice, for bio-energy.

II. Price Movement in Crops

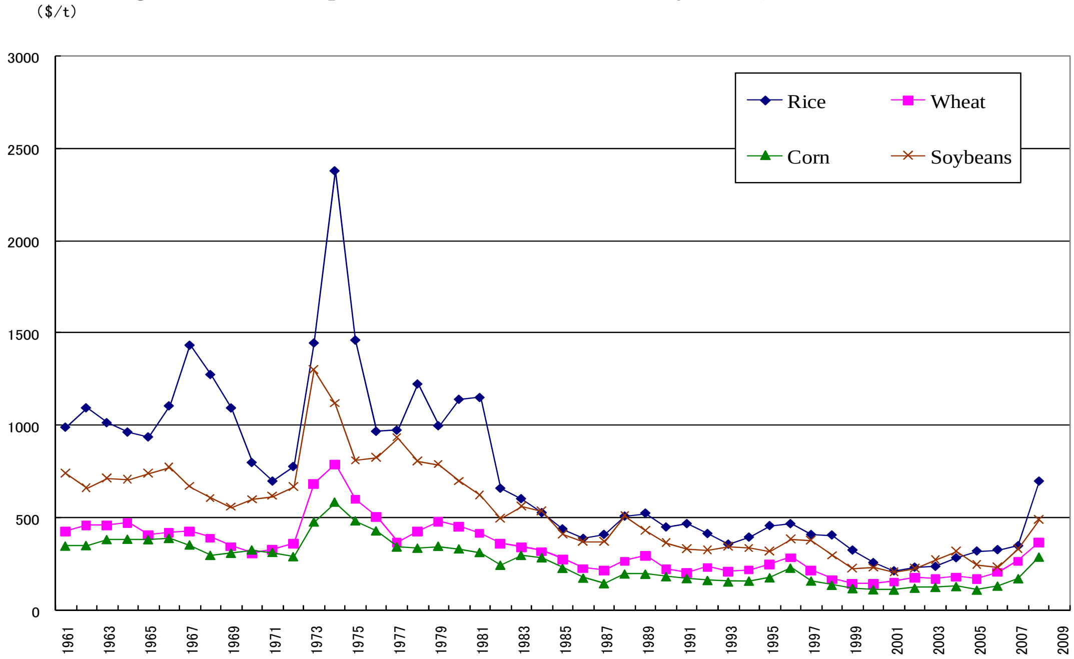
Historically since the 1960s, crop prices of rice, wheat, corn and soybeans have fluctuated dramatically from time to time. Fig. 2-1 shows the nominal price movements of these major crops during the last 5 decades. The prices increased sharply in the early 1970s and some around 1980. The current high prices in 2008 appear to be no comparison to those in the past in these nominal price figures. However, Fig. 2-2 shows the same source of prices in the real term which converts the nominal prices to real prices using the consumer-price-index (CPI). This figure shows the price level from the current point of view, that is, it shows the price level based on our current currency value. In this respect, the prices in the 1960s were already quite high, and the spikes during 1973 and 1975 were extremely high. In the case of rice, it were as if 2,400 US dollars per ton (milled-base) . Note that this is the average price for the whole year. The current 2008 market prices, on the other hand, are not the average of the year but only the average during the first 8 months in 2008, and they are still way below the early 1970s level, roughly half for wheat, corn, and soybeans and less than a third for rice.

Fig. 2-1. Nominal world prices of rice, wheat, corn and soybeans (Annual since 1961)



ｿｰｽ：IMF：International Financial Statistics（IFS）の年次ﾃﾞｰﾀを直接使用している（http://ifs.apdi.net/imf/）
注1：最近年のﾃﾞｰﾀは、その年の月次ﾃﾞｰﾀの平均値で示す。
注2：コメ：Bangkok, 5% broken, milled. コムギ：No.1, Hard Red, US Gulf. コーン：Yellow No.2, Gulf. ダイズ：U.S. c.i.f. Rotterdam.
注3：Calendar year. 注4：実質価格は2008年のアメリカの消費者物価指数（CPI）を100として計算した。

Fig.2-2. Real world prices of rice, wheat, corn and soybeans (Annual since 1961)



ｿｰｽ：IMF：International Financial Statistics (IFS)の年次ﾃﾞｰﾀを直接使用している (http://ifs.apdi.net/imf/)
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注3：Calendar year. 注4:The real prices are calculated with the US 2008 consumer price index (CPI) to be 100 as the base year.

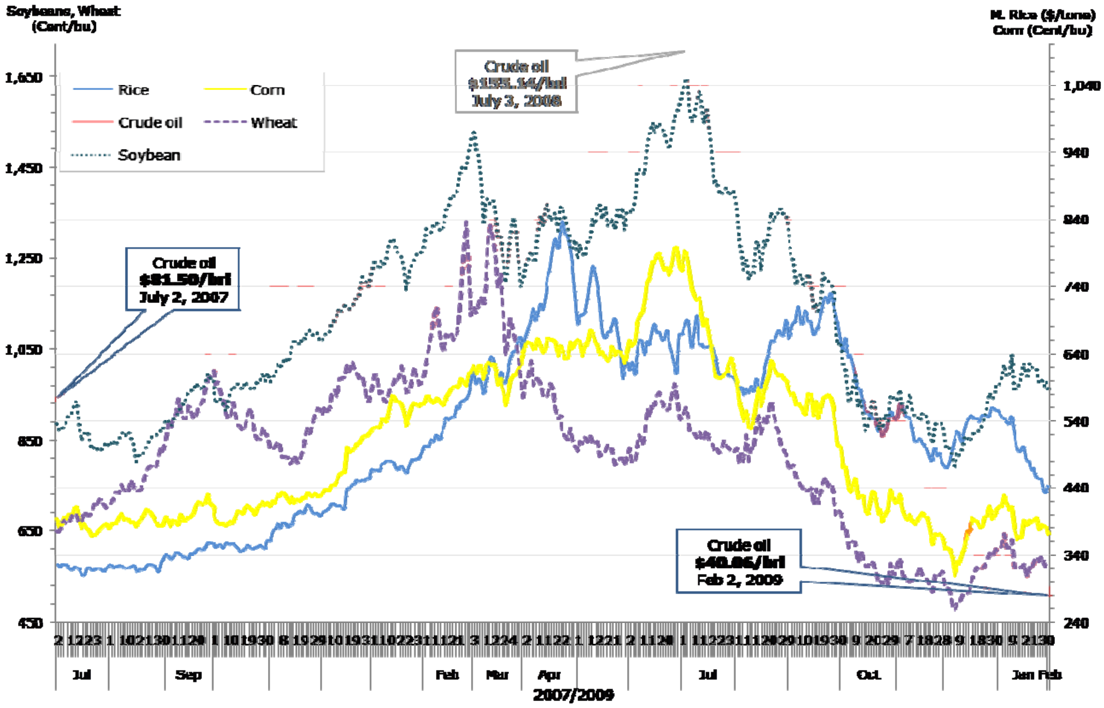
The overall downward trend of real prices implies that production costs have been decreasing over time due to technology improvement. During this almost 5 decade period, production increased approximately 3 times to 4 times depending upon the crops. During this period, the world population increase only slightly over 2 times from 3 billion people to 6.5 billion people.

The price movements among those major crops are in harmony with rising together and declining together, although some lags for a year or so occasionally exist. This harmonized price movement strongly indicates that those commodities are substitutes with one another. In food, feeding, and processing, they are certainly used as substitutes with each other to a certain degree. In Japan, it has been reported that rice consumption has bee increasing since last year due to higher price of bread, which was derived from the raised price of imported wheat.

Now, the influences of oil prices on commodity prices are examined. Fig. 2-3 shows daily price movements among the oil (WTI), rice, wheat, corn, and soybeans (CBOT prices) during July 2007 to the early February 2009. It is quite surprising to see the ag-prices (of the four crops) are moved along with the change in prices of oil not only during the whole period but day-by-day basis. Because of the situation that a large amount of corn is being used for producing ethanol which is a substitute for gasoline, the oil price should influence the corn prices which also influence other ag-prices such as rice, wheat and soybeans. The prices of soybeans, in particular, are more directly influenced by the oil prices since soybean oil can be converted to diesel. They influence one another almost instantly, and changes in oil prices influence all of the ag-prices almost directly. At least, the bidders act so at the exchange markets.

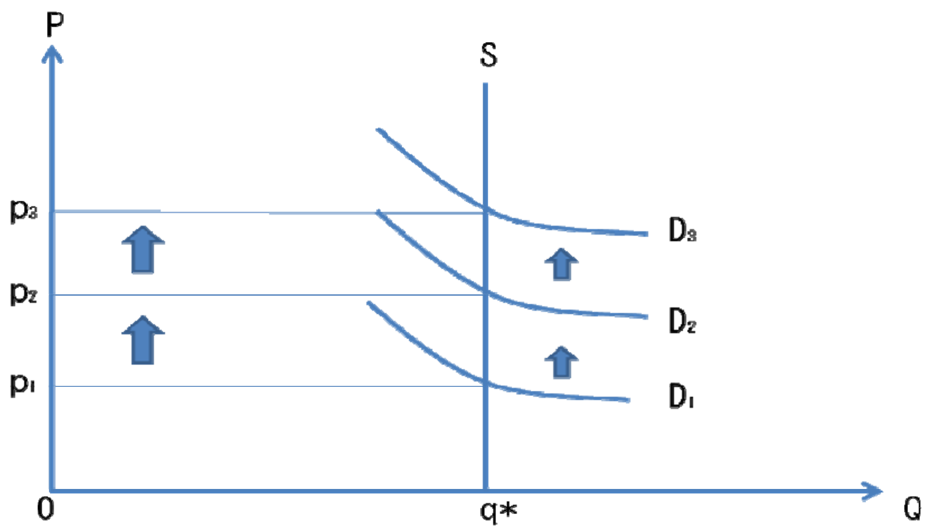
Therefore, once the oil prices are speculated by the bidders and bid to higher prices, all of the ag-prices also get speculated for higher prices. This is why the daily price movement of the ag-prices are so close to that of oil prices. Accordingly, ag-prices can be raised up unreasonably high by the bidders. Fig. 2-4 shows the relationship between the supply curve, which is completely inelastic in the short-run, and the speculative demand.

Fig. 2-3. Daily Price change of Oil, Rice, Wheat, Corn and Soybeans in the U.S
(Daily Prices, July 2, 2007 - Feb 2, 2009)



Rice prices are reported on orginal website in the rough rice basis in unit of US$/cwt. Milled rice price data were calculated from equation: Original data multiplied by 1000/(45.36*0.6) for 1 ton, which implies approximately equivalent to 4-percent-broken milled-rice package for U.S. No.1.
Source: GFT - Online Futures Trading, http://futures.tradingcharts.com

Fig. 2-4 Mechanism of price hikes in speculation



The oil prices peaked at 155 US dollars on July 3, 2008 and then started declining, dropping to around 40 dollars a barrel in the early February 2009. The ag-prices also generally declined along with the oil prices. If, however, oil prices rise again, the ag-prices can also move upward direction.

A basic regression analysis was conducted to evaluate the relationship between the oil rice prices during July 2007 to the early August 2008 with the daily market data. The results are as follows:

$$\text{Price} = -4.06 + \underset{(0.007)}{0.180}\,\text{Poil} - \underset{(0.063)}{0.341}\,\text{RTDRICQ} + \underset{(0.03)}{0.0340}\,\text{SDVXB} + \underset{(0.31)}{3.33}\,\text{DTHS}$$

R^2=0.917, DW=0.254, N=276, Data daily basis, ( ) are standard errors

Where,

Price: price of rice, rough, per cwt, Chicago Board of Trade, CBOT

Poil: price of oil per barrel, West Texas Intermediate (WTI), NYMEX,

RTDRICQ, SDVXB, and DTHS: trend and dummy variables

In this preliminary result based on the daily data during July 2007 and September 2008, the estimated coefficient for the oil price is statistically significant and indicates that price of rice positively moves upward by 0.18 dollars per 100 pounds (CWT) of rough rice as price of oil increase by 1 dollar per barrel. The similar results are basically anticipated for other ag-prices.

Wheat prices started falling in March 2008, while the oil prices were still rising. With the bumper crop estimates in the U.S. and the global total for this year, then wheat prices started declining. This indicates that supply and demand situation in each commodity of agriculture still uniquely influence the market prices. Therefore, prices of rice and wheat, in particular, may drop faster than the others due to the fact that the use of rice and wheat for ethanol and fuel production is quite limited relative to corn and soybeans at this moment.

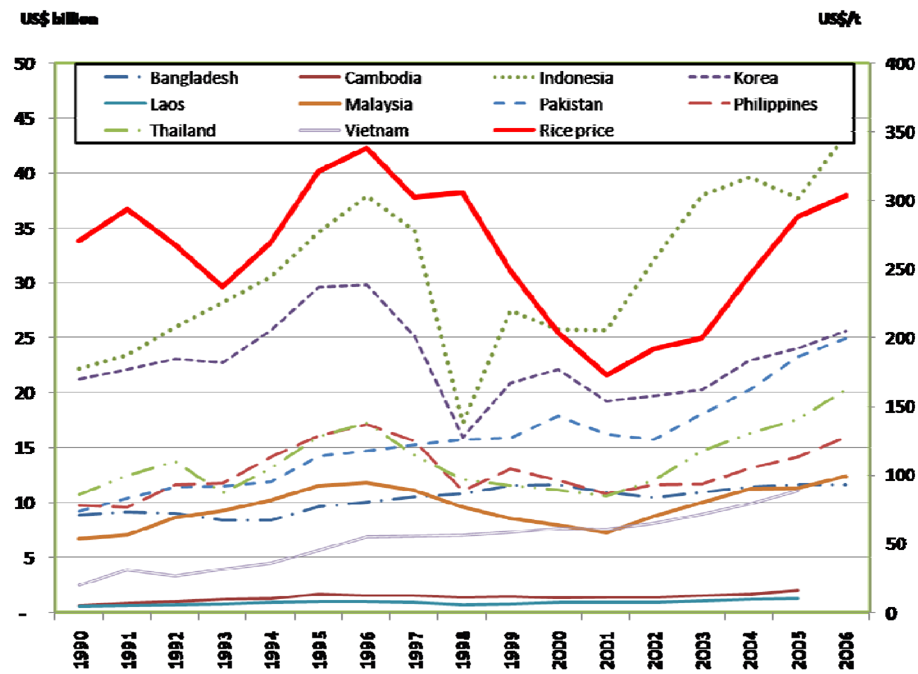
III. Income Growth for Producers

Agriculture is the major source of income in many developing countries accounting for about 30 % in the total GDP (gross domestic products) in each country. In 2005, agricultural GDP accounts for 20%, 34%, 45%, 22% and 21% relative to the total GDP in Bangladesh, Cambodia, Laos, Pakistan, and Vietnam (World Development Indicator (WDI) Online Data).

The agricultural GDPs are heavily influenced by agricultural prices. In Asian developing countries, for example, world prices of rice and the domestic agricultural GDP shows strong correlations. The Fig. 3-1 shows the situation in the ASEAN countries during 1990 and 2006. Except for the financial crisis in 1998, the agricultural GDP in individual countries are positively related with the rice prices. During the recent years when the rice prices have been rising, the agricultural GDPs have also been rising in the most of the countries, while they showed some drops along with the rice prices around 2001.

As mentioned earlier, the prices among the crops more-or-less move together due to the fact that they are substitute, to a certain extent, with one another. Therefore, when rice prices are high, price of other crops are also high. These high prices together push the agricultural GDP upward.

Fig. 3-1. Change in Agriculture GDP along with World Rice prices in ASEAN Countries, 1990-'06



Source: World Development Indicator (WDI) online data
http://worldfood.apionet.or.jp/pricechart/chartE/No1-3.htm

Under the current increases in oil prices, the input prices have gone up as well. In the recent study, however, the increases in market prices of crops are much greater and the producers in the U.S. are expected to make a record of net income in 2008 (Taylor and Koo, 2008). According to the surveys in Vietnam, Cambodia, and Laos done by the authors also show that the producers may have made much more agricultural income during the recent years under the high market prices after admitting that the input prices have risen some. Rice millers, in particular, collected unusually larger amount of rice this year than previous years. Additionally, the rice millers have been making significant amount of income from the rice-bran which is purchased by the livestock producers at high prices because of the ordinary feedstuff being already expensive.

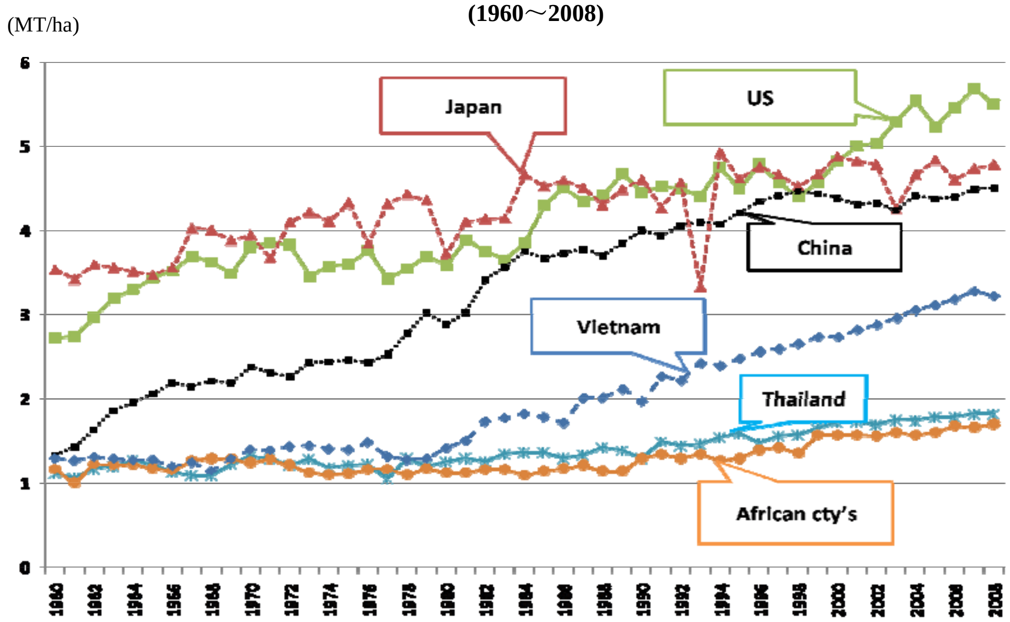
In this situation, the economy in the rural areas in developing countries must be booming under the high crop prices in the developing countries as well. This should encourage more production of crops in the region rendering more food supply in the area in the long-run.

Further, the growth in economy in the rural areas should keep people from migrating to the city areas from the rural. Lee (2008) states clearly that “the basic scarcity of income sources and job opportunities plus rapid out-migration from countryside are the causes of more and faster shrinking of rural economies. …. ever—widened gaps of living standards between rural and urban areas including infrastructures, welfare and social safety net and relative inferiority and belatedness to urban areas are encouraging out-migration escaping from countryside no later than too aged.”

IV. Potential for Production Growth of Crops

The technology improvement has pushed yields of crops upward over time. Fig. 4-1 shows the growth in yields per hectare for rice in Japan, the U.S., China, Vietnam, Thailand and African countries. At the beginning of 1960s, Japanese rice yields were at the top among the four countries/region and remained the highest until around 1990. Afterward, however, the yields in the U.S. continued to grow while the Japanese yields got stagnated rendering the U.S. yields atop the rest of the world. In Japan, increase in rice production has not been a target since the 1970s, while the producers in the U.S. can earn more subsidies and income as they increase their yields under their farm bills. This may have made the difference between the two countries.

Fig. 4-1. Evolution of rice yields in Japan, U.S., China, Thailand, and Africa (1960～2008)



Note; Africa shows the average of the rice producing countries in Africa.
Source : Ito: The World Food Statistics and Graphics http://worldfood.apionet.or.jp/graph/index.html/, Aug.2008

The growth of Chinese yields is remarkable. At the beginning of the 1960s the Chinese yields were just about the same level as Thailand and Africa at 1.3 tons per hectare. However, they increased dramatically and reached 4.5 ton level by the late 1990s. This more than 3 times growth of the yields appears to be quite unusual among the rice producing countries, but the Chinese people realized this great establishment.

The Vietnamese have also established a tremendous increases in rice yields after their civil war, which ended in the mid-1970s. Their average rice yields were rather similar to those in Thailand and African countries around 1.3 tons per ha until the 1970s; however, the Vietnamese yields took off in the 1980s and increased to 3.3 tons by 2007. The cases of China and Vietnam tell us that the yields can be increased dramatically if the people really try hard. Meanwhile, those in Thailand and Africa did not grow much during the 5 decades remaining less than 2 ton level even in the 2000s.

The low yield achievement in Thailand and Africa, however, do not mean that their soil situation was unfertile. The experiments in the past showed that yields in African countries could be as high as those in the developed countries if the appropriate procedure for rice production was provided. Sufficient investment such as in irrigation, in particular, is important to improve the yields. If the market prices are low, investors becomes reluctant to spend money for agriculture. Also, producers may not be so enthusiastic to increase yields under the low prices, and they tend to spend more time for their off-farm work for cash income.

If, however, the commodity prices increase, then producers get more serious to produce more, and public/private investment in agriculture gets more attention. Accordingly, it is not unusual to find high yields when prices are high in various countries.

It is well reported that high oil prices also brought to farmers more expensive fertilizers and chemicals. It may be true. However, the producers tend to find alternative ways to put fertilizers. They may increase application of manure and compost of organic matters to reduce costs as well as they pay more attention to management of farm as prices go up. In many ways, they try hard to increase yields. Accordingly, these high ag-prices should increase yields of individual corps dramatically if the current high prices remain. This should happen to African countries without exceptions. This rice situation is also true in other crops such as wheat, corn and soybeans.

Weak economic performance generally discourages agricultural production. The Russian case in crop production in the 1990s strongly indicates that the decline of production was due to economic failure in the country. An economic growth in Russia should increase agricultural production significantly.

V. Conclusion

The more demand, the better for the producers. Ethanol production using grains is a new demand for crop producers. Together with other demand, the producers can generate more income as demand gets stronger. It may be true that high food prices can jeopardize the food security in a country. However, food security is more needed in developing countries, and the less developed countries depend on agriculture more. The less developed the country, the more people dependent on agricultural activities in the rural areas. The low farm prices can negatively affect the development of agriculture in the developing countries.

While the global population grows continuously, demand for individual crops does not necessarily grow. The global demand for wheat got stagnated after 1990 causing low wheat prices and less production of wheat in the world. Per capita rice consumption in the global average has been declining trend since 2001, so is wheat since the mid-1980s. The total rice consumption has not being increasing as expected before and it will not grow for the future as expected before (Ito, et al, 1989; Ito and Kako, 2005; Smil, 2004; and Ito, et al, 2007). Only production of corn and soybeans among the major crops increased significantly led by the greater demand during the last two decades; corn for feeding and soybeans for oil and soybean-meal which is heavily used for feeding as well (Ito, 2008).

Overall, however, the prices were detrimentally low just before the surge in the recent period derived by use of corn for ethanol and the subsidy for ethanol in the U.S. The rise of crop prices in the world has provided the crop producers in the world with a tremendous opportunity to make more profits in not only in the developed countries but also developing. Given that more share of the people depend on agriculture in the developing countries than the developed, the high prices of crops bring relatively more benefits to the developing countries in the long-run.

Certainly the food must be secured for the poor people. An export ban of food during high food prices in exporting country may not be an appropriate measure to secure food (Nguyen, et al, 2008). A boost in production derived from higher market prices should end up with more supply of food from the domestic agriculture together with more farm income in developing countries. Production of bio-fuel using cellulose and other non-food products should be encouraged as well. Both from food crops and non-food materials can increase demand for agriculture in the long-run, and the agriculture as a whole shall bring more welfare to the society than before.

Especially the hybrid rice, for which production costs per unit generally lower due to higher yields, can become a vital source of ethanol production. Rice demand for human consumption is getting weaker, and rice areas would have to be reduced along this trend. Given that Asia accounts for over 90% of the global rice production, the reduction of rice areas would damage Asian agriculture and this would prolong the poverty problem in Asian rural areas. If hybrid rice is being planted and used for not only ethanol but feeding taking advantage of lower costs, that should revitalize the Asian agriculture and bring a tremendous amount of economic benefit to the Asian rural areas.

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Session 1

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Genomics-Based Germplasm Enhancement and a New Paradigm in Rice Breeding

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Abstract

The whole-genome sequence information of rice has provided new tools for genetics and has created a new paradigm of plant breeding. Many phenotypic traits of economic interest are controlled by multiple genes and often show complex and quantitative inheritance. Recent progress in rice genomics has had a great impact on the genetic dissection of such complex traits into single genetic factors. Such genetic factors can subsequently be identified at the molecular level by map-based strategies. So far, my colleagues and I have identified several genes involved in heading date, field resistance to rice blast, cool-temperature tolerance, and pre-harvest sprouting, and genetic dissection of root morphology and yield-related traits is progressing. We have begun marker-assisted introgression of particular genes of interest into elite rice cultivars. Exploitation of economically important genes in natural variants will be essential to enhancing the potential of new breeding strategies made possible by genomic analysis. Several mapping populations, such as recombinant inbred lines and chromosome segment substitution lines, will allow us to extract useful alleles from natural variants. Genetic analysis allows us to identify tightly linked markers, and nearly isogenic lines of elite cultivars for target QTLs can be readily and quickly developed by marker-assisted selection. Several different genes derived from the same or different cultivars can be introduced into elite cultivars by gene pyramiding. To enhance the capacity of allele mining using a wide range of germplasm, we have embarked on the genome-wide detection of single-nucleotide polymorphisms (SNPs) using a next-generation sequencing strategy. SNP discovery will lead to the development of an array-based SNP genotyping system which will facilitate effective use of diverse germplasm in rice breeding. Recent advances in rice genomics will serve as a launching pad for the effective exploitation and use of natural variations in rice breeding.

Key Words: Complex traits, map-based cloning, marker-assisted selection, gene pyramiding, single nucleotide polymorphism

Introduction

It is about 4 years since the whole rice genome was decoded (IRGSP 2005). The sequence information has provided new tools for genetics and has created a new paradigm of selection strategy in plant breeding. Many phenotypic traits of economic interest are controlled by multiple genes and often show complex and quantitative inheritance. Recent progress in rice genomics has had a great impact on the genetic dissection of such traits into single genetic factors or quantitative trait loci (QTLs) (Yamamoto and Yano 2008). These resources have already contributed to both our understanding of biological phenomena in plants, and to the application of genomics tools to the development of new crop cultivars. Genes with agronomic value have been tagged by DNA markers and have been introduced into elite cultivars by marker-assisted selection (MAS). Technological innovations in large-scale sequencing and genotyping have opened new possibilities in rice genetics and breeding. This paper introduces our recent activity on the genetic dissection of complex traits, marker-assisted introgression, and pyramiding of agronomic traits, and future prospects in genomics-assisted breeding of rice.

Uncovering the naturally occurring variations in complex traits

In the last decade, much effort has been paid to the genetic and molecular dissection of complex traits. An excellent example is the analysis of heading date in rice. Heading date is a key determinant for the adaptation of rice to different cultivation areas and cropping seasons. Therefore, control of heading date is a leading objective in rice breeding. Many genetic studies have been conducted for QTL mapping of heading date using advanced backcross progeny (Yano et al., 2001). Fifteen QTLs, called *Heading date* (*Hd*)*1–Hd3a* and *Hd3b–Hd14*, have been detected by using several kinds of progeny from a cross between *japonica* cultivar 'Nipponbare' and *indica* cultivar Kasalath (Yano et al., 2001). Among them, nine QTLs—*Hd1*, *Hd2*, *Hd3a*, *Hd3b*, *Hd4*, *Hd5*, *Hd6*, *Hd8*, and *Hd9*—were mapped as single Mendelian factors (Yano et al., 2001; Lin et al., 2000; 2003). Detection of QTLs for heading date has allowed further genetic analyses, such as the development of nearly isogenic lines (NILs), analysis of epistatic interactions among QTLs, and map-based cloning. *Hd1* has been found to encode a protein with zinc finger and CCT motifs and to be an ortholog of *Arabidopsis CONSTANS* (Yano et al., 2000). *Hd6* and *Hd3a* were found to encode a casein kinase 2 alpha and an *Arabidopsis* FT-like protein (Takahashi et al., 2001; Kojima et al., 2002). A major QTL, *Early heading date 1* (*Ehd1*), for heading date was detected on chromosome 10 by using a BC_1F_1 population derived from a cross between cultivar T65 and an accession of another cultivated species, *Oryza glaberrima* (Doi et al., 1998). Further analysis revealed that *Ehd1* encodes a B-type response regulator (Doi et al., 2004). In all cases of QTL cloning for heading date, large-scale linkage mapping was required to narrow the candidate genomic region for the QTLs. These efforts led us to identify functional nucleotide polymorphisms in *Hd1*, *Hd6*, and *Ehd1*. To comprehensively dissect the genetic factors controlling naturally occurring variations in rice flowering, we have performed a QTL analysis using 12 populations derived from crosses of the *japonica* cultivar Koshihikari with cultivars and lines that originate from various regions in Asia. By QTL mapping, several QTLs were detected on the 12 rice chromosomes, some of which were shared among the different cross combinations. The chromosomal locations of these QTLs corresponded to those detected in Nipponbare and Kasalath (Yano et al., 2008). However, the allelic effects of each QTL varied among the parental combinations used, suggesting that a large proportion of the wide range of phenotypic variations in flowering time could be generated by the combination of different alleles of the corresponding QTLs. These genetic and molecular studies have definitely contributed to our understanding of heading date in rice (Izawa, 2007; Tsuji et al., 2008).

Much effort has also been paid to the analysis of other complex traits, such as grain size, shattering habit, disease resistance, and environmental stress tolerance. These activities are summarized in the “Gramene-QTL” database (Jaiswal et al. 2002). Around 8000 QTLs have been detected so far. Among them, several with major effects have already been cloned by a map-based strategy (Yamamoto and Yano, 2008).

Current status of marker-assisted selection in rice breeding

Once genes controlling traits with economic and agricultural interest are cloned or mapped precisely on the respective chromosomes, it becomes possible to use information such as gene sequences and chromosomal locations in breeding programs. Since the paradigm of MAS emerged nearly 20 years ago, much effort has been invested in the practice of MAS. Several examples of the development of NILs with particular traits in elite cultivars have already been reported. Submergence by deep water causes severe stress to rice in Southeast Asia, where flooding occurs during the monsoon season. A major QTL, *Submergence 1* (*Sub1*), was detected near the centromere of chromosome 9 (Xu et al., 2000). The underlying gene was cloned (Xu et al., 2006), and the *Sub1A* allele was introgressed by MAS into an elite cultivar grown widely in Asia. The resultant lines showed promising performance in yield and other agronomic traits, as well as tolerance to submergence (Neeraja et al., 2007; Septiningsih et al., 2009). Four QTLs for rice heading date—*Hd6*, *Hd1*, *Hd4*, and *Hd5*—were introgressed from Kasalath into Koshihikari by MAS to enhance the cropping potential of Koshihikari, one of the leading cultivars in Japan (Takeuchi et al., 2006). As a result, NILs of Koshihikari with early and late heading dates have been successfully developed. The size of the introgressed chromosomal segments in those lines was very small: 300 to 600 kb in NILs for *Hd1*, *Hd6*, and *Hd5*. Precise information on the chromosomal locations of the genes allowed breeders to minimize the length of the substituted chromosome segments containing the target QTLs. That study clearly demonstrated the potential power of MAS in rice breeding. MAS also offers a new concept in breeding: Once NILs with particular economic value are developed, gene pyramiding can be performed by simple crossing between them (Ashikari and Matsuoka, 2006). To develop a new line with lodging resistance and high yield, the combination of two genes controlling semi-dwarfing and grain number were successfully introduced into Koshihikari (Ashikari et al., 2005). This concept can also be applied to multiple genes controlling specific traits. Four QTLs controlling partial resistance to rice blast in upland rice have been successfully pyramided into lowland rice cultivars by MAS (Fukuoka and Saka, 2006; Saka et al., 2007).

Allele mining for rice breeding

Many successes have been achieved in cloning and MAS of particular QTLs in rice. However, these successes have largely depended on allelic differences. In most cases, the allelic difference was relatively large, allowing reliable determination of the chromosomal location. One major QTL, *Grain number 1a*, was successfully isolated by a map-based strategy (Ashikari et al., 2005). This finding contributed both to our understanding of the genetic control of spikelet development in rice, and to MAS to improve grain number per panicle. However, in general, one major QTL alone is not enough to acquire the level of phenotypic performance needed. To this end, it would be necessary to combine genes with major and minor effects. Owing to the statistical power of detection, it is usually very difficult to detect QTL with minor effects in QTL analysis using F_2 and recombinant inbred lines (RILs). To solve this problem, we developed chromosome segment substitution lines (CSSLs) (Ebitani et al., 2005; Takai et al., 2007; Ando et al., 2008). In these novel plant materials, a particular chromosomal segment from a donor line is substituted into the genetic background of the recurrent line. The substituted segments cover all chromosomes in a whole set of lines. The potential of CSSLs in QTL detection has been demonstrated in many ways. We have established a systematic research flow for exploration and cloning of useful genes (Fig. 1). For example, CSSLs can be used in genetic analysis to associate QTLs with particular chromosomal regions and to quickly develop NILs of target regions containing QTLs of interest. In general, when an association is detected between a chromosomal region and a trait, it is often difficult to validate the QTLs, especially those with very small genetic effects. In such a case, NILs are required in order to analyze genetic effects in detail (Miura et al., 2001; Sato et al., 2003; Ueda et al., 2004). Because CSSLs normally have one chromosomal region substituted, they can be used as NILs themselves or as starting material to develop NILs. Such NILs enable us to combine two or three QTLs in one genetic background in order to clarify epistatic interactions among them (Lin et al., 2000; 2003; Yamamoto et al., 2000).

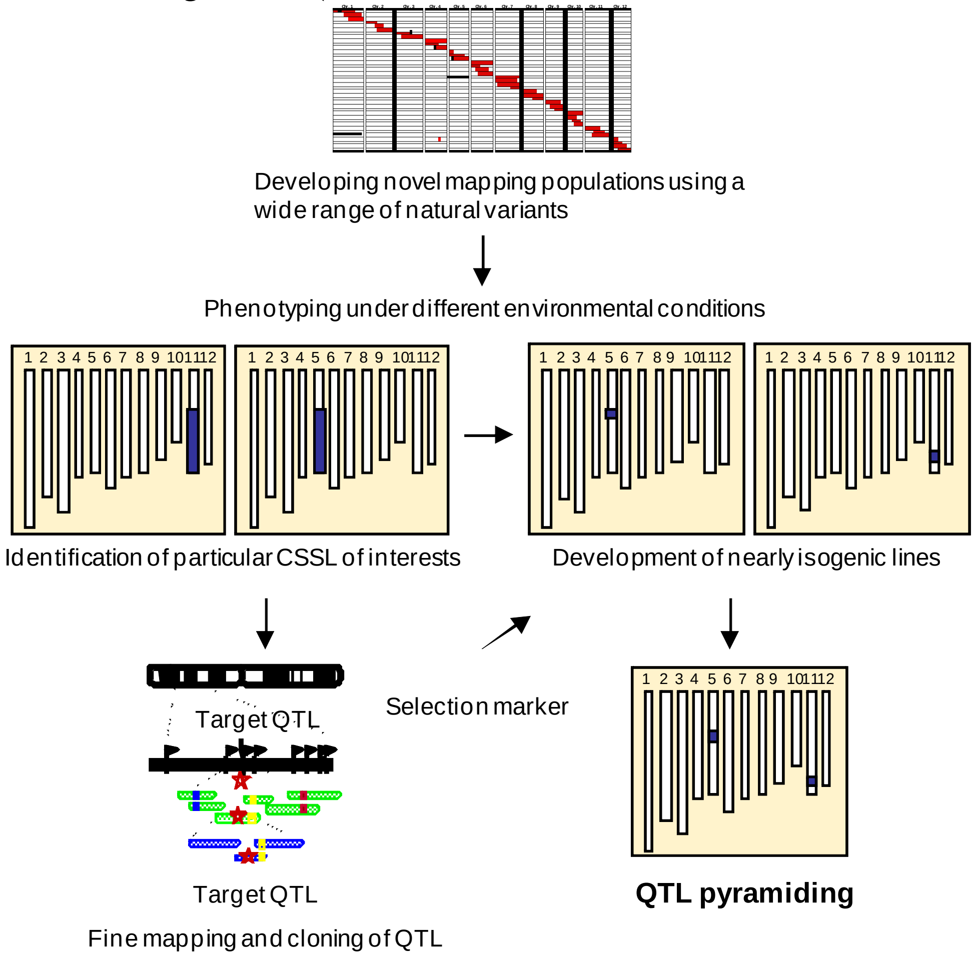

Fig.1 Systematic research flow for the exploration and utilization of natural variations in rice

Furthermore, once we detect significant differences between the CSSLs and the recurrent parental line, comparison of the size of the substituted segments enables us to delineate candidate chromosomal regions of QTLs (substitution mapping). If a significant difference is found between a particular CSSL and the recurrent parent, a large mapping population can be easily produced by a simple crossing of the CSSL with the recurrent parent. Map-based cloning of the QTLs detected can be started quickly by using such plant materials. A simple survey of target traits on the CSSLs allows us to detect minor phenotypic differences with reference to the recurrent parent, because there is almost no effect of background genetic noise (i.e., allelic effect of other QTLs). Although the resolution of QTLs in terms of linkage mapping and the power to detect epistatic interactions are not comparable with those given by primary mapping populations such F_2s and RILs, the use of CSSLs can facilitate the discovery of valuable alleles from donor chromosome segments. To enhance the potential of CSSLs, we are now developing CSSLs from a wide range of cross combinations, with Koshihikari as the recurrent parent. Donor parental lines are *indica* and *japonica* cultivars, including some of our core collections (Kojima et al., 2005).

Genome-wide discovery of SNPs and development of genotyping arrays

The genetic dissection of natural variations requires novel and effective genotyping and phenotyping. New technology recently enabled us to perform massive analysis of sequences (Blow, 2007; Hutchison, 2007). This method, called next-generation sequencing technology, has opened new opportunities for polymorphism discovery (Lister et al., 2009). In Arabidopsis, this system has been applied to two natural accessions to perform genome-wide single-nucleotide polymorphism (SNP) and insertion/deletion (InDel) discovery (Ossowski et al., 2008). This method may provide a unique opportunity to identify nucleotide polymorphisms between genetically closely related strains, such as Japanese cultivars. In addition, a system of simultaneous genotyping of thousands of SNPs on the genome scale has been recently developed (Steemers and Gunderson, 2007). The combination of both new technologies has also facilitated the genetic dissection of complex traits by QTL mapping and whole-genome association studies (Nordborg and Weigel, 2008).

We have detected about 5000 SNPs from our core collection of Asian cultivated rice accessions (Ebana et al., 2007). In addition, we have sequenced the whole genome of Koshihikari by using a next-generation sequencing technology, and have discovered a comprehensive set of SNPs and enhanced the potential power of allele mining among *japonica* cultivars (Nagasaki et al., 2008). An enormous amount of genomic sequences, equivalent to more than 20 genomes, has been obtained for Koshihikari, and a consensus sequence of Koshihikari established from the mapped sequences covers nearly 80% of the reference Nipponbare sequences. Comparison of these two sequences has provided more than 60 000 SNPs. These candidate SNPs were validated by an array-based SNP detection system. These SNPs will facilitate the genetic analysis of traits with economic interest among temperate *japonica* cultivars.

From gene selection to genome selection

The development of a genome-wide SNP typing system allows us to perform large-scale genotyping of recent breeds of rice. We have genotyped a large set of SNPs using landraces, old cultivars, and current leading cultivars (Yamamoto et al., 2008). By including their pedigrees, it has been possible to visualize the genotype of the whole genome (pedigree haplotype) of those successions. This analysis provided valuable information on current rice breeding. For example, we can visualize the proportion of the genome derived from Koshihikari, and which chromosomal regions are shared among current leading cultivars. In addition, recombination events that contributed to the improvement of cultivars can also be identified. Previously, MAS has targeted particular chromosomal regions or genes, because DNA markers are genotyped one by one. However, the simultaneous analysis of a large number of SNPs provides a new concept of selection criteria in breeding: It might be possible to perform selection based on a whole-genome genotype image and haplotype images of particular chromosomal regions.

Future prospects

MAS, developed as an armchair theory about 20 years ago, has now been realized by the accumulation of information on precise chromosomal locations and tightly linked DNA markers flanking genes with major effects. However, its application to rice breeding has been limited in the precision mapping of genes with minor effects and their introduction into elite cultivars. This limitation is not matter of genomics—the tools and information—but depends on phenotyping methods and plant materials; for example, it depends on how we discover useful genes from diverse germplasm and how we establish reliable phenotyping methods. Integration of all resources, such as tools, analytical methods, and plant materials, will be necessary to facilitate further dissection of complex traits with agricultural importance, such as yield performance, drought tolerance, and grain quality. These efforts will make genomic-assisted breeding more effectively and practically.

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Vietlai 50 – A New Super Hybrid Rice Variety Bred in Vietnam

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Introduction:
Releasing in large Scale of Hybrid rice need varieties which bringing for the farmer high yield enough. objective of the this research as following:

- To breed new hybrid rice variety with new plant type and high yielding ability.
- To form high yielding F1 Seed production practice
- To release new variety on the farming condition Vietlai 50 is the result of such breeding program. The TGMS line 135s use as female and inbred line R50 use as restorer.

Materials and methods:
Materials:

- TGMS line: Peiai 64S; 103S; 135S
- Restorer line: R50; R45; 9311; R63; No44; No154
- Check variety: Boi Tap Son Thanh

Methods:

Heterosis effect, on farm testing and evaluation, field experiment follow Hunan Hybrid Rice Research and Development Center – China

Results obtain:
Table 1: Morphological and agronomical characters of 135S line under field in summer season

	Characters	135S line
1.	Day to flowering	78 – 80
2.	Plant height (cm)	86.57
3.	Effective tillers	4.31
4.	Leaf number	14.3
5.	Time of flowering	9h30
6.	Out crossing rate (%)	74.29
7.	Grains panicle –1	239.5
8.	Plant type	New plant type
9	Fertility	Completely fertility
10.	Combining ability	Good
11.	1000 – grain weight (g)	22.0
12.	Stigma exertion rate (one sides) (%)	37.22
13.	Stigma exertion rate (both sides) (%)	41.8
14.	Effect of GA3 to seed set (%)	87.82

Table is showing main character of female TGMS line 135S. Very high out crossing rate, especially when spraying with GA3 is bring to 135S high yield on hybrid seed production (Table 5 and 7)

Table 2: Yield and yielding components of some F1 combination

Characters Combination	Effective tillers	Grain pan^{-1}	Seed Set pan^{-1}	Seed set rate (%)	1000 Grains weight (gr)	Biomass yield (gr)	Harvest index	Grains yield (tons ha^{-1})
135S/R50	4.7	293.1	259.0	88.4	23.5	37.6	0.52	9.35
135S/R45	3.9	307.4	265.1	86.2	23.5	34.2	0.53	7.88
135S/9311	4.0	204.5	173.8	85.0	28.1	37.2	0.47	6.45
135S/R63	4.2	233.6	204.0	87.3	28.5	37.9	0.39	8.06
135S/44	3.8	227.6	193.1	84.8	26.6	39.2	0.52	7.17
135S/154	4.4	199.5	187.2	93.8	27.1	36.4	0.49	7.80
BTST(check)	4.0	185.4	173.6	93.6	21.5	36.6	0.41	4.93

The accepted combinations in test crossing is shown in table 2. Recognize that effective tiller of all combinations is about 3.8 to 4.7. It is similar of new plant type (NPT) of rice of IRRI. Most of the combination has the high heterosis effect both on Hb and HS (table 3). Comparison main character and heterosis effect the combination 135S/R50 is the best. It was chosen as a new variety and it was named as the Vietlai50.

Table 3: Heterosis for grain yield and yield components (%)

Complicity	Number tiller		Seed set $panicle^{-1}$		1000 – grains weight		Individual yield	
	HB	HS	HB	HS	HB	HS	HB	HS
135S/R50	46.9	17.5	37.1	49.2	4.0	9.3	68.5	36.6
135SS/R45	17.2	-15.5	57.4	52.7	11.8	23.3	57.3	24.2
135S/9311	48.1	0.0	16.7	0.1	-3.1	30.7	78.2	20.8
135S/R63	-6.7	5.0	29.4	17.5	0.0	32.6	-26.2	3.2
135S/44	-7.3	-5.0	-23.9	11.2	4.6	37.7	1.0	42.3
135S/154	-18.5	10.0	39.7	7.8	-1.0	33.5	28.6	21.5

Table 4: On farm testing in spring season

Location	Tiller plant-1	Yield (tons ha^{-1})
Lao cai	13.5	15.1
Ha noi	9.6	12.3
Bac giang	11.5	14.1
Ha nam	11.1	13.7

Vietlai50 variety was taken on-farm testing in Spring season in 4 locations. There are: Laocai (Mountain reason), Hanoi (Red River Delta reason), Hanam (Thaibinh River Delta) and Bacgiang (Middle-land reason). Three seedlings per hill were doing at transplanting and made the yield of Vietlai50 very high (table 4). The highest yield is in Laocai (15.1 tons per hectare)

Table 5: Transplanting row ratio of male and female on hybrid seed production of Vietlai 50

Row ratio	Full grains (%)	Weight 1000 Grains (gr)	Yield (kg ha^{-1})
2:12	83.2	22.6	2854.2
2:14	81.6	22.5	3338.5
2:16	80.1	22.8	3812.6
2:18	70.6	22.6	3752.4
2:20	51.4	22.7	3037.2
2:22	36.5	23.1	2358.2

$LSD_{0.05} = 213.2\ kg\ ha^{-1}$

Supplementary study on hybrid seed production was made. Results are showing at table 5,6 and 7. The best row ratio between TGMS 135S and restorer R50 is 2: 16. At this ratio the yield of F1 seed reaches to 3812.6kg per hectare. It is classified as the high yield in Red River Delta reason.

Table 6: Time of sowing on hybrid rice seed production of Vietlai 50 – Red River Delta

Times of Sowing	Heading time	Sterility rate of Female line (%)	Situation at Heading
1 - Jun	20 - Aug	100	Heavy rain
5 - Jun	26 - Aug	100	Heavy rain
10 - Jun	30 - Aug	99.8	Rain 3 days
15 - Jun	6 - Sep	100	Rain 1 day
20 - Jun	12 - Sep	100	No rain, Good weather
25 - Jun	16 - Sep	99	Rain in night

Time of showing was investigated (table 6). The result shows that: to make showing of TGMS line 135S around 20^{th} Jun is bringing absolutely sterility of TGMS 135S (female) and good condition for pollination.

Table 7: GA3 application

Dose (gr ha^{-1})	Yield (kg ha^{-1})
80	3518^{b}
100	3613^{b}
120	3808^{a}
140	3522^{b}
160	2916^{c}
Check (water)	1800^{d}

$LSD_{0.05} = 176kg\ ha^{-1}$

GA3 application is made higher yield than check (water spraying) clearly. Solution of 800l per quantity and 120gr per hectare, application by spraying was given highest yield (3808kg per hectare)

Conclusion

- Vietlai 50 is a new hybrid rice variety bred in Hanoi University of Agriculture in 2007. This cross combination was crossed between female parent TGMS 135S line and male parent R50 line. Grain yield potential of Vietlai 50 is very high and reaches of 14.7 – 15.1 ton ha^{-1} in spring season and 12.6 – 13.1 ton ha^{-1} in early autumn season.
- Main interested characters of Vietlai 50 includes: growing duration is in a range of 125 – 127 days in spring crop and 100 – 105 days in autumn crop. Plant height is 105 – 107cm. The number of spikelets per panicle is 300 – 305 and 1000-grain weight is 26 – 27gr. The ratio of brown rice is 85 – 86%. Especially, Vietlai 50 is high resistant to many virulent races of rice blast and bacterial leaf bright in Northern of Vietnam.
- Thus, the advantage in potential yielding of Vietlai 50 can be classified this combination as a super hybrid rice variety.

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Screening of Some Promising Rice Varieties (*Oryza Sativa* L.) in Thai Nguyen Province, Vietnam

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Abstracts
In period of 2000-2006, rice output increased significantly as a result mainly from the rice yield increase from 4.243 tons/ ha(in year 2000) to 4.893 tons/ ha (in year 2006). Predicated rice output of Vietnam is 40.10 millions tons and exported rice is estimated to 5.5 million tons in the year 2010. However, in North Highland and Mountainous Region food security is not ensured and hybrid rice is not popular. The objective of the research is to select the most promising rice varieties for local rice production. The results indicated that most of tested promising rice varieties belonged to short growing duration group, ranging from 126 -129 days in spring rice and 103 - 113 days in early summer rice. As a result, these varieties are suitable for early summer rice in the rice-based land with three cropping seasons per year. Even thought, yield of these rice varieties was not higher than the control rice variety in summer crop but significantly higher than the control rice variety in spring rice (increased by 0.65 to 1.27 tons/ha). Two rice cultivars: CL02 and NL061 had higher rice quality than control Khang Dan cultivar, Therefore, we proposed to continue to test CL02 and NL061 in large scale and determine the suitable cultivation techniques for higher yield and economic proficiency from the two promising rice cultivar production.
Key words: rice breeding evaluation, spring and summer season, Thai Nguyen province

I. Introduction

Table 1. Areas, yield and production of Vietnam from 2000 to 2006

Year	Area (million ha)	Yield (tons/ha)	Production (million tons)
2000	7.67	4.24	32.53
2001	7.49	4.28	32.11
2002	7.50	4.59	34.45
2003	7.45	4.63	34.57
2004	7.45	4.85	36.15
2005	7.33	4.88	35.83
2006	7.32	4.89	35.83

Rice production in Vietnam during period 2000-2006 increased rapidly in all sector of area, yield and production. Rice cultivated area is slightly reduce tendency cause by the increase of new industrial zones and new residential area. However, the yield is roughly increased as a result of intensive cultivation. In 2000, yield is 4.24 tons per ha and the average yield in 2006 is 4.89 tons per ha the adding increase is 0.65 tons per ha. The production increase from 32.53 million tons in 2000 to 35.83 million tons in 2006. The estimate of rice production in Vietnam in 2010 is about 40.10 million tons and annual rice exporting is about 5.5 million tons (Table 2)

Table 2. The estimate of rice production in Vietnam (2006-2010)

	Unit	Year 2006	Year 2007	Year 2008	Year 2009	Year 2010
Cultivated area	1000 ha	7320	7315	7313	7307	7304
Average yield per	Tons/ha	49,0	49,6	51,1	52,7	54,9
Production of	Million tons	35,90	36,32	37,41	38,55	40,10
Exporting rice	Million tons	5,0	5,1	5,2	5,4	5,5

Source: Department of statistics

In Vietnam, the main rice production area is concentrated in the Red River Delta and Mekong River Delta as a commodity rice area. Other area such as the highland and mountainous area of the northern Vietnam, most of rice production is self supporting. In this area conventional varieties are grown about 60%-65%. The advantages of conventional variety are yield stable, low input and farmer can keep the varieties for the next season by themselves.

Therefore, researching to identify promising line of rice is necessary to meet the requirement of farmer such as high yield varieties, high quality varieties, better tolerance to environment stress and disease

II- Objectives

Selecting new rice cultivars with high and stable yield to introduce into rice production in Thai Nguyen for higher income and economic efficiency

III- Material, contents and methodology

III.1-Materials: The materials include 6 rice varieties: Khang Dan variety as control, Thien Huong variety and three lines of NL061, X25, CL02 as testing.

III.2.Location of research

The first experiment was conducted in early summer season of 2006, and two other experiments were conducted in the spring season and early summer season in 2007, respectively. All experiments have been conducted at Thai Nguyen Province.

III.3. Contents of the research

- Studying the growth characteristics of the experimented rice cultivars.
- Studying some physiology criterias of the experimented rice cultivars during growth stages
- Assessment the drought and disease resistance of rice cultivars
- Evaluating the yield components and yield in order to find out some prospecting varieties adapting to the spring season and early summer season at Thai Nguyen province.

III. 4. Criteria

The grow duration of the cultivars in the experiment

Yield and yield components of the cultivars

Resistance ability of the cultivars to environmental conditions and disease and insects.

III.5- Methodology of experiment

Experiment was conducted in randomize complete block design with 3 replications of 5 treatments.

Treatment 1: Khang dan (Control)

Treatment 2: HT1

Treatment 3: CL02

Treatment 4: X25
Treatment 5: NL061

All data collected was evaluated by standard evaluation of rice system of International Rice Research Institute (IRRI).

4- Results and discussion

4. 1- The growing of rice cultivars in experiment

Table 3. Growing period of rice cultivars in the experiment

Unit: Day

No.	cultivars Line,	Early summer season of 2006	Spring season of 2007	Early summer crop of 2007
1	KD(Control)	104	124	102
2	HT1	102	129	103
3	CL02	113	129	113
4	X25	105	126	107
5	NL061	105	129	105

Comparing with the control variety (Khang dan, all of lines and cultivars have growth period longer 5 days in the spring crop and 1 to 9 days in the early summer crops.
All of testing varieties belong to early maturing group and adapting to early summer crop.

Table 4: Tillering capacity and tiller efficiency of the tested rice cultivars
Unit: Tiller/hill

Cultivar/line	Spring season			Early summer season		
	Maximum tiller number	Tiller with panicle	Efficient percentage	Maximum tiller number	Tiller with panicle	Efficient percentage
KD(Control)	11.3	7.0	61.9	10.0	4.6	46.0
HT1	15.3	10.0 **	65.3	8.3	5.3 ns	63.8
CL02	13.0	7.6 ns	58.4	8.6	4.1 ns	48.8
X25	11.1	6.8 ns	61.3	9.6	3.3 **	43.8
NL061	9.3	7.4 ns	79.5	6.0	4.5 ns	71.7
CV (%)		7.2			9.5	
LSD05		0.6			0.761	

In the spring season, all line and cultivars of rice in the experiment have number of tillers as well as no. of tillers higher than those in the summer season. The highest number of tillers are 15.3 tillers of HT1 line . NL061 have the lowest tillers. However, it has the highest the rate of number of panicles per number of tillers. To study practical method to improve the rate of panicles number per tillers is necessary in the future.

4. 2- Insects and diseases

Table 5. Insects and diseases damaged situation in the early summer crop

Unit : Score

Cultivars	Insects		Diseases
	Stem borer (Chilo Suppressalis)	Leaffolder (Cnaphalocrosis)	Bacterial blight (Rhizoctonia solani)
KD(Control)	1	1	3
HT1	0	0	1
CL02	0	1	1
X25	1	1	1
NL061	1	1	1

In the early summer, there are only CL02 and HT1 line have not damaged of stem borer, however the others cultivars were damaged by leaffolder. All of cultivars were damaged at 1 point except Khang dan variety was damaged at 3 point level.

In spring season in 2007, all line and cultivars in the experiment were damaged by stem borer. Line X25, HT1 have not damage by stem borer as well as leaffolder . However, both NL061 and CL02 were damaged by Bacterial blight at 1 point level. Therefore, to maintain the yield of prospecting cultivar, it is necessary to conduct some disease and insect practical methods.

Table 6. Insects and diseases damaged situation in the spring season

Unit: Point

Cultivars	**Stem borer**	Leaf folder	Brown planthopper	sheat blight	Blast	Bacterial blight
Khang dan (Control)	1	1	0	1	1	0
HT1	1	0	0	1	1	0
CL02	1	1	1	3	1	1
X25	1	0	0	1	1	0
NL061	1	1	1	1	1	1

4.3- Yield and yield components

Table 7. Yield and yield components of rice cultivars and line in the experiment in the spring season 2007.

Varieties	Panicles per m^2	No. of filled seed per panicle	weight of 1000 seeds (gr)	Yield potential Ton/ha	Harvested yield (ton/ha)
KD (Control)	231.0	106.1	22.0	5.39	4.40
HT1	330.0^{**}	80.9^{**}	22.7	6.06^{*}	5.05 *
CL02	250.8^{ns}	122.0^{**}	22.8	6.97^{**}	5.67 **
X25	224.4^{ns}	123.7^{**}	22.8	6.33^{**}	5.25 **
NL061	244.2^{ns}	120.0^{**}	23.0	6.74^{**}	5.65 **
CV(%)	4.02	3.9		6.90	0.54
LSD05	20.03	8.08		5.77	0.53

In spring season, all tested promising lines indicated higher yield potential than check variety (Khang Dan), of which, harvested yield of HT1 variety gained higher than control variety at 95 % level , other three promising varieties gained higher than check variety at 99% level.

Table 8. Yield and yield components of rice cultivars and line in the experiment in the early summer season in 2006 and 2007.

Varieties	Panicles per m^2	No. of filled seed per panicle	weight of 1000 seeds (gr)	Harvested yield in 2006 (ton/ha)	Harvested yield in 2007 (ton/ha)
KD (Control)	196.6	120.0	21.4	4.23	4.72
HT1	213.2	92.9 **	21,5	3.74*	4.02 *
CL02	165.2	132.4 ns	22.4	4.33 ns	4.48 *
X25	121.2	113.2 ns	28.3	4.17 ns	4.60 ns
NL061	168.0	144.6**	23.6	4.26 ns	4.56 *
CV(%)		7.0		5.3	2.0
LSD05		15.45		0.39	0.16

In summer season, Although the harvested yield and yield potential have gained not significant different however, the line of NL02 had the highest of number of filled seed per panicle and secondly is NL061.

4.4-Miling quality of rice cultivars in the experiment

Table 9. Rate of Miling quality of rice

Unit : %

No.	Varieties	Milling rice recovery (MR)	Heading rice rate (HR)	Brown rice rate (BR)
1	KD (control)	65,0	83,27	80,67
2	HT1	70,5	91,06	81,0
3	CL02	73,0	91,87	81,42
4	X25	70,0	85,0	80,30
5	NL061	69,0	85,84	80,1

MR is the percentage of milled rice to paddy rice
HR expressed as the percentage of head rice to paddy rice
BR defined as the percentage of brown rice to paddy rice.

Data from table 09 and table 10 shows that the tested rice cultivar had higher percentage of grilled rice and unbroken rice than the control Khang Dan cultivar. Most of the tested rice cultivars and line had medium grain length, low faded percent and grilled rice had opaque white color.

Table 10. Milling quality of rice

Cultivar	Monitoring grain characters					
	Grain length (mm)	Grain width (mm)	Length/ width (point)	Grain shape	Faded point	Colors
KD(Check)	6.0	2.1	4	Slender	1	White
HT1	6.6	2.1	5	Slender, long	0	Opaque white
CL02	7.0	2.0	5	Slender, long	0	Opaque white
X25	7.2	2.2	5	Slender, long	1	Opaque white
NL061	6.8	2.4	4	Slender	1	Opaque white

5- Conclusion

- All of the tested rice cultivars and lines were short growth duration. Their growth duration varied from 102 to 129 days and suitable for early- planted rice season.
- The tested rice cultivars and lines was early tillering with short tillering duration but panicle efficiency was not very high.
- The tested rice cultivars and lines have performed good ability to resistant to pest and disease. Therefore, no any cultivars was seriously infected with pest and disease.
-Yielding of all tested cultivars and lines gained lower than of control or equal compared to control variety in early summer season. But higher than control variety in spring season from 0.65 tone/ha to 1.27tone/ha.
-CL02 and NL061 lines had high grain quality showing high percent of grilled rice, long and slender grain shape, low percent of fade, quality of grain for consumption was equal to what of HT1.
- Both CL02 and NL061 are prospective lines with high yield and quality. It is suitable in spring season. So, It is necessary to evaluating in the future.

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Rice Planthoppers in Vietnam and Their Migration

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Abstract

Migration source for immigrants of *Nilaparvata lugens* and *Sogatella furcifera* in southern China from April to May was estimated by using a three-dimensional backward trajectory method and light trap data in China. Sources in most cases were estimated to be in Red River delta in northern Vietnam and in middle Vietnam. Population density of macropterous adults of the two species in Red River delta was high in May, which supported the analytical result in this study. Forward migration simulations of the brown planthopper from Mekong Delta in southern Vietnam indicated that brown planthoppers in some cases could migrate from the south to middle Vietnam, depending on weather condition. Although outbreak of virus diseases such as rice grassy stunt virus disease and rice ragged stunt virus disease has not occurred in northern regions so far, it is important to keep careful monitoring of migration of brown planthoppers.

Key Words. *Nilaparvata lugens*, *Sogatella furcifera*, long-distance migration

Introduction

The East Asian population of rice planthoppers, the brown planthopper *Nilaparvata lugens* (BPH) and white-backed planthopper *Sogatella furcifera*, overwinters on rice plants of winter-spring crop in Red River delta in Vietnam and emigrates to southern China in early summer (Sogawa, 1993). This migration is called as the first step migration. The planthoppers produce a few generations on rice plants of the early crop in southern China, and migrate to the Yangtze delta, Korean peninsula and Japan in *Bai-u* rainy season (Kisimoto, 1976, Sogawa, 1993). This migration is called as the second step migration. Although many pieces of analysis have been reported on the second step migration (Kisimoto, 1976; Rosenberg and Magor, 1983; Sogawa, 1995; Otuka et al, 2005a, b; Furuno et al 2005; Otuka et al 2006), there has been little analytical report on the first step migration, except some descriptive reports (Sogawa, 1992; Sogawa, 1993; Suzuki and Wada, 1994; Otuka et al, 2007). This was mainly because trap data available for foreign scientists had been limited until recently. If trap data in southern China was available, a backward migration simulation (Otuka et al, 2005a) could be conducted and show possible source and destination regions of the first step migration, presenting new ecological knowledge on the first step migration.

After the outbreak of BPH in East Asia in 2005, more information on their occurrence has been available at Internet sites of plant protection institutes in Chinese provinces, including a part of their light trap data. Therefore this study reports migration analyses conducted using those light trap data and presents a concrete picture of the first step migration.

In addition, the brown planthopper is a major insect pest of rice in Mekong Delta, southern Vietnam. In 2006, the outbreak of BPHs occurred and two virus diseases transmitted by BPHs, Rice Ragged Stunt Virus disease (RRSV) and Rice Grassy Stunt Virus (RGSV) disease, spread over in the delta, resulting in big loss of rice production. Furthermore, Matsumura et al. (2008) have shown that insecticide-resistance of BPH in the delta has risen recently. Therefore, it is very much necessary to properly control the highly-virulent BPHs. If such BPHs in Mekong Delta could migrate to northern part of Vietnam, it would be a huge risk to the East Asian population. Therefore, this study investigates the possibility of long-distance migration of BPHs from Mekong Delta to northern or middle Vietnam by using a migration simulation model (Furuno et al, 2005; Otuka et al, 2006).

Materials and Methods

Catch data in southern China

Catch data of light traps were cited from rice disease and pest section at following three provincial Internet sites; *http://www.gxzb.com* of Guangxi Plant Protection General Station in Guangxi Zhuang Autonomous Region, *http://gdzbz.com* of Guangdong Plant Protection General Station in Guangdong province and *http://zhibao.jxagri.gov.cn* of Jiangxi Plant Protection and Quarantine Station in Jiangxi province. These stations released planthopper occurrence information for several times during rice cultivation season in 2006 and 07, which included catch number of their light traps, or sum of the catches during a period, which showed clear migration peaks. The catch data in April and May were used for backward trajectory analysis.

Backward trajectory analysis

A three-dimensional backward trajectory analysis (BTA) (Otuka et al, 2005a) was conducted to estimate possible migration source for catch peaks in southern China. The starting times of the trajectories were set every 1 h within 24 h of the catch date. For each starting time at each site, 20 backward trajectories were calculated with different initial heights ranging from 100 to 2000 m at an interval of 100 m above the trap site. The backward trajectories were terminated at dusk, 11 Coordinated Universal Time (UTC) or at dawn, 23 UTC on one or two days before the catch, when planthoppers was assumed to fly out of the source areas. The terminal points were plotted on a map to determine the possible source areas.

In Vietnam, which lies north to south for a long distance along the eastern Indochina Peninsula, populations in the northern part, or Red River delta, and the southern part, or Mekong delta, are thought to be ecologically isolated without known genetic interaction, and with only the northern population thought to comprise the East Asian population (Sogawa, 1992; Sogawa, 1993). There are two crops in the northern delta: a winter-spring crop and a summer crop. Planthoppers overwinter, multiplying on the winter-spring crop, for which rice is transplanted in January to early March and harvested in June (Sogawa, 1993; Suzuki and Wada, 1994; Otuka et al, 2007). Red River delta forms a triangle-shaped region with Red River running through the center, which is a major rice cultivating region and located above latitude 20 degrees north. Below the latitude, paddy fields are distributed along the coast. In this paper, the former triangle region and the latter one are referred to as northern Vietnam and middle Vietnam, respectively (Fig. 1).

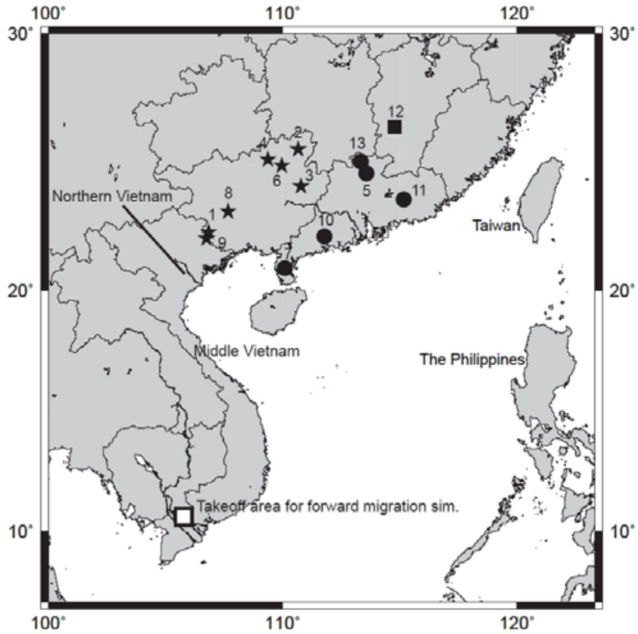

Fig. 1. Location of light traps in southern China, and a takeoff area in Mekong Delta

Forward migration simulation

A migration simulation model developed by Otuka et al (2006) was utilized to estimate destination regions of migrations from Mekong Delta. In the model, as many as 34,000 planthoppers took off from a takeoff area in the delta (a white square in Fig. 1) at dusk, 11 UTC (Coordinated Universal Time), every day from July to August 2007 and in April 2008. These months were selected because they corresponded to rice harvesting season in the delta, expecting emigrations from paddy fields. The positions of migrating planthoppers were calculated using meteorological data simulated by a weather prediction model, and the planthoppers were assumed to move mainly by wind vectors in the time step, taking vertical diffusion into account (Otuka et al, 2006). The planthoppers in flight were also kept from entering cooler upper air at less than a temperature of 16.5 °C. Simulation duration was 48 h. Relative aerial density of the insects was hourly calculated based upon their number in a simulation grid cell stretching 33 km horizontally and 100 m vertically above the ground. An area of non-zero value of the relative aerial density was used. The relative aerial density drawn on a map, which looks like a cloud, is referred to as a migration cloud hereafter. Movement of the migration cloud during the survey period was investigated to know possible destination of migrations from the south.

Results and Discussion

BTA

Based upon light trap information from the provincial plant protection stations, 24 clear catch peaks recorded at 13 trap sites in 2006 and 07 were used for BTA (Table 1). The number in Map column shows location number in Fig. 1. These catch peaks were named as migration a to x in the first column. Table 1 indicates two major tendencies. The first one is that large catch peaks appeared in late April (migration l, m, n, q, r, s) to early May (a, b, c, g, h, t) and in late May (d, e, i, j, k, u, v, w, x). Among catches during the period, the second point is that a site closer to Vietnam showed larger catch. For example, the catch at Zhaoping on 22 April 2007 (q) was larger than that at Lechang (m). In other words, the catch in Guangxi, which is adjacent to Vietnam, was larger than in Guangdong or Jiangxi.

Migration source regions estimated by BTA are shown in Table 2. Examples of terminal point distribution are shown in Fig. 2. Source regions in most cases were found to be northern Vietnam and middle Vietnam, and in some cases Hainan province. Since no information on population density in Hainan province in the period is available, it is suspended for now to judge whether Hainan is possible source or not. Source region for the sites in Guangxi were mainly in Red River delta, which is located to the southwest of

Table 1 Catch of light traps in Jiangxi, Guangdong and Guangxi

Migration	Date	Province	Catch	City	Map	Latitude	Longitude
a	7 May 2006	Jiangxi	512	Wanan	12	26.47	114.78
b	06 May 2006	Guangdong	6858	Leizhou	7	20.91	110.10
c	1-10 May 2006	Guangdong	1641	Qujiangqu	5	24.68	113.58
d	21-30 May 2006	Guangdong	642	Leizhou	7	20.91	110.10
e	21-30 May 2006	Guangdong	21658	Qujiangqu	5	24.68	113.58
f	11 Apr 2006	Guangxi	4032	Yongfu	6	24.98	109.97
g	6-10 May 2006	Guangxi	20864	Zhaoping	3	24.17	110.79
h	6-8 May 2006	Guangxi	CP*	Xingan	2	25.61	110.66
i	21-25 May 2006	Guangxi	32200	Longzhou	1	22.35	106.85
j	21-25 May 2006	Guangxi	4689	Pingxiang	9	22.10	106.75
k	21-25 May 2006	Guangxi	5114	Longan	8	23.17	107.68
l	21-25 Apr 2007	Guangdong	337	Zijin	11	23.65	115.17
m	21-25 Apr 2007	Guangdong	340	Lechang	13	25.13	113.34
n	27 Apr-8 May 2007	Guangdong	2358	Yangchun	10	22.18	111.78
o	6-10 May 2007	Guangdong	1402	Zijin	11	23.65	115.17
p	1-10 May 2007	Guangdong	7293	Leizhou	7	20.91	110.10
q	22 Apr 2007	Guangxi	24288	Zhaoping	3	24.17	110.79
r	22 Apr 2007	Guangxi	10240	Yongfu	6	24.98	109.97
s	22-25 Apr 2007	Guangxi	HH*	Longzhou	1	22.35	106.85
t	3-5 May 2007	Guangxi	31100	Longzhou	1	22.35	106.85
u	19-20 May 2007	Guangxi	85000	Longzhou	1	22.35	106.85
v	22-25 May 2007	Guangxi	38021	Xingan	2	25.61	110.66
w	22-25 May 2007	Guangxi	30921	Zhaoping	3	24.17	110.79
x	22-25 May 2007	Guangxi	26079	Rongan	4	25.22	109.38

CP: Clear peak, HH: Historically high

Table 2 Estimated source regions

Migration	Estimated source				
	Northern Vietnam	Middle Vietnam	Hainan	Taiwan	Philippines
a	+		+		
b		+			
c	+	+	+		
d	+	+			
e	+	+	+		
f	+	+			
g	+	+			
h	+	+			
i	+	+			
j	+	+			
k	+	+			
l	+	+	+		
m	+	+	+		
n	+		+	+	
o				+	+
p	+		+	+	+
q	+	+			
r	+				
s	+	+			
t	+				
u	+				
v	+				
w	+				
x	+				

Guangxi (Fig.2g, i, q, t and u). It was natural result since the planthoppers were carried by the southwesterlys. On the other hand, source for Guangdong, which is located to the east of Guangxi, were likely to be in middle Vietnam (Fig. 2b, e). Southern Guangdong is located to the northeast of middle Vietnam. In cases in early May 2006, sources were found to be in the Luzon, the Philippines (Fig. 2o, p). Property of the population in the Philippines is different from that of the East Asian population. Therefore it is necessary to carefully monitor whether the property of the insects was affected by immigrants from outside or not. The result also showed Taiwan could be source. However, because population density there in early May or before is very low, Taiwan may be not likely to be source.

The first step migration of rice planthoppers of the East Asian population was analyzed with the numerical method. Although small migration happened in southern China by early April, major migrations of the first step occurred in late April through late May. During that period, rice plants in eastern provinces in Red River delta were in milky or ripening stage and the population density of macropterous adults of *N. lugens* and *S. furcifera* was high in fields with susceptible rice varieties. It was considered that the planthoppers were carried by the prominent southwesterlys and migrated to a diagonal belt region which includes Guangxi, southern Hunan, northern Guangdong and Jiangxi provinces. Since area of rice field in Red River delta is larger than that in middle Vietnam, this diagonal belt region is likely to be a major invaded region in the first step of migration. For the same reason, southern part of Guangdong, which is outside the diagonal belt, probably had smaller number of immigrants (Matsumura et al, 2006). Within the diagonal migration belt, sites closer to Red River delta got more number of immigrants. The analysis also showed that the migration from the Luzon to southern China could happen, on which a careful attention has to be paid because of different insect's properties between the populations.

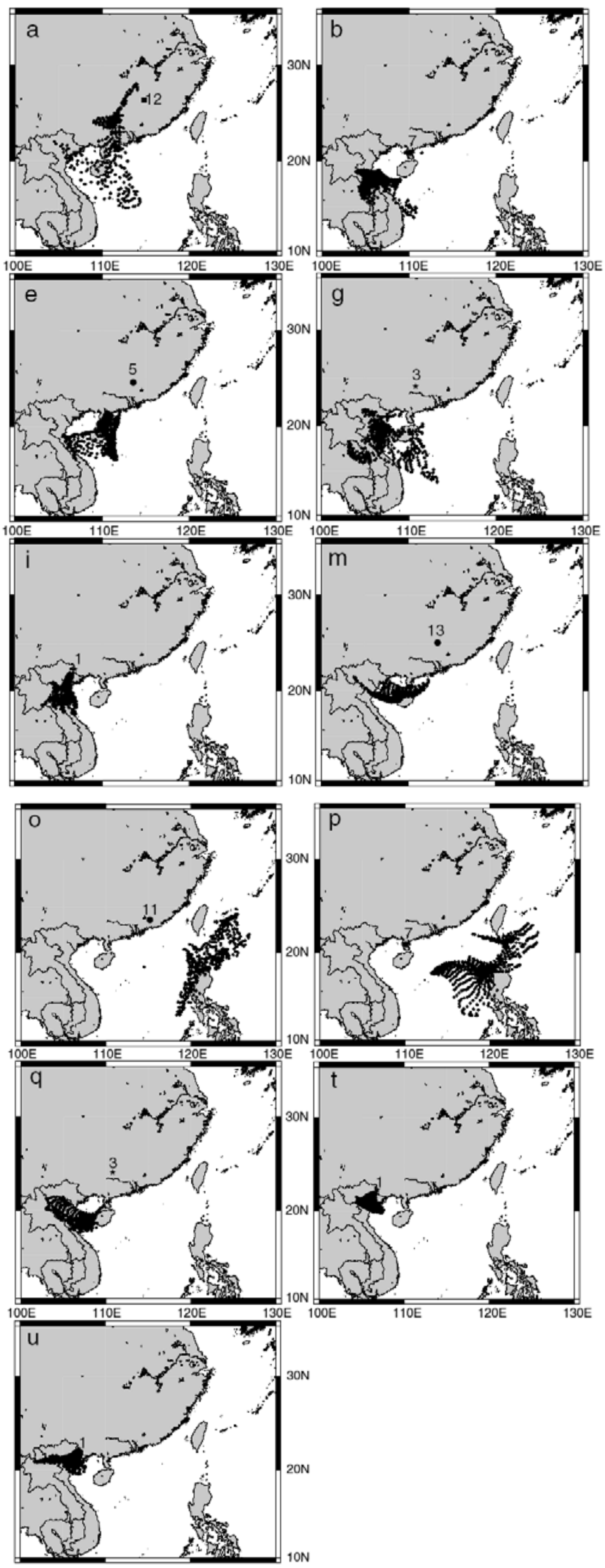

Fig. 2 Terminal point distribution by the backward trajectory analysis

Table 3 Estimated destination of possible migrations from Mekong Delta

Month	Destination				
	PH	MV	TH	SC	SJ
All	**19**	**7**	**21**	**2**	**2**
Jul-07	9	3	3	0	0
Aug-07	10	2	0	2	2
Apr-08	0	2	18	0	0

PH: the Philippines, MV: Middle Vietnam, TH: Thailand, SC: southern China, SJ: southeast Japan

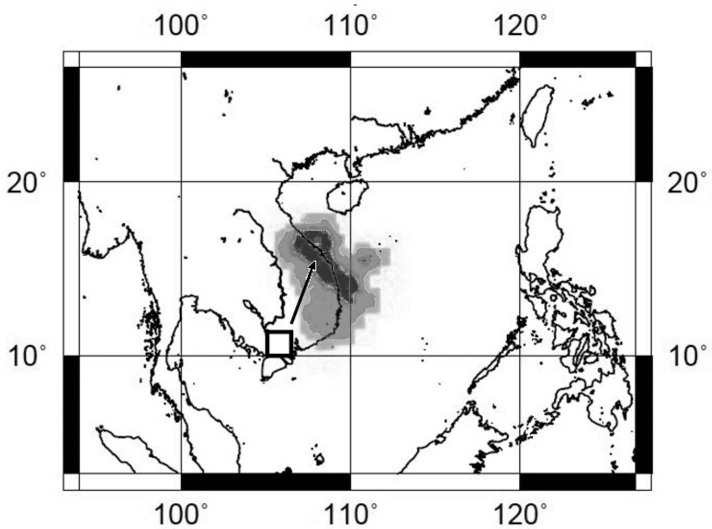

Fig. 3 An example of the migration cloud to move to middle Vietnam.
This migration cloud started to take off on 20 August 2007.

Forward migration simulation

Migration clouds moved to various regions around Mekong Delta. Possible destination was summarized in Table 3. The table shows that Thailand (movement in northwest direction) and the Philippines (movement in east direction) were common destinations in many migration cases. However, seven cases were found to move in north direction to middle Vietnam, where is the source for the first step migration of the East Asian population (Fig. 3). The result implies that a migration of BPHs from Mekong Delta could occur in some weather condition. To confirm whether such a migration actually occurs or not, further field surveys are needed. There has been no reported outbreak of the virus diseases (RRSV, RGSV) in middle Vietnam so for. But it is important to keep a careful migration monitoring of the highly-virulent BPHs in the delta.

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Current Status of Insecticide Resistance and Virulence to Resistant Rice Varieties in Asian Rice Planthoppers

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Abstract

Insecticide susceptibility and virulence to resistant rice varieties were determined and evaluated in the brown planthopper (BPH) and the whitebacked planthopper (WBPH), collected from Asian countries (Japan, China, Taiwan, northern Vietnam, southern Vietnam, and Philippines) in 2006. Insecticide susceptibility was determined by a topical application method using four insecticides. Virulence to resistant rice varieties was evaluated using five differential rice varieties carrying different planthopper resistance gene(s). Species-specific changes in insecticide susceptibility were found in Asian rice planthoppers (i.e. imidacloprid resistance in BPH and fipronil resistance in WBPH). The topical LD_{50}-values for imidacloprid in the BPH strains in East-Asia (Japan, China, and Taiwan) and Vietnam were significantly higher than those in the Philippines, suggesting that insecticide resistance in BPH against imidacloprid occurred in East Asia and Indochina, but not in the Philippines. Almost all the WBPH populations collected had extremely large LD_{50}-values for fipronil, suggesting that insecticide resistance in WBPH against fipronil occurred widely in East and Southeast Asia. The virulence of Asian BPH strains was classified into three groups: (1) The BPH strains in East Asia and northern Vietnam were virulent to Mudgo (*Bph1*) and ASD7 (*bph2*) but avirulent to other three varieties, (2) The BPH strains in Southeast Asia (the Philippines) were virulent to Mudgo, ASD7 and also partially virulent to Babawee (*bph4*), and (3) The BPH strains in southern Vietnam were highly virulent to Babawee in addition to Mudgo and ASD7. The varieties Rathu Heenati (*Bph3*, *Bph17*) and Balamawee (*Bph9*) still have a broad spectrum of resistance against all the Asian BPH strains tested.

Keywords: topical application, imidaclopirid, fipronil, virulence, resistant gene

Introduction

The brown planthopper (BPH), *Nilaparvata lugens* (Stål), and the whitebacked planthopper (WBPH), *Sogatella furcifera* (Horváth) (Homoptera: Delphacidae), are the two serious pests of rice throughout Asia. The northern limit of breeding area for these species is around the Red River Delta, Vietnam, where rice (*Oryza sativa*, their only host plant) is cultivated all year round. Neither of these species is able to overwinter successfully in temperate areas (Japan, Korea, and most areas of China), and colonization occurs annually following long-distance migration from overwintering area (Kisimoto, 1976).

To control these planthoppers, neonicotinoid and phenylpyrazole insecticides such as imidacloprid and fipronil have been used since middle 1990s in many East-Asian countries and Indochina. Treatment methods of these insecticides vary among countries. In Japan, imidacloprid and fipronil are used exclusively for seedling box treatment to control the rice planthoppers. In Vietnam and China, in contrast, these insecticides are usually sprayed on the rice fields. In any event, the population densities of the BPH and WBPH had been relatively low since middle 1990s when these insecticides were began to use.

In 2003, however, the development of insecticide resistance against neonicotinoids (mainly imidacloprid) in BPH was first observed in Thailand and has since been found in other neighboring countries such as Vietnam, India, and China. However, until now the LD_{50}-values of BPH and WBPH against both neonicotinoid and phenylpyrazole insecticides tested by highly accurate methods such as topical application method have been poorly reported in many Asian countries. Therefore, the insecticide susceptibility of BPH and WBPH which were collected from East and Southeast Asian countries in 2006 were determined and compared.

Against BPH, many resistant varieties were released since 1973 by the International Rice Research Institute (IRRI) and other countries (Khush, 1979). Wide-scale monoculture of rice varieties with monogenic resistance to the BPH resulted in the development of a new biotype of BPH that broke the resistance of rice to the BPH in Philippines, Indonesia, Vietnam and the Solomon Islands during 1974-1977, soon after the introduction of resistant varieties (Khush, 1979; Sogawa, 1982; Gallagher et al., 1994). Changes in BPH biotypes are a continued threat to increased rice production in Asia.

Monitoring of the virulence of BPH to resistant varieties has been conducted in many Asian countries. The BPH migrate to Japan became virulent to a resistance gene *Bph1* around 1987-1990 (Sogawa, 1992a, b). This trend was also found in China and northern Vietnam in the same period. The BPH populations in Japan became virulent to *bph2* beginning in 1997 (Tanaka, 1999; Tanaka and Matsumura, 2000), and the virulence remained at that high level through 1999. This change also has been occurred coincidentally in China and northern Vietnam. However, the current status of virulence of BPH to resistant rice varieties in Asia is unknown. Thus, current virulent status of the Asian BPH populations to the rice differential varieties was evaluated based on the feeding response.

Materials and Methods

Insecticide susceptibility

The 16 and 17 populations for BPH and WBPH, respectively, were collected from East Asia (Japan, China, Taiwan), Indochina (Vietnam) and Southeast Asia (Philippines) in 2006. These populations were maintained in the laboratory for 2-5 generations prior to the test using rice seedlings (var. Reihou) at a day length of 16h and a temperature of 25°C. The insecticide susceptibility of these populations was monitored by a standard topical application method (Fukuda and Nagata, 1969). Four insecticides (imidaclopirid, thiametoxam, fipronil, and BPMC) were tested. Thiamethoxam was tested only for BPH.

The long-winged female adults within 7 days after emergence were anaesthetized with carbon dioxide for about 5s prior to treatment. A 0.08μl droplet of acetone solution was applied topically on the dorsal surface of the thorax with a hand microapplicator (Burkard Manufacturing Company Ltd.). The treated insects were kept at a day length of 16h and a temperature of 25°C, with rice seedlings in a transparent plastic box (5cm diameter, 10cm high). Mortality was determined 24h after treatment for all insecticides. In case of fipronil on WBPH, mortality was also determined 48 and 72 hours after treatment because mortality was less than 50% at 24h after treatment in some populations. All the tests were conducted on 2-5 generations after collection. More than 45 females were used for each concentration. Tests were carried out on 5-6 concentrations. The LD_{50}-value, 95% confidence interval, and slope of regression line were calculated by the Bliss's probit method. Control mortality was corrected for by using Abbott's formula for each probit analysis..

Virulence to resistant rice varieties

Five rice differential varieties with different resistance gene(s) to BPH: Mudgo (carrying *Bph1*), ASD7 (carrying *bph2*), Rathu Heenati (carrying *Bph3* and *Bph17*), Babawee (carrying *bph4*), Balamawee (carrying *Bph9*) and Taichung 65 (T65) (no resistance gene) were used. The 10 strains of BPH were collected from East Asia (Japan, China, Taiwan), Indochina (Vietnam) and Southeast Asia (Philippines) in 2006. The BPH strains were the same as those used in the test of insecticide susceptibility described above. These strains were maintained in the laboratory prior to the test using susceptible variety (var. Reihou) at a day length of 16h and a temperature of 25°C.

Seeds of the test variety were sown individually in plastic cups (220ml) with soil. One-month old seedlings were trimmed to 15cm height, and each trimmed plant was covered with a transparent plastic cylindrical cage (5cm D x 25cm H). Five brachypterous (short-wing form) females within 24h after emergence were released into the cage and the open end was covered with a nylon cloth. The number of surviving insects and the shape of their abdomens were monitored at 5 days after infestation. We classified females survived for five days and with heavily swollen abdomens as virulent, and females died within five days as avirulent. This system of classification is similar to that used by Tanaka (2000) for identifying virulent and avirulent females. Eight independent replicates of the experiment were performed.

Results

Insecticide susceptibility

In case of imidaclopirid the LD_{50}-values for the BPH populations collected from East-Asia (Japan, China, Taiwan) and Vietnam were remarkably larger than those collected from the Philippines (Fig. 1). The East-Asian and Vietnam populations had significantly larger LD_{50}-values for thiamethoxam to compare with Philippines ones. In contrast to the two neonicotinoids (imidacloprid and thiamethoxam), all the Asian BPH populations had much smaller LD_{50}-values for fipronil and no difference was found among locations. In BPMC, the LD_{50}-values were larger in several Vietnam and Philippines populations than those in other populations, but there was no significant difference among countries.

In WBPH, almost all the populations collected from Japan, Taiwan, China, Vietnam and the Philippines had extremely larger LD_{50}-values for fipronil except for several populations from the Philippines and China (Fig. 2). In case of imidaclopirid all the WBPH populations had small LD_{50}-values. In case of BPMC the LD_{50}-values for WBPH ranged from 6.1-26.6 µg/g. There were no significant differences in LD_{50}-values for all the three insecticides between East-Asian and Southeast Asian WBPH populations.

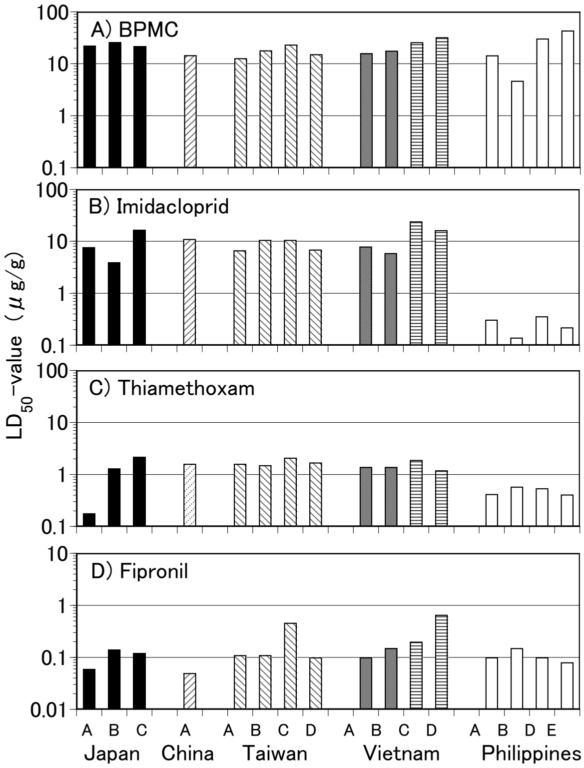

Fig. 1. The LD_{50}-values of *Nilaparvata lugens* strains collected in East and Southeast Asia in 2006 (Matsumura et al., 2008).

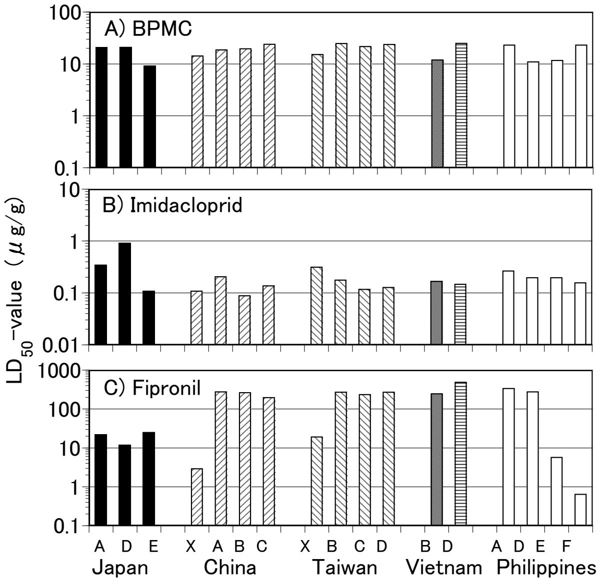

Fig. 2. The LD_{50}-values of *Sogatella furcifera* strains collected in East and Southeast Asia in 2006 (Matsumura et al., 2008).

Virulence to resistant rice varieties

The survival rate of Taiwan, China, Japan, and northern Vietnam BPH females on Mudgo and ASD7 were high and all the surviving females showed a swollen abdomen (Fig. 3). In contrast, only small proportions of these strains survived on other three varieties (Rathu Heenati, Babawee and Balamawee) and all of them did not show the swollen abdomen. The Philippines strains were virulent on Mudgo and ASD7 and showed high survival rates, and high proportions of females with swollen abdomen. Survival rates ranged from 31.4 to 37.1% on Babawee and surviving females became swollen abdomen in all Philippines strains. On the other hand, high proportions of southern Vietnam strains survived on Mudgo, ASD7 and Babawee, and almost all of them show swollen abdomen. In contrast, small proportions of all Asian BPH strains survived on Rathu Heenati and Balamawee, and all of them did not show the swollen abdomen.

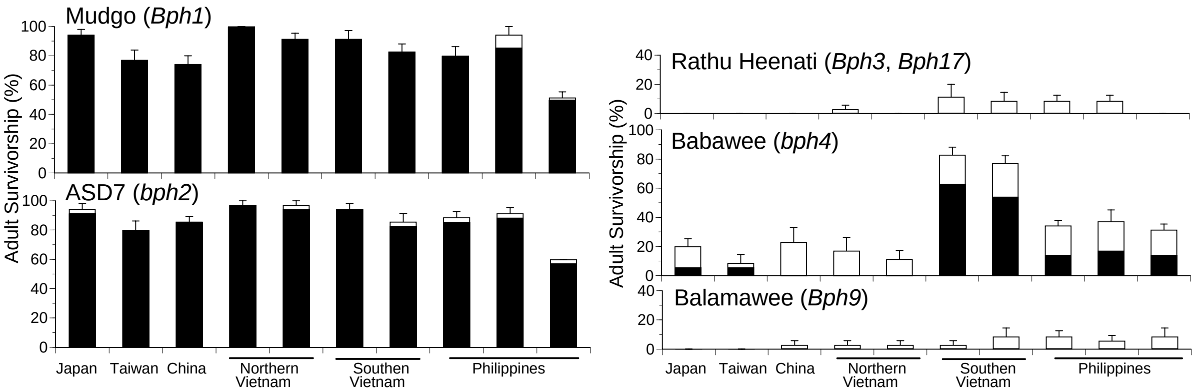

Fig. 3. Adult survivorship (solid bar) and the proportion of females with swollen abdomen (open bar) of *Nilaparvata lugens* strains collected in East and Southeast Asia in 2006 on rice differential varieties carrying the resistance genes (Myint et al., unpublished).

Discussion

Imidacloprid has been used widely to control rice planthoppers since early 1990s in East-Asia and Indochina. The topical LD_{50}-values of imidacloprid for BPH were in range of 0.09-2μg/g from 1992 to 2003 in Vietnam, China, and Japan (Endo et al., 2001; Ping et al., 2001; Nagata et al., 2002; Nagata and Kamimuro, 2002; Liu et al., 2003a, 2003b). In the present study, however, the East-Asian and Vietnam BPH populations in 2006 had remarkably higher LD_{50}-values than those before 2003. In contrast, the BPH populations collected in the Philippines in 2006 had similar LD_{50}-values for imidacloprid to compare with those in East-Asian population before 2003. These results suggest that insecticide resistance against imidacloprid occurred only in East-Asia and Indochina but not in the Philippines.

In contrast to BPH, no significant differences in LD_{50}-values for imidacloprid were found among Asian WBPH populations except for one Japanese population. The LD_{50}-values in 2006 were similar with those in Japanese and Chinese populations collected in 1992-2001 (Ping et al., 2001; Liu et al., 2003b). These results suggest that no insecticide resistance against imidacloprid occurred in WBPH in Asia. However, it should continue to monitor the insecticide susceptibility of WBPH against fipronil because one Japanese population had a slightly higher LD_{50}-value than others.

Almost all the Asian WBPH populations collected in 2006 had large LD_{50}-values for fipronil at 24h after treatment. Although no topical LD_{50}-values for fipronil in the field WBPH populations have been published previously, these results suggest that insecticide resistance of WBPH against fipronil occurred widely in East-Asian and Southeast-Asian countries. On the other hand, all the Asian BPH populations had much smaller LD_{50}-values for fipronil, suggesting that no insecticide resistance against fipronil occurred in BPH in Asia. However, the LD_{50}-values of these two populations are slightly larger than others. Thus, the monitoring of insecticide susceptibility to fipronil in BPH should be continued in this region.

In case of BPMC, the LD_{50}-values of BPH and WBPH in 2006 were similar with those in Japan, China, and Vietnam in 1992-2001 (Endo et al., 2001; Ping et al., 2001; Nagata et al., 2002; Liu et al., 2003b). No significant differences were detected among countries.

The present study revealed a species-specific change in insecticide susceptibility in Asian rice planthoppers (i.e. BPH for imidaclopirid and WBPH for fipronil). Imidacloprid has been used commonly to control BPH in later stage of rice in Vietnam and China (around May to early June in winter-spring rice cropping in northern Vietnam). Fipronil has been used commonly to control the rice leaffolder, *Cnaphalocrocis medinalis* (Guenée) and the rice stem borers in early stage of rice in Vietnam and China (around early April in winter-spring rice cropping in northern Vietnam). Spraying fipronil in early season could also be more affected on WBPH than on BPH, because WBPH increases earlier than BPH in the rice growing season. This could be a possible reason why insecticide resistance against fipronil occurred only on the WBPH species. The overuse of insecticides is often the precursor to the development of insecticide resistance and many Asian countries rely heavily upon a limited number of compounds for planthopper control (Nagata et al., 2002; Sun et al., 1996).

The present study suggests that the insecticide resistance of BPH against imidacloprid not occurred in the Philippines. This is because the BPH outbreaks has not occurred recently and imidacloprid has not been used commonly in the Philippines. In contrast, fipronil has been used commonly to control rice stem borers in the Philippines. In this reason, the insecticide susceptibility of WBPH against fipronil in the Philippines was as low as those in East-Asia and Vietnam.

In the Mekong Delta of southern Vietnam, the outbreaks of the two BPH-transmitted virus diseases, rice ragged stunt virus (RRSV) and rice glassy stunt virus (RGSV), have occurred since 2005, resulting in the heavily use of insecticides to control BPH. The present study showed that the LD_{50}-values in two southern Vietnam BPH populations tended to be larger than those in the other locations for BPMC, imidacloprid, and fipronil. Thus, it should be continued carefully to monitor the status of insecticide susceptibility in BPH against these insecticides in southern Vietnam and neighboring countries such as Thailand.

Based on the virulent spectrum, the current Asian BPH populations were classified into three groups: The first group: East Asian BPH populations from Taiwan, China, Japan and northern Vietnam were virulent to Mudgo (*Bph1*) and ASD7 (*bph2*), while avirulent to the other four varieties. The second group: Southeast Asian BPH populations from Philippines were virulent to Mudgo (*Bph1*), ASD7 (*bph2*), and also partially virulent to Babawee (*bph4*). The third group: BPH populations from southern Vietnam were virulent to Mudgo (*Bph1*), ASD7 (*bph2*) and also involving quite high percentage of the BPH females were virulent to Babawee (*bph4*).

The present results showed that the virulent status of the BPH populations from southern Vietnam is higher than that from northern Vietnam. In Vietnam, rice cropping system is quite different from north and south region. In Northern Vietnam, Red River Delta region, rice is cultivated two times per year. In southern Vietnam, especially in the Mekong River Delta region; high-yielding improved rice varieties are cultivated all year round. Thus, the BPH population became adapted to cultivated rice varieties in this area. This adaptation may have been accelerated under conditions of insecticide overuse.

Present study demonstrates that the varieties Rathu Heenati and Balamawee have a broad spectrum of resistance against all the Asian BPH populations tested. This result agrees well with the previous studies that Rathu Heenati and Balamawee carried multiple resistance genes against the BPH (Sun et al., 2005; Jairin et al., 2007). These multiple genes help maintain their durable resistance to BPH. To avoid the development of virulent biotypes, considerable effort is being devoted to developing strategies such as the sequential release of resistance genes and use of pyramided lines carrying multiple genes in an attempt to control the BPH.

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Management of Rice Planthoppers in Vietnam

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Abstract

The Brown planthopper (BPH), *Nilaparvata lugens* Stal and the White backed planthopper (WBPH), *Sogatella furcifera* Horvath are two serious pests throughout Asia. The dominance of BPH or WBPH in each zone depends on ecological conditions where the different types of varieties have been cultivated. In Southern Vietnam, BPH has been dominant for a long time due to the widespread of elite resistant varieties originated from the International Rice Research Institute (IRRI). It was frequently reported since 2000 that BPH transmitted ragged stunt virus and grassy stunt virus in Southern Vietnam. On the other hand, hybrid and inbred varieties have been imported from China in Northern Vietnam where WBPH has become a major pest. The light trap data showed that the proportion of WBPH is recently 60-70% of rice planthoppers in the Northern part while this percentage is only 2- 4% in Southern provinces.

The virulence of BPH population is quite different in Vietnam. The virulence of BPH in Northern and Central Vietnam are moderate and almost same level. However, The virulence of BPH in Southern Vietnam, is stronger than those in Northern and Central Vietnam. The virulence of BPH population in Northern Vietnam is changing these days although the area of resistant varieties is limited in the region.

During the winter-spring season of 2008, WBPH occurred with high density in several Northern provinces. At the second generation of BPH (just before heading stage), they seriously damaged rice field and caused 72% of yield loss because of " hopper burn" symptom. The breeding resistant rice varieties against BPH in Southern and against WBPH in the Northern Vietnam are extremely importance.

Key Words: rice plant hopper, WBPH, BPH, RRSV (Rice ragged stunt virus), RGSV (Rice grassy stunt virus), resistant variety.

Introduction

The Brown planthopper(BPH), *Nilaparvata lugens* (Stal) and the Whitebacked plant hopper (WBPH), *Sogatella furcifera* (Horvath) are two serious pests throughout Asia. In the context of rapid industrialization and urbanization, rice production in Vietnam has achieved a considerable progress. However, the change of ecological system with an emphasis of using widely Chinese varieties (especially hybrid rice varieties), using numerous crops per year, high seed rate pesticides and nitrogen application in the South of Vietnam are the reasons leading to the change of the situation of rice plant hoppers and virus diseases. In the North, with virulent variation of BPH and outbreaks of WBPH in a large scale and In the South, period of 2005-2007, destroyed areas by BPH nearly 600.000 ha and infected virus disease 400.000ha. In the year 2008, over 180 thousand ha has infected by BPH in which 10.632 ha infected by virus diseases. Sustainable of rice production are threatened by rice planthoppers and virus diseases. Some research results of PPRI will be presented in this paper.

Materials and methods

Materials

Rice varieties: Rice varieties (hybrid and inbred rice) used for experiments were collected from both Northern and Southern Viet nam.

BPH and WBPH: 5 BPH strains were collected from the different provinces and areas in the North and South.

RRSV, RGSV diseases were evaluated in the greenhouse and surveyed in the field in the South.

Methods

The light trap were set up in 3 main regions (Northern, centre and Southern). The light was turned on at 19:00h everyday and the sample was collected and analyzed in the next morning.

The ratio of RRSV, RGSV diseases has evaluated following the method of IRRI.

The demonstration of rice production was presented in the South following PPRI's method.

Results and discussion

1. The density of rice planthopper in Northern Viet Nam in the recent year.

From 1990s to now, the rice structure in Northern Viet Nam has changed toward fast increasing hybrid rice areas (in the year of 2000 there were only 435.508 ha, but the year of 2008 it was 642.000ha). This has been changing the role and position of two species of rice plant hopper towards the opposite direction. The position and the role of WBPH has dominated comparison with BPH in some recent years. In the year of 2000,WBPH were broken out in the winter- spring crop and the hopper burn symptom occurred in Northern Viet Nam (Fig 1).

Table 1: Hybrid rice areas in Northern Viet Nam

Year	Total		Spring season		Summer season	
	Area (ha)	Yield (ton/ha)	Area (ha)	Yield (ton/ha)	Area (ha)	Yield (ton/ha)
1992	11.094	5.77	1.156	7.20	9.938	6.10
2000	435.508	6.44	227.615	6.50	207.000	6.37
2005	588.000	6.50	353.000	6.50	235.000	5.56
2007	620.000	6.50	400.000	6.50	220.000	5.68
2008	642.000	6.40	422.000	6.40	220.000	5.48

(source: National Extension Agriculture Centre-2008)

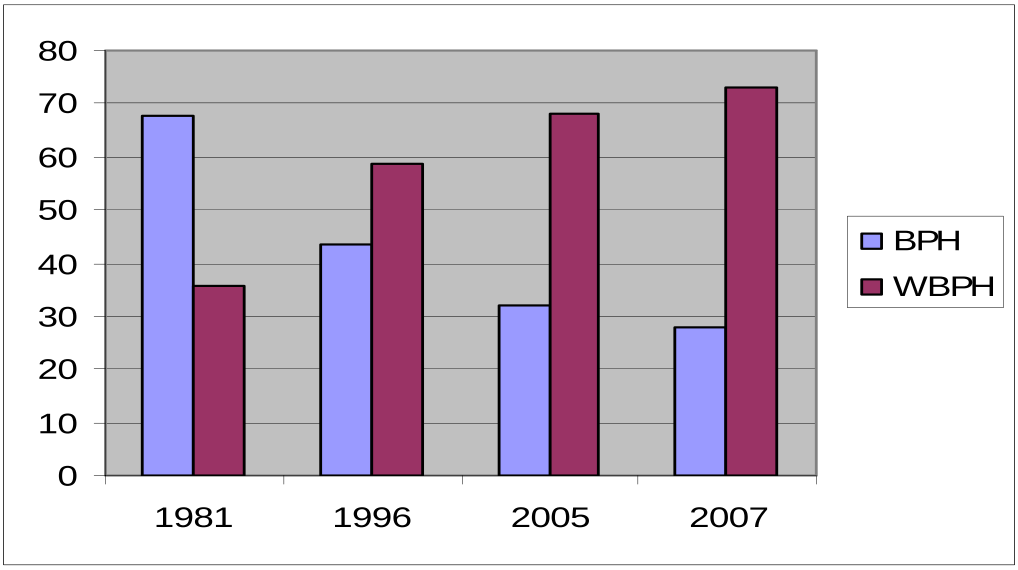

Fig.1. The rate of BPH and WBPH in the field in Northern Vietnam

The investigation in the fields of Northern Vietnam showed that the high peak of BPH occurred in the pre- ripen stage to the ripen stage, while the tillering to booting stage of rice were sensitive to WBPH. The peak of BPH and WBPH adults in the field coincided with the pick of that in the light trap. There were 6-7 generations of rice plant hoppers in the year in which WBPH generation appeared at the end April - early May and early September are the most serious and necessary to control. In the winter season, with lower temperature, WBPH and BPH could be presented in the fields but their life cycle is longer.

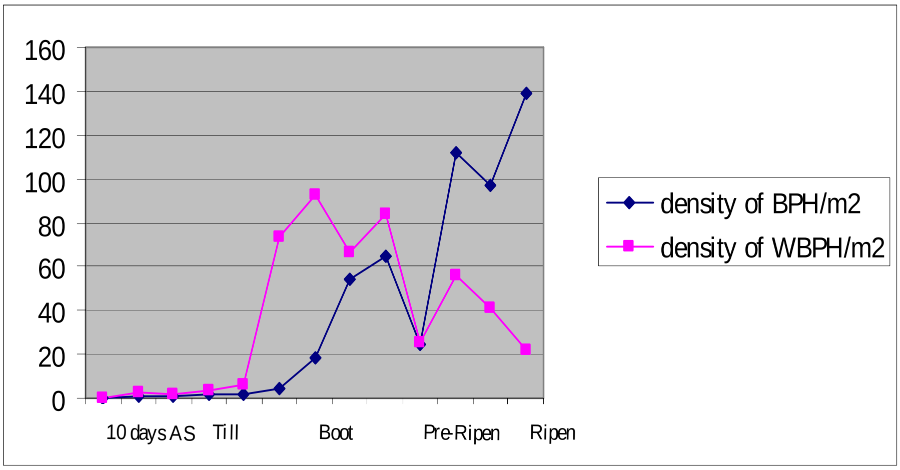

Fig.2.The density of BPH and WBPH in spring-winter season in Ha Tay province - Northern VietNam-2008

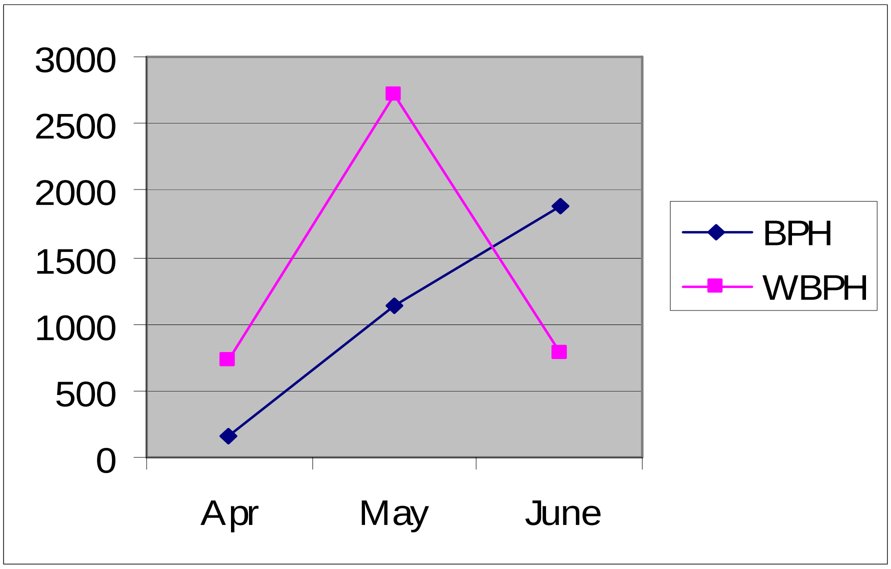

Fig.3. Population dynamic of BPH and WBPH in spring-winter seasonin Hai Phong Province-Northern VietNam-2008

The density of BPH and WBPH are different in different rice varieties. With the varieties such as hybrid rice, inbred rice originated from China and sticky rice, they had higher density than the inbred rice from IRRI(fig 4 and fig 5).

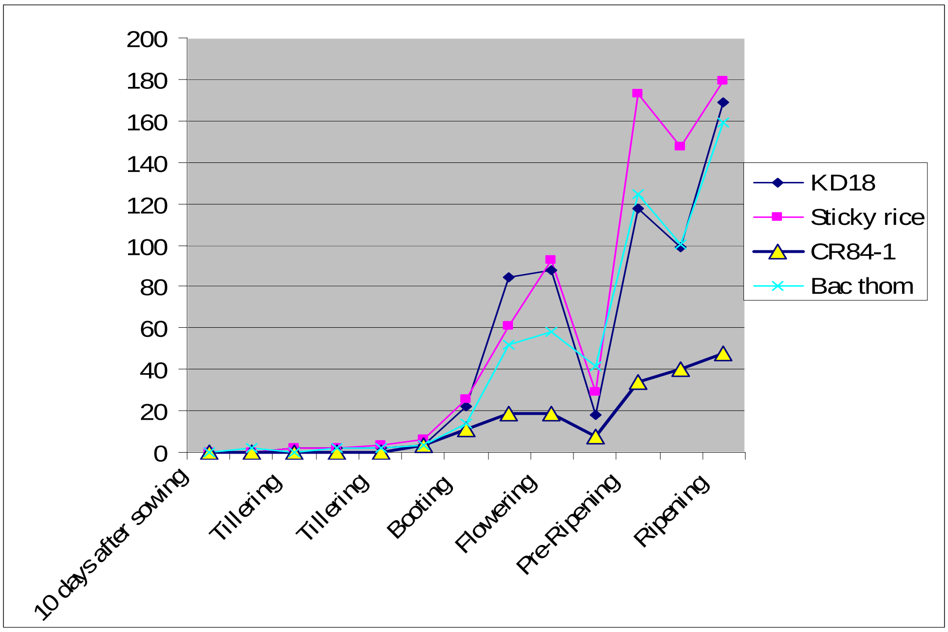

Fig.4. Population dynamic of BPH in spring-winter seasonin Hai Phong-Northern VietNam-2008

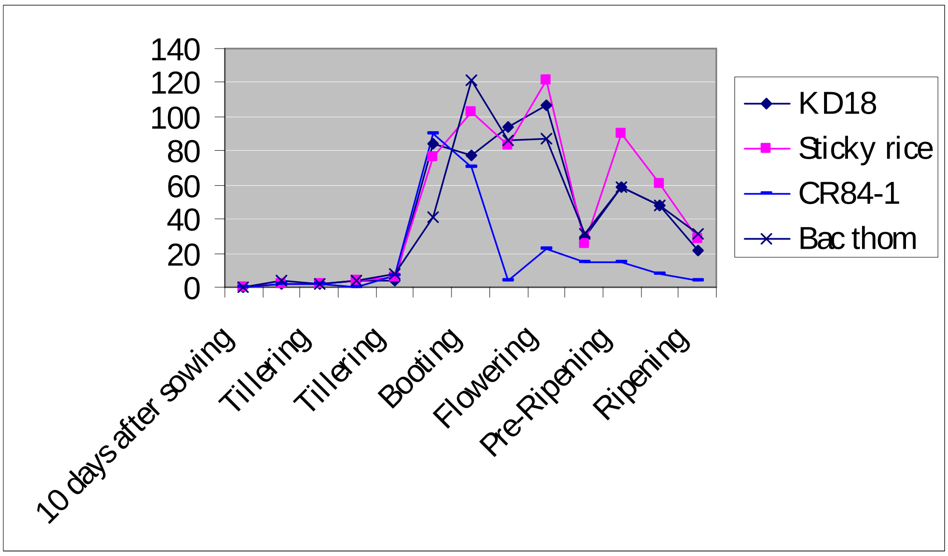

Fig.5.Population dynamic of WBPH in spring-winter season in Hai Phong-Northern VietNam-2008

2. The density of the rice planthopper in Southern Viet Nam and virus diseases in the recent year.

- In the years of 2005-2007, the infected area of virus diseases causing by BPH outbreaks were the highest. Total paddy rice production lost was around 400.000 tons in 2006. The appearance of BPH was all the time in the field. The reasons to make high BPH density were suggeted that there were synchronized cropping season, using more nitrogenous fertilizer; susceptible varieties and over chemicals in the field .

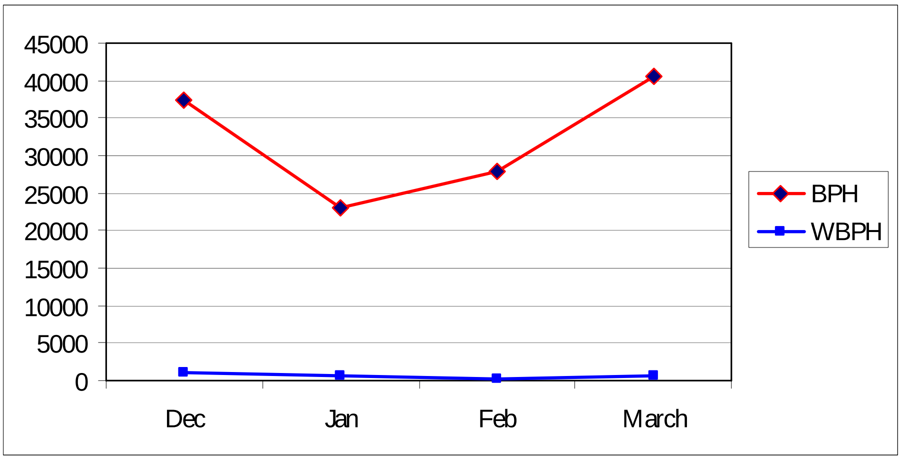

Fig.6.Population dynamic of BPH in the field of Thu Thua- Long An-2007

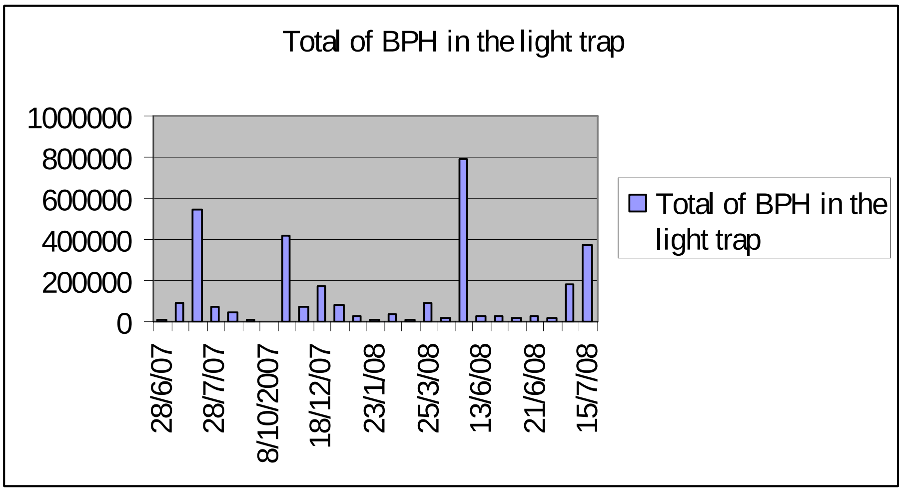

Fig.7. The density of BPH in the light trap in Long An-2007

The light trap datas in the South indicated that the dominant proportion of BPH comparison with WBPH from 1979 to 2008 due to both 2 periods using the same rice varieties originated from IRRI (Fig 8).

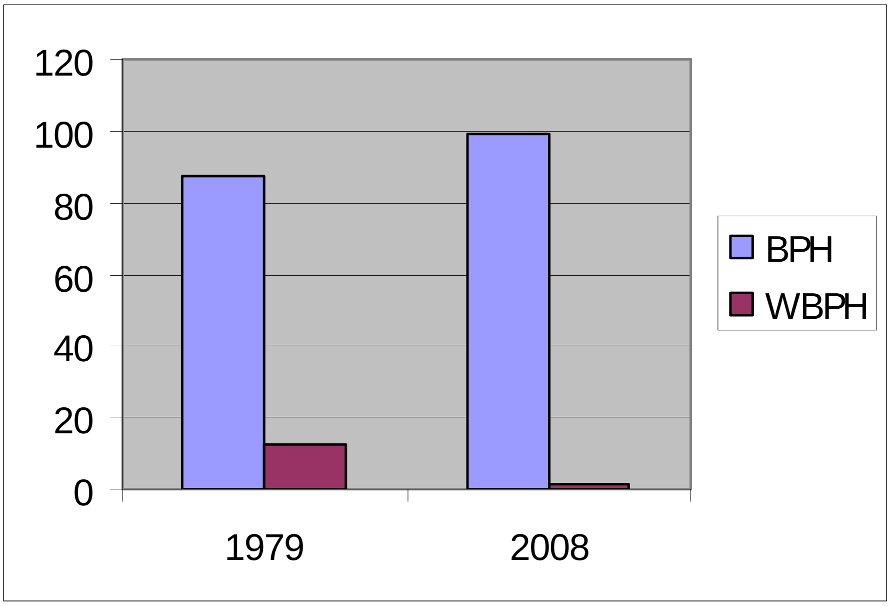

Fig.8. The ratio of BPH and WBPH in Long An

There was no difference between egg and nymph stage of BPH rearing on rice infected by virus and healthy rice, but the adult stage of BPH rearing on rice infected by virus was about 5 days longer than BPH rearing on healthy rice (Table 2).

Table 2: The time of nymphal stages between healthy rice and infected rice.

Stages	**Time of nymphal stages(date)**		
	healthy	**RGSV infected plant**	**RRSV infected plant**
Egg	7.23± 0,42	7,18± 0,45	7,27± 0,45
Nymph	14,14± 0,54	13,43± 0,47	13,8± 0,68
1 st	3,23± 0,42	3,09± 0,41	3,28± 0,45
2 st	2,32± 0,47	2,39± 0,49	2,36± 0,48
3 st	2,41± 0,49	2,43± 0,5	2,4± 0,49
4 st	2,68± 0,56	2,35± 0,48	2,44± 0,5
5 st	3,5± 0,58	3,17± 0,38	3,32± 0,47
Pre- oviposition	3,36± 0,77	2,4± 0,66	3,0± 1,04
Adult	22,36± 6,25	17,48 ± 4,33	17,84± 3,33

Food	Number of eggs/female BPH	Number of hatched egg	The rate of the hatched egg (%)
Healthy plant	193± 23,49	185,9± 23,41	96,29± 1,39
Rice infected RRSV	145,38± 19,42	130,5± 19,42	89,62± 2,24
Rice infected RGSV	134,78± 20,23	121,11± 19,49	89,74± 2,64

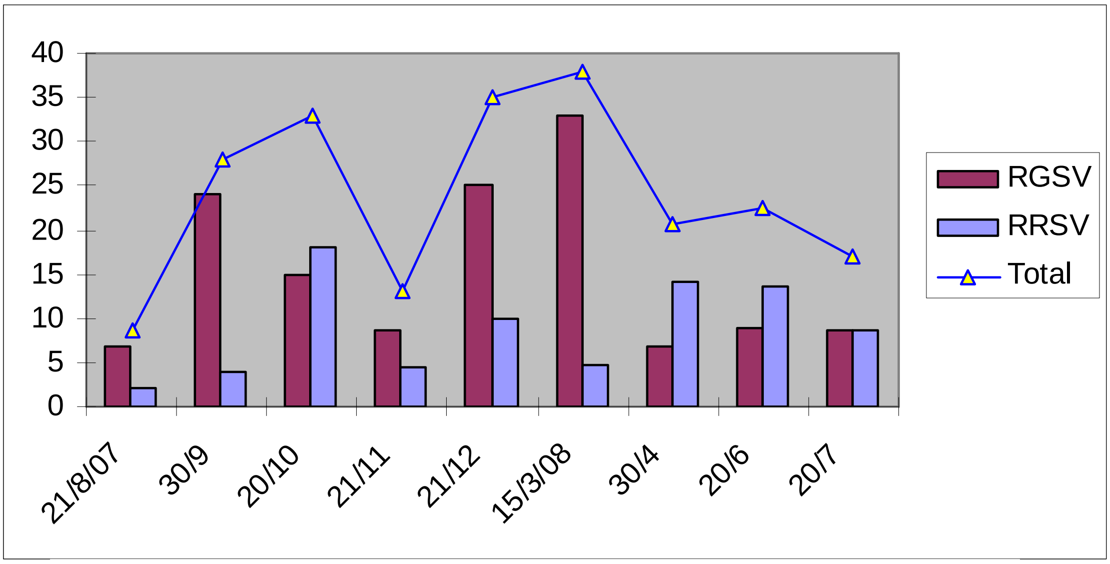

Fig 9. The ratio of two virus diseases in the field in Long An-2008

3. Demonstration fields

Table 3: The result compared between applying escape strategy in the demonstration

Season/ location	Demonstration			Farmer field	
	Areas	Rate of disease (%)	Yields (ton/ha)	Rate of disease (%)	Yields (ton/ha)
spring- winter (2006-2007)					
Long An	78.5	1.7	8.6	39.1	6.8
Summer- autumn (2007)					
Long An	45	4.3	6.2	7.9	6.0
Tra vinh	110	2.7	6.8	2.6	6.3
Autumn- winter (2007)					
Tra vinh	110	1.8	6.8	1.7	6.1
Spring –winter (2007-2008)					
Long An	45	4.3	6.7	15.7	6.4
Tra vinh	110	2.5	6.6	7.4	5.9

- Results of 7 demonstrations carried out at Long An and TraVinh using diseases management with escape strategy and synchronized cropping season base on light trap systems showed that the rate of disease is lower and the yields is higher than farmer fields. These are the moderns to present for expanding rice production in the south.

Table 4: Virulence of the BPH strains in three areas of Vietnam-2008

Variety	Resistant gene	HaTay	Khanh Hoa	Long An
Tai chung 69	None	7.5	9.0	6.4
Tai chung 65	None	9.0	9.0	7.0
TN1	None	9.0	9.0	9.0
Mudgo	Bph1	8.5	8.3	6.0
N22	Bph1	-	-	6.5
ASD7	bph2	9.0	9.0	7.5
Rathuheenati	Bph3	6.3	6.3	5.3
ADR52	Bph3	-	-	6.0
Babawee	bph4	6.3	5.0	5.3
Swarnalata	Bph6	5.0	5.7	5.2
Mangan	Bph6	-	-	5.6
T12	bph7	5.0	5.7	-
Chinsaba	bph8	6.3	5.0	5.3
Ptb33	bph2+Bph3	1.0	-	3.0

The virulence of BPH population in Khanh Hoa seem to be similar to that in HaTay- HaNoi. Overall, the virulence of BPH in the South was higher than that in the North.

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Forward the Design Breeding of Resistance to Planthoppers in Rice

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Key Words: Rice, brown planthopper (BPH), resistance gene, nearly-isogenic line (NIL), pest management

Abstract

The incorporation of host plant resistance to planthoppers into elite rice cultivars and the sustainability of pest management using resistant cultivars are important for a stable food supply in most rice production areas. The brown planthopper (BPH), *Nilaparvata lugens* Stål., is one of the most serious and destructive rice pests that can be found throughout rice growing areas in Asia. Twenty one major BPH resistance genes have been identified in several Indica cultivars and wild relatives. Recent molecular mapping of genes which are resistant to the planthoppers suggested that highly resistant cultivars/accessions often carried multiple genes for resistance. It suggests that gene pyramiding which combines more than two resistance genes derived from same/different donor(s) will delay the occurrence of virulent biotypes. Here, I describe the identification of BPH resistance genes and the development of nearly-isogenic lines for each resistance gene in order to improve rice cultivars through molecular genetic approach. Genetic enhancement of rice exotic germplasm is future target for breeding elite cultivars with resistance to the BPH. Marker-assisted selection, gene pyramiding, and map-based approach for gene isolation were discussed. We also discussed the monitoring of the genetic constitution of the BPH population; those probably involve several virulent types to the specific resistance gene(s), for sustainable pest management using resistant cultivars against the BPH.

Introduction

The planthopper species damage the plant epidermises and parenchyma with their stylets and suck the plant sap from the phloem. Among the phloem-feeding insects, the brown planthopper (BPH), *Nilaparvata lugens* Stål, is the most serious insect pest of rice (*Oryza sativa* L.) throughout Asia. The populations migrate from China to Japan during the rainy season every year (Kisimoto 1976). Though the migrant populations are not large, the progenies sometimes break out. The insect sucks out the plant sap and causes damage to rice plants such as reduction of crop vigor, plant height, productive tillers, perfect grains, and yield. In extreme cases, a heavy infestation of BPH results in complete necrosis of the rice plants, a condition commonly known as 'hopper burn'. It influences yield loss and also causes poor grain quality. The BPH is also a vector of the grassy stunt virus and ragged stunt virus, which seriously decrease rice production. Several kinds of resistant cultivars and accessions of rice against the planthoppers have been reported (Heinrich et al 1985). Host plant resistance to insects has been classified into three mechanistic types: antibiosis, antixenosis and tolerance (Painter 1951). However, distinguishing between these mechanisms against the planthopper species have been difficult with bulk seedling tests (Athwal et al 1971). Kishino and Ando (1978) established a simple method for evaluating antibiosis to the green rice leafhopper (GRH), and the survival ratio of the GRH nymphs was examined on the tested cultivars. Using this evaluation method, genetic analyses of resistance to the GRH have been carried out, and at least six loci for the GRH resistance have been identified with the aid of DNA markers. The simple sequence repeat (SSR) marker loci are widely distributed throughout the genome and can be easily analyzed using a polymerase chain reaction (PCR). The SSR markers have been used extensively to map agronomically important loci in rice, such as disease and insect resistance. It has opened the door to further revelations regarding the mechanisms of host plant resistance to the insect pests through molecular mapping and the cloning of genes which will confer resistance to the phelom-sucking insects such as BPH and GRH. The relationship between rice and the GRH is a model case of plant-insect interaction. The knowledge obtained from a series of molecular cloning is expected to reveal the sucking resistance and system of host-plant resistance breakdown.

The objectives of the present study are to understand the genetic basis for a resistance to BPH found in rice cultivars and accessions of wild rice, as well as facilitate the use of germplasm for future rice improvements. First, a quantitative trait loci (QTL) analysis for resistance to the insect pests was conducted using an initial mapping population derived from the cross between a susceptible cultivar and a resistant accession. Subsequently, new loci for the resistance to insect pests were mapped onto a molecular linkage map using a nearly isogenic population, which was developed by continuous backcrossing and marker-assisted selection (MAS) of the targeted QTL region. Finally, we discuss the necessity of monitoring genetic constitutions of the insect populations, which probably involve several virulent types to the specific resistance gene(s), for sustainable pest management using resistant cultivars against the insect pests.

Materials and Methods

Plant materials

Nine rice cultivars with different levels of resistance to the BPH: ADR52, PodiwiA-8, Mudgo, ASD7, Rathu Heenati, Babawee, Chin Saba, Balamawee, Taichung 65 (T65) (no resistance gene) were used. Nearly-isogenic lines derived from the BPH resistant cultivar ADR52 were used.

Insect strains

Three BPH strains were evaluated: (1) Hatano-66 strain collected from Hatano, Kanagawa Prefecture, Japan in 1966, (2) Chikugo-89 strain collected from Chikugo, Fukuoka Prefecture, Japan in 1989, and (3) Isahaya-99 strain collected from Isahaya, Nagasaki Prefecture, Japan in 1999. They are maintained separately by continuously rearing on susceptible variety ‘Reihou’ at 25±1°C under 16 h light and 8 h dark condition in the National Agricultural Research Center for Kyushu Okinawa Region (KONARC). Chikugo-89 strain was used to map the QTLs involved in ADR52. The BPH strains collected in 1989 and 1999 in Japan have different virulence characteristics to rice differential cultivars (Myint et al., 2009). Chikugo-89 strain was virulent to

Mudgo carrying *Bph1* but avirulent to ASD7 carrying *bph2*. The BPH strain collected in 1999 was virulent to Mudgo carrying *Bph1* and ASD7 carrying *bph2*.

In 2006, ten populations of BPH were collected in East Asia. Four populations were collected from the Red river delta (Vietnam-HT, Vietnam-HP) in Northern Vietnam and Mekong river delta (Vietnam-TGL, Vietnam-TGH) in Southern Vietnam. Three populations were collected from the Philippines; Northern and Central Luzon islands (Philippines-NE-B, Philippines-AN) and Mindanao island (Philippines-CG). Each population from Japan (Japan-KG), China (China-FJF), and Taiwan (Taiwan-CH) were collected. These populations were maintained by continuous rearing on susceptible cultivars 'Reiho' at 25±1°C under 16h light and 8h dark conditions in the laboratory of Pest Management System, National Agricultural Research Center for Kyushu-Okinawa Region, Kumamoto, Japan. Thus, these BPH strain was used for monitoring the current status of virulence in BPH strains against the resistance gene, *bph20*(t) and *Bph21*(t).

Evaluation of the resistance to BPH

The one-month old plants were trimmed and covered with a transparent plastic cylindrical cage (5.5 cm D x 20cm H). The antibiosis test were carried out using the method described by Tanaka (2000). Five brachypterous females within 24h after emergence were released to a single rice plant at one month after sowing. The score was observed from 3 to 5 DAI. The adult mortality as well as the shape of abdomen were examined. Females that formed a heavily swollen abdomen or survived for five days were defined as virulent, and females died within five days as avirulent. Plants with adult mortality found to be less than 30% were categorized as susceptible and those with adult mortality found to be greater than 70% were categorized as resistant. The experiment was carried out with 8 replications.

Statistical analysis

The data was analyzed using two-way ANOVA. *bph20*(t)-NIL, *Bph21*(t)-NIL and *bph20*(t)/*Bph21*(t)-PYL were developed through continuous backcrossing with T65 and MAS. These NILs and PYL were evaluated for BPH resistance at the seedling stage and T65 was used as a susceptible control. The resistance level was compared by the adult mortality and by females of a swollen abdomen at 5 DAI. The experiment was carried out with seven replications. Data were analyzed using one-way ANOVA and treatment means were pair-wise compared using the Tukey-Kramer test (SAS Institute Inc., 2003). The adult mortality (%) and females with a swollen abdomen (%) was arcsine transformed prior to analysis.

Results and Discussion

QTL analyses of highly resistant cultivars to BPH and developing the NILs

The advent of detailed molecular linkage maps in rice has made it possible to detect the quantitative trait loci (QTLs) which control agronomic characters such as biotic and abiotic stresses. In screening germplasm resistance to the BPH under antibiotic tests, four Indica cultivars, ADR52, Podiwi A8, ASD7 and Balamawee, were selected as highly resistant. QTL analyses for antibiosis to BPH were conducted using F2 populations derived from a cross between a susceptible Japonica cultivar and resistant Indica cultivars. The study has assured future mapping of the BPH-resistance gene using nearly isogenic populations developed through marker-assisted selection (MAS). In the case of ADR52, a total of three QTLs controlling antibiosis to the BPH were detected on chromosomes 5, 6 and 12. Nearly isogenic lines (NILs) and pyramided lines (PYLs) for respective QTLs were developed through continuous backcrossing and MAS. The newly identified resistance genes on chromosomes 6 and 12 were tentatively designated as *bph20*(t) and *Bph21*(t), respectively.

Development of NILs and pyramided lines PYLs for the BPH resistance genes

Since highly resistant cultivars often carried multiple genes for resistance to the BPH, a nearly isogenic population was necessary to map the BPH resistance gene, precisely. The MAS for BPH resistance genes with advanced backcrossing with the recurrent parent can facilitate transferring the resistance to the BPH from the resistant cultivars and wild relatives. The NILs and PYLs derived from the resistant germplasm are useful not only for the improvement of BPH resistance in rice improvement but also for monitoring BPH virulence to the specific resistance gene.

Understanding the mechanisms of a breakdown of the resistance gene

Virulent insect pests, the so-called new biotypes, often appear after the release of modern improved varieties of rice that carry a single major gene for resistance to the insect pests. These pests represent a serious threat to rice paddies, because they have acquired virulence to the specific resistance gene, which will have subsequently lost its effectiveness in insect pest management. For example, the BPH population migrating into Japan began to become virulent to the *Bph1* (*Brown planthopper resistance 1*) in the late 1980s (Sogawa 1992) and has become highly virulent for rice cultivars carrying both *Bph1* and *bph2* since the late 1990s (Tanaka and Matsumura 2000). The virulent biotypes of the BPH were experimentally identified by continuous rearing of the BPH on resistance lines, each carrying a single major gene for BPH resistance (Ketipearachchi et al 1998). By a similar methodology, virulent biotypes against each of the three resistance genes *Grh1*, *Grh2* and *Grh3* were isolated (Hirae et al, 2007). It suggests that natural strains of GRH are likely to feed on rice plants having a single major gene for the resistance. In contrast, virulent biotypes against the PYL carrying both *Grh2* and *Grh4* did not occur experimentally (Hirae et al, 2007). In line with these findings, we have demonstrated that, although the nymph mortality of *Grh4*-NIL showed susceptibility to the GRH, the PYL carrying *Grh2* and *Grh4* showed higher nymph mortality than *Grh2*-NIL. Additionally, both *Grh2* and *Grh4* have been essential to express resistance to the green leafhopper (GLH), which is closely related to the GRH and a major vector of Tungro, a destructive viral disease found in tropical rice fields in Asia (Yasui and Yoshimura 1999). The PYLs carrying *Grh2* and *Grh4* may thus have an important role in expressing durable resistance to the rice leafhoppers. It suggests that gene pyramiding that combines multiple resistance genes with different mechanistic types will suppress the dominancy of virulent biotypes in the insect population. The PYLs carrying these resistant genes may suppress the dominancy of virulent biotypes and show durable resistance to the GRH. To study the durability of resistance to insect pests, the development of PYLs carrying multiple resistance genes is essential using MAS and advanced backcrossing with a recurrent parent.

Virulence of the Asian BPH strains against rice differential cultivars

Matsumura demonstrated that the adult survival rate and the ratio of virulent females of the 10 Asian BPH strains on 6 differential cultivars and T65 are a susceptible check (Proceedings: this issue). Based on the resistance spectrum, the Asian BPH strains seem to be classified into three groups: the first group virulent to Mudgo and ASD7 but avirulent to the other 4 differential cultivars, the second group involving quite high percentage of the BPH individuals virulent to Babawee and ADR52 in addition to Mudgo and ASD7, the third group partially virulent to Babawee in addition to Mudgo and ASD7. The first group involved BPH strains collected from Japan, China, Taiwan and two strains of Northern Vietnam. The second group consisted of the two BPH strains collected from Southern Vietnam. The third group consisted of three strains from the Philippines, one which was collected from Mindanao Island and involved about half of BPH individuals virulent to Mudgo and ASD7. We concluded that the cultivars Rathu Heenati and Balamawee are still keeping a broad spectrum of resistance against the Asian BPH strains.

Monitoring the BPH virulence using rice NILs

Adult survival rates and development of the proportion of BPH females with swollen abdomen are shown in Table 1 and Table 2, respectively. Small proportions of Hatano-66 and Chikugo-89 females survived on NILs (*bph20*(t)-NIL and *Bph21*(t)-NIL), PYL (*bph20*(t), *Bph21*(t)-PYL), and ADR52 (resistant check) ranging from 0 to 20.0% and all the females that survived did not show a swollen abdomen. In contrast, high proportions of Isahaya-99 females survived on the *bph20*(t)-NIL (87.5%) and on *Bph21*(t)-NIL (100.0%). Eighty percent of Isahaya-99 females showed swollen abdomens on the two NILs. However, adult survivorship in Isahaya-99 strain remained small on the PYL and ADR52 (12.5 and 20.0%, respectively), and all the surviving females did not show swollen abdomens. These results indicate that Hatano-66 and Chikugo-89 strains were avirulent to *bph20*(t)-NIL, *Bph21*(t)-NIL and their PYL. However, Isahaya-99 strains was virulent to *bph20*(t)-NIL, *Bph21*(t)-NIL but avirulent to the PYL.

Table 1. Adult survival rates (%) of *Nilaparvata lugens* strains on NILs and their PYL of rice

		***Nilaparvata lugens* strains** [a, b]		
Line	**Resistance gene**	**Hatano-66**	**Chikugo-89**	**Isahaya-99**
bph20(t)-NIL	*bph20*(t)	20.0±6.5 b	5.0±3.3 b	87.5±3.7 a
Bph21(t)-NIL	*Bph21*(t)	2.5±2.5 c	2.5±2.5 b	100.0±0.0 a
bph20(t), *Bph21*(t)-PYL	*bph20*(t), *Bph21*(t)	0.0±0.0 c	2.5±2.5 b	20.0±3.8 b
ADR52 (R. check)	*bph20*(t), *Bph21*(t)	0.0±0.0 c	2.5±2.5 b	12.5±3.6 b
T65 (S. check)	no resistance gene	82.5±2.5 a	85.0±5.0 a	95.0±3.3 a

[a] Hatano-66, Chikugo-89, Isahaya-99 strains were collected in 1966, 1989 and 1999, respectively.

[b] Means (mean ± S.E.) followed by the same letter are not significantly different at *P*<0.01, by the Tukey-Kramer multiple comparison test.

Table 2. The proportion (%) of *Nilaparvata lugens* females whose abdomen became swollen on NILs and their PYL of rice

		Nilaparvata lugens **strains**[a, b]		
Line	**Resistance gene**	**Hatano-66**	**Chikugo-89**	**Isahaya-99**
bph20(t)-NIL	*bph20*(t)	0.0±0.0 b	0.0±0.0 b	80.0±3.8 a
Bph21(t)-NIL	*Bph21*(t)	0.0±0.0 b	0.0±0.0 b	80.0±5.3 a
bph20(t), *Bph21*(t)-PYL	*bph20*(t), *Bph21*(t)	0.0±0.0 b	0.0±0.0 b	0.0±0.0 b
ADR52 (R. check)	*bph20*(t), *Bph21*(t)	0.0±0.0 b	0.0±0.0 b	0.0±0.0 b
T65 (S. check)	no resistance gene	80.0±3.8 a	83.0±5.9 a	90.0±3.8 a

[a] Hatano-66, Chikugo-89, Isahaya-99 strains were collected in 1966, 1989 and 1999, respectively.
[b] Means (mean ± S.E.) followed by the same letter are not significantly different at *P*<0.01, by the Tukey-Kramer multiple comparison test.

Tables 3 and 4 showed that the adult survival rate and the ratio of the virulent females of the 10 Asian BPH strains on the NILs and the PYL carrying the BPH resistance genes are derived from ADR52. Based on the resistance spectrum to NILs and the PYL for *bph20*(t) and *Bph21*(t), the Asian BPH strains seem to be classified into four groups: the first group avirulent to all the tested lines, the second group virulent to the *Bph21*(t)-NIL but avirulent to the *bph20*(t)-NIL and the *bph20*(t)+*Bph21*(t)-PYL, the third group virulent to both the *bph20*(t)-NIL and the *Bph21*(t)-NIL but avirulent to the *bph20*(t)+*Bph21*(t)-PYL, and the fourth group virulent to all tested lines. The first group is the Mindanao strain, which could not adapt to any lines. The second group consisted of BPH strains from China, and Taiwan. The third group consisted of BPH strains from Japan, Northern Vietnam and two Luzon strains from the Philippines. The discrimination between the second and the third groups is still ambiguous because of differentiation among the BPH strains from China, Taiwan and Japan as well as Northern Vietnam which have never been identified. The fourth group consisted of BPH strains from Southern Vietnam, those were most virulent and half of the adult females had swollen abdomens on the PYL within 5 days. The results indicate that both of the BPH resistance genes, *bph20*(t) and *Bph21*(t), are necessary to express broad-spectrum resistance against the East Asian BPH strains. The PYL, however, had lost their resistance against the Southern Vietnam strains of BPH. Monitoring the virulence of BPH strains using the NILs and the PYLs will open the door for utilization of the BPH resistant cultivars and sustainable pest management in the Asian rice field.

Table 3. Survival rates (means ± S.E.) of Asian *Nilaparvata lugens* strains on rice nearly isogenic lines and pyramided line

Variety	Resistance gene	Asian *N. lugens* strain *									
		Philippines AN-06	Philippines NE-B-06	Philippines CG-06	Taiwan CH-06	China FJF-06	Japan KG-06	Vietnam HT-06	Vietnam HP-06	Vietnam TGL-06	Vietnam TGH-06
bph20 (t)-NIL	*bph20* (t)	25.7±5.3 b	85.7±3.4 a	60.0±5.7 b	31.4±8.9 b	31.9±4.8 b	85.7±3.4 a	94.3±5.3 a	60.0±4.0 b	74.3±5.3 ab	88.6±6.8 a
Bph21 (t)-NIL	*Bph21* (t)	37.1±2.6 b	80.0±5.7 a	91.4±3.7 a	85.7±3.4 a	80.0±4.0 a	88.6±5.5 a	91.4±5.5 a	94.3±3.4 a	94.3±3.4 a	91.4±3.7 a
bph20 (t)+*Bph21* (t)-PYL	*bph20* (t),*Bph21* (t)	28.6±7.9 b	17.1±6.3 b	25.7±6.7 c	28.6±5.5 b	20.0±4.0 b	17.1±6.3 b	28.6±3.7 b	25.7±5.3 c	71.4±6.8 b	65.7±3.4 b
Taichung 65	no resistance gene	91.4±5.5 a	91.4±5.5 a	94.3±3.4 a	97.1±2.6 a	94.3±3.4 a	91.4±3.7 a	97.1±2.6 a	94.3±3.4 a	91.4±5.5 ab	91.4±3.7 a

* Means followed by the same letters are not significantly different at $P<0.01$, by the Tukey-Kramer multiple comparison test.

Table 4. The proportion (%) of *Nilaparvata lugens* females with swollen abdomen at five days after infestation

Variety	Resistance gene	Asian *N. lugens* strain*									
		Philippines AN-06	Philippines NE-B-06	Philippines CG-06	Taiwan CH-06	China FJF-06	Japan KG-06	Vietnam HT-06	Vietnam HP-06	Vietnam TGL-06	Vietnam TGH-06
bph20 (t)-NIL	*bph20* (t)-NIL	0.0±0.0	37.1±4.8	34.3±5.3	5.0±0.0	6.0±0.0	62.9±2.6	82.9±6.3	51.4±5.5	68.6±3.7	71.4±3.7
Bph21 (t)-NIL	*Bph21* (t)-NIL	11.4±3.7	51.4±3.7	77.1±6.3	77.1±2.6	80.0±4.0	85.7±5.3	71.4±3.7	77.1±6.3	88.6±3.7	85.7±3.4
bph20 (t)+*Bph21* (t)-PYL	*bph20* (t),*Bph21* (t)	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	48.6±5.5	51.4±5.5
Taichung 65	no resistance gene	88.6±5.5	91.4±5.5	94.3±3.4	97.1±2.6	94.3±3.4	85.7±5.3	97.1±2.6	88.6±5.5	80.0±5.7	85.7±3.4

* The data were given as mean ± S. E.

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Session 2
"Crop Science and Horticulture"

Horticultural Development in Northern Upland Region of Vietnam

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Key Words: Horticulture, fruit crop production, vegetables production, Northern upland of Vietnam.

Abstract

The Northern Upland of Vietnam (the targeted service area of Thai Nguyen University of Agriculture and Forestry- TUAF) is consist of 16 provinces with total area of about 10.313.876 ha (31% of nation-wide area), population is 13.291.000, of which, 40% are ethnic minority people separated in to 54 different groups. The annual income is about 430 USD/person (55% compared to the nation-wide average level), GDP in the area is occupied only 9,6 % of the total country's GDP.

Horticultural production in Northern Upland of Vietnam is mainly fruit crops and vegetable production. To date, the flower production is not yet available except some very few productions to be produced by small private companies.

Fruit production: Northern upland is a sole ecological area of Vietnam which can be growth many different kind of fruit crop as: temperate types (pear, apple, persimmon…) subtropical types (lichee, citrus, plum…) and tropical (banana, pineapple,..), however, the current fruit production of Northern upland is only 9,4% of country production (313,600 tons).

Vegetable production: vegetable produced in Northern Upland is mainly for domestic consumption. The production is mainly produced by local varieties with traditional cultivation methods. Application of advance technology is still new to almost producers (farmers). The total vegetable production is about 1,008,000 tons (10,5 % of country's production).

Hybrid Rice: Current Status in Thailand and Its Prospect on Transformation of Farming Systems

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Abstract

Thailand has been the largest rice exporter for a decade. In 2007, Thailand had 32 percent share in the world rice market and up to 9.2 million ton of milled rice was exported with a value of US$ 3,400 million while 11.2 million ton of milled rice was consumed domestically. An average yield of 2.5 ton per hectare of Thai rice cultivars is relatively low as compared to an average yield more than 4 ton per hectare of other major rice cultivating countries that use hybrid rice. Hybrid rice development has been carried out in Thailand since 1979 but only two F1 hybrids commercially released by a private company are currently available and grown in very limited areas. More than 60 percent of rice cultivation areas in Thailand are rain-fed and may not be suitable for hybrid rice that performs well in irrigated areas and requires intensive cultivation. Inconsistent yield, inferior grain quality, complication of seed production, limited seed supply and high seed cost are major concerns of farmers to shift from the current improved cultivars and native cultivars to hybrid rice. As hybrid rice has shorter growth duration, a triple cropping system in irrigated areas is possible and it is less likely that farmers will have other rotation of crops in this intensive rice-based farming. With approximately 20 percent increase in yield per area of hybrid rice, it has been proposed that production areas could be decreased down to 4 million hectare to produce the same yield as 10 million hectare of rice fields at present. Then some rice fields will be turned to plantations of economic crops such as rubber and oil palm for better gain. Roles of a typical farmer will be changed to a farm manager as an efficient hybrid rice production will rely more on out-source services of field preparation, seedling nursery production, transplanting, plant protection and harvesting provided by experienced crews using modern technologies. Potential cash crops and perennials that can be incorporated into a hybrid rice-based farming system are discussed.

Key Words: Hybrid rice, rice-based farming, triple cropping, Thai

Introduction

Hybrid rice technology developed in the 1970s in China has a great influence on rice production. An increase in grain yield of hybrid rice reaching 15-20 percent over superior inbred cultivars and its relatively short growth duration enhance its popularity in China and in other rice producing countries including Vietnam, India, the Philippines, etc. (Virmani, 1996). With an increasing world demand of rice, expansion of hybrid rice cultivation can ensure food security and be able to generate more local income on hybrid rice seed production. Effects of hybrid rice cultivation on transformation of farming systems in Vietnam have been reported recently (Isshiki and Miyajima, 2007). In Thailand, commercial production of hybrid rice is still in a very small scale. This paper aims to present the fact and figure of rice production in Thailand, current status of hybrid rice and prospect scenario that hybrid rice may have on transformation of farming system.

Rice Production in Thailand

Thailand is one of the major rice producing countries in the world. Rice is grown in every part of the country with the total production area of 10.7 million hectare in the year 2007. Most of rice production areas are in-season rice field in the northeastern region growing only one crop per year under rain-fed condition while double or triple crops per year have been commonly practiced in the central region with ample irrigation supply (Table 1). Production of Thai rice in 2007 yielded 29.9 ton of paddy and more than 70 percent of which are from in-season rice field (Table 1). Among three major kinds of Thai rice, long grain white rice is predominant sharing 45 percent of total paddy yield followed by long grain aromatic rice or the world famous "Jasmine" rice and long grain glutinous rice or sticky rice which is preferable in the north and northeastern regions (Figure 1). Up to 53 percent of paddy is consumed domestically and the surplus of 47 percent is exported to the world market. Thailand has been the world largest rice exporter for 20 years and currently holding the market share of 32 percent. Milled rice of 11.2 million ton was consumed domestically and 9.2 million ton was exported generating income of US$ 3,508.9 million in 2007.

Table 1. Rice production in Thailand in 2007: production area, paddy yield and average yield per area of in-season rice and double-crop rice from irrigated and rain-fed areas.

Sources	Production area (x million ha)	Paddy yield (x million ton)	Average yield/area (kg/ha)
In-season rice field	**9.2**	**23.4**	**2,544**
Irrigated field	2.3	7.8	3,356
Rain-fed	6.9	15.6	2,275
Double-crop field	**1.5**	**6.5**	**4,275**
Irrigated field	1.1	5.0	4,375
Rain-fed	0.4	1.5	3,956
Total	**10.7**	**29.9**	**-**

Source: Office of Agricultural Statistics, Ministry of Agriculture and Cooperatives

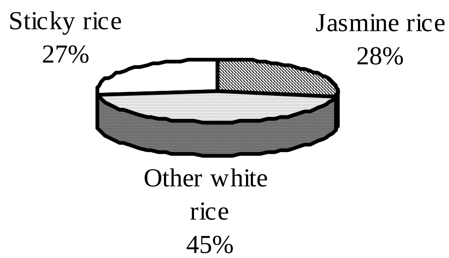

Figure 1. Proportion of white rice, Jasmine rice and sticky rice production in Thailand.

In-season rice fields are mainly rain-fed and their average yield per unit area is generally lower than that of double crop fields under irrigated areas (Table 1). Despite the fact that Thailand is the world largest rice exporter, the average yield of 2.5 ton per hectare of Thai rice cultivars is quite low as compared to the average yield more than 4 ton per hectare of other major rice cultivating countries such as China and Vietnam that use hybrid rice.

Status of hybrid rice in Thailand

The Rice Department, Ministry of Agriculture and Cooperatives is in charge of rice cultivar improvement. Hybrid rice introduced from China was tested for the first time in 1979 but the results were not satisfactory due to poor adaptation of Chinese hybrid rice to Thailand conditions. In 1980, the hybrid rice research program was established and several research works on hybrid rice have been done with good collaboration with IRRI and other research institutes both in Thailand and other countries. Recently, the Rice Department has introduced the new hybrid rice 'PTT06001H' to the public. The hybrid is a long-grain non-glutinous type with short growth duration, photoperiod insensitive, high yield and non-aromatic characteristics (Table 2). With high amylose content of 28 percent, texture of this new hybrid rice is relatively hard. The department clearly states that this new hybrid rice is an alternative choice for farmers and it will not aim to replace the existing regular rice cultivars.

Table 2. Characteristics of PTT06001H hybrid rice

	Characteristics
Photoperiod	Insensitive
Grain type	Long grain, non-glutinous
Growth duration (days)	116
Yield (ton/ha)	> 6.3 in irrigated areas
Amylose (%)	28

Another group of hybrid rice research in Thailand is led by Dr. Pattama Sirithanya, Faculty of Agricultural Science and Technology, Rajamungkala Lanna University in Lampang province. The research program has been established since 2000. Up to 20 hybrids (non-glutinous type) with average yield more than 9 ton per hectare are being tested in different locations. Distinct hybrids are expected to be released within 3 years from now. Due to their hard texture which is not preferable by Thai consumers, these hybrids are aimed for related industry such as processing, rice flour and ethanol.

Charoen Pokaphand Group (CP), the largest agricultural business conglomeration in Thailand has developed hybrid rice since 1994. In 2007, CP launched CP 304 and CP 357 hybrid rice for Thai farmers for the first time and these are only two hybrid rice cultivars commercially grown in Thailand at present. CP 304 and CP 357 are non-glutinous long grain type with short growth duration, photoperiod insensitive, high yield and non-aromatic characteristics (Table 3). They perform well in irrigated areas. These two hybrids have different texture due to their different amylose content. From small production areas of 64 hectare in 10 provinces in 2007, production areas were expanded to 480 hectares in 2008. According to a survey report, an average yield of CP hybrid rice was 7.5 ton per hectare which is still below their full potential. Cultivation techniques, transplanting services, loan and buy back contract were provided by CP to encourage farmers to grow CP hybrid rice. Irrigated fields in the lower northern region of Thailand are targeted as major CP hybrid rice production sites and CP group expects to cover 9 percent of the areas within 5 years (Biothai, 2008).

Table 3. Characteristics of CP304 and CP357 hybrid rice

	Characteristics	
	CP304	CP357
Photoperiod	insensitive	insensitive
Grain type	long grain, non-glutinous	long grain, non-glutinous
Growth duration (days)	90 - 100	90-100
Yield (ton/ha)	9.4	9.4
Amylose (%)	23-24	16-17
Texture	medium - hard	soft

Why is hybrid rice not widely grown in Thailand?

At present, hybrid rice is not highly promoted in Thailand as in China and Vietnam. Production capacity of Thai rice with existing cultivars has met the demand for both domestic and export markets. Therefore, high yield hybrid rice is not in urgent need. Ministry of Agriculture and Cooperatives considers hybrid rice as an alternative choice for farmers and its development is important to keep up with current trend of technology. Other reasons that limit hybrid rice production in Thailand include limited seed availability, inferior grain quality, inconsistent yield, high production cost and farmers' preference.

The demand for rice seed in Thailand is approximately 900,000 ton annually. Major seed sources are private producers and seeds kept by farmers for their own uses while the Rice Department can provide only 70,000 ton of good quality seeds at affordable price. Hybrid rice seeds are not widely available due to its complication of production techniques and ownership of the parent lines. Importation of hybrid rice seed for commercial production is prohibited by law. Hybrid rice seeds are almost 10 times more expensive than regular rice seeds. CP hybrid rice seeds cost US$ 4.4 per kilogram while hybrid rice seeds from the Rice Department cost US$ 2.1 per kilogram as compared to less than US$ 0.4 per kilogram for regular rice seeds. As farmers cannot keep their seeds as before and have to buy expensive hybrid seeds for every crop, they considered this as a disadvantage.

Commercial hybrid rice in Thailand has lower grain quality than existing cultivars. Despite of high yield advantage of hybrid rice, farmers still get the same price per unit weight when compared to the existing cultivars. According to a survey, yield of commercial hybrid rice in irrigated areas of central Thailand is not significantly higher than that of some existing improved cultivars. Moreover, farmers have to invest more on hybrid rice production to get targeted yield. Production cost of hybrid rice is US$ 797 per hectare while farmers invest only US$ 433 per hectare for regular rice. High production cost involves with more expensive seeds and higher requirement for fertilizer and pesticide in hybrid rice. Above all, most Thai farmers still prefer to grow high quality, low-yielding traditional cultivars to fetch a premium price in the domestic and the world markets (Biothai, 2008).

Hybrid rice and transformation of farming system: a scenario

A scenario that hybrid rice cultivation may transform farming systems in Thailand is proposed based on current situation and focused only in irrigated areas of the central region which is suitable for hybrid rice production. Mr. Thanin Jiaravanon, Chairman and CEO of Charoen Pokphand (CP) Group suggested that the government should invest more to improve irrigation canal system so that rice production zone of 4 million hectare can be developed. Growing hybrid rice 2 – 3 crops per year in this zone will get comparable yield to that of 10 million hectare of rice field at present. Thus rice production areas will decrease and some rice fields with low yield will be switched to other economic crops such as rubber trees and oil palms. Approximately 4.8 million hectare of rubber trees and 1.9 million hectare of oil palm have been proposed.

To be more efficient in double or triple rice cropping, farmers will rely more on out-source services. Land preparation by professional tractor can be hired at the rate of US$ 74-110 per hectare. This high power tractor is more efficient and reliable than a small plowing machine run by family members. The field will be ready for the next crop faster. As hybrid rice seeds are expensive, planting method will be changed from broadcasting of germinated seeds (125 kg of seeds per hectare), a common method in irrigated areas of the central region, to transplanting which requires less seeds per area (63 kg of seeds per hectare). Farmers will rely more on a seedling nursery and machine transplanting services which cost US$ 202 per hectare (hybrid rice seedling production and transplanting service). Harvesting by a combine machine will become more popular. A farmer will be charged for harvesting service at the rate of US$ 65 per hectare and a minimum of one hectare is required per call. A good coordination among neighboring farms to plant and harvest at the same time will decrease the cost for land preparation, transplanting and harvesting.

An average farm size in Thailand is about 3.6 hectare per household and farmers will think about getting more rental lands to make more profit from hybrid rice. A small self reliance rice farm will be transformed to a full scale commercial farm. With this scenario, rice farmers will become farm managers and good management will be very important.

Possibility to incorporate other crops into the hybrid rice farming system

Due to a shorter growth duration of hybrid rice, it is enable for farmers in the northern part of Vietnam to cultivate various kinds of high valued horticultural crops such as tomato, broccoli, cauliflower and kohlrabi in the winter period after rice cropping (Isshiki and Miyajima, 2007). High profitability of horticultural products encourages Vietnamese farmers to practice this crop rotation pattern. In the central region of Thailand which is suitable for hybrid rice cultivation, such a crop rotation pattern is less likely to happen. Under a true tropical climate with ample supply of irrigation water and very short winter period conditions, most of Thai farmers tend to practice triple cropping of rice or 5 crops within 2 years whenever it is possible. However, flooding in this region can limit the triple cropping practice. Large areas of rice fields in the central region are commonly flooded from October to January. Aquatic crops may be an alternative choice for rice farmers during the flooding period. A part of rice field can be modified to grow "water morning glory", a common vegetable in Thailand, as a cash crop. It can be simply propagated by shoot cuttings and planted directly into the rice field. Water level in the field is kept at 50 cm depth. Harvesting can be done after planting for 4 weeks and thereafter until 4 months. An average yield of 1,500 - 1,700 kg per hectare per week can be produced to generate a farm income in a range of US$ 155 – 412 per hectare per week (Anon., 2007). Effective management is very important to ensure continuous supply of fresh water morning glory to meet the market demand.

An incorporation of eucalyptus trees (*Eucalyptus camaldulensis*) into the rice field is an alternative choice to gain more income. Eucalyptus was introduced to Thailand more than 30 years ago for village firewood. Along with rice cultivation, eucalyptus can be planted on a ridge around the rice field in a single row with 2 – 3 m spacing between each tree. With a modification of ridge size, a ridge of 60 – 100 cm wide has enough room for eucalyptus roots to grow without any interference to rice in the field. Trees require very low maintenance and they are ready to be harvested within 4 – 5 years yielding 18 ton of log per hectare and generating US$ 550 per hectare (Anon., nd.). Sprouts grown after the first harvesting can be harvested later as a ratoon crop. Eucalyptus clones with narrow canopy have been selected so that trees do not block too much sunlight and can be planted well with rice. Currently, 7 million ton of eucalyptus wood is needed for industry such as paper and pulp and medium density particle board. The industrial demand for eucalyptus wood is increasing while wood production is still under supply. This situation encourages rice farmers to incorporate eucalyptus trees into their farmland.

Conclusions

Hybrid rice research and development in Thailand have been actively progressed but commercial production of hybrid rice is still in a very small scale. Its slow expansion is associated with limitation on seed production, inferior grain quality, high production cost and less governmental promotion. Although yield of hybrid rice is high, farmers still prefer to grow low-yielding cultivars with superior quality to fetch the market demand and some improved cultivars nowadays also have high yield in comparable to hybrid rice under irrigated areas. Scenario that hybrid rice will influence farming systems in Thailand include a decreasing of total rice production areas and an establishment of rice growing zones with well irrigation system to ensure high yield potential of hybrid rice. Some rice fields will be turned to other economic crops such as rubber trees and oil palm for better gain. Rice will be intensively cultivated 2-3 crops per year mainly for commercial purpose. Rice farmers will become farm managers and will rely more on out-source services. Rotation of other crops into this intensive rice farming system is less likely to happen; however, farmers may incorporate cash crops such as water morning glory into parts of their rice field in the areas that prone to flooding. With an increasing demand of fiber for paper industry, a fast growing tree, *Eucalyptus camaldulensis* can be planted along the ridge of the rice field to generate more income without any detrimental effect on growth and yield of rice.

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Development and Characterization of Bunching Onion (*Allium fistulosum*) Chromosome Addition Lines of Shallot (*A. cepa* Aggregatum group)

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Abstract

First and second backcrosses of amphidiploids (2*n*=4*x*=32, AAFF) between the shallot and *A. fistulosum* were conducted to produce shallot - *A. fistulosum* chromosome addition lines. When the shallot was used as a pollinator, the amphidiploids and allotriploids set germinable BC_1 and BC_2 seeds, respectively. The 237 BC_1 plants mainly consisted of 170 allotriploids (2*n*=3*x*=24, AAF) and 42 hypo-allotriploids possessing 23 chromosomes, i.e., shallot - *A. fistulosum* single-alien deletion plants (2*n*=3*x*–1=23, AAF-nF). Eight shallot - *A. fistulosum* monosomic addition plants and 62 single-alien deletion plants were analyzed by seven chromosome-specific markers of shallot in order to reveal an extra chromosome and a deleted chromosome in some of the monosomic addition and single-alien deletion plants, respectively. The eight monosomic addition plants consisted of one AA+2F, two AA+6F, and five AA+8F lines. Of the 62 single-alien deletion plants, 60 could be identified as six different single-alien deletion lines (AAF-1F, -3F, -4F, -6F, -7F, and -8F) out of the eight possible types. Several single-alien deletion lines were classified on the basis of leaf and bulb characteristics. AAF-8F had the largest number of expanded leaves of five deletion lines. AAF-7F grew most vigorously, as expressed by its long leave blades and biggest bulb size. AAF-4F had very small bulbs. AAF-7F and AAF-8F had different bulbs from those of shallot as well as other types of single-alien deletion lines in skin and outer scale color. Regarding the sugar content of bulb tissues, the single-alien deletion lines showed higher fructan content than shallot. Moreover, shallot could not produce fructo-oligosaccharide with the degree of polymerization (DP) 12 or higher, although the single-alien deletion lines showed DP 20 or higher. The content of *S*-alk(en)yl-L-cysteine sulfoxide (ACSO) in the single-alien deletion lines was significantly lower than that of shallot. These results indicated that chromosomes from *A. fistulosum* might carry anonymous factors to increase the highly polymerized fructan production and inhibit the synthesis of ACSO in shallot bulbs. Accordingly, alien chromosomes from *A. fistulosum* in shallot would contribute to modify the quality of shallot bulbs. Furthermore, the chromosomal assignment of the two different *A. fistulosum* linkage maps constructed by NIVTS is currently taking place via the use of our population.

Keywords: Shallot, Japanese bunching onion, chromosome addition lines, chemical composition, linkage map

Introduction

Shallot, which is classified as *Allium cepa* L. Aggregatum group (genomes AA, 2n=16), has more adaptability to tropical and sub-tropical zones than common onion (Fig. 1). This vegetable crop is, therefore a potentially important genetic resource as well as an indispensable food crop worldwide. Great differences between the species of section *Cepa* exist in many morphological characters, bulb formation habit, resistant to pests and diseases, and so on (Hanelt, 1990). Crosses between the species have been made in order to transfer desirable features from one species into another. For *A. cepa*, the cross between *Allium fistulosum* ($2n=2x=16$, FF) and *A. cepa* has been studied the most extensively, because *A. fistulosum* possesses many agronomical desired traits, such as high dry-matter content, cold hardiness and resistance to thrips and many diseases (van der Meer and van Benekom, 1978), that would be valuable if incorporated into *A. cepa*. The F_1 hybrids are completely sterile because of chromosomal rearrangements between the two species. The development of alien addition lines, therefore, has proved to be a practical approach for introgressing genes from the related species. Sears (1956) transferred genes for leaf rust resistance from *Aegilops* into wheat. Recently in *Allium*, a similar trial via *A. fistulosum* – *A. cepa* monosomic addition lines was applied in transferring rust resistance from chromosome 1A of *A. cepa* into *A. fistulosum* (Wako et al., unpublished data). *A. cepa* – *A. fistulosum* chromosome addition lines seem to be beneficial for the study of genome organization in *A. fistulosum* as well as for the practical breeding of *A. cepa*. Peffley et al. (1985) reported the production of four *A. cepa* – *A. fistulosum* monosomic addition lines ($2n=17$) and several hypo-triploids ($2n=20$, 22, 25). However, these lines still do not cover all the genomes of *A. fistulosum*. Further, Shigyo et al. (1994) proposed using hypo-allotriploids ($2n=3x-1=23$, AAF-nF) together with the *A. cepa* – *A. fistulosum* monosomic addition lines ($2n=2x+1=17$, AA+nF) in allocating the genes and genetic markers to the *A. fistulosum* chromosome. In this study, shallot – bunching onion (*A. fistulosum*) chromosome addition lines were produced to enhance studies on genetics of bunching onion and breeding of shallot.

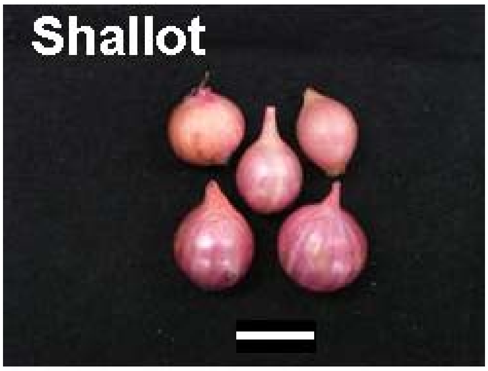

Fig. 1 Bulb postures of shallot
Scale bar = 20 mm.

Materials and methods

Production of shallot – bunching onion chromosome addition lines

The amphidiploids AAFF ($2n=4x=32$) as well as the allotriploids AAF were backcrossed to shallot (*A. cepa* Aggregatum group) as the pollinator to produce BC_1 and BC_2 seeds, respectively. Immature embryos of all backcrossed progenies were cultured in vitro to obtain the seedlings. The survived seedlings were applied to chromosome observation by Feulgen reaction staining, and then counted the number of chromosome. Chromosome-specific genetic markers of four isozymes (1F, *Lap-1*^{F}; 2F, *Got-1*^{F}; 6F, *Got-2*^{F}; and 8F, *Gdh-1*^{F}) reported in Shigyo et al. (1994, 1995), one 5S ribosomal DNA for 7F described in Shigyo et al. (1996), two microsatellites (1F, AFS015-355 and 8F, AFS096-127) developed by Song et al. (2004), and four expressed sequence tags (ESTs) (3F, ACAHN07F; 4F, ACABE16F; 5F, ACAEJ67F; and 6F, ACAHN07F) based on ESTs isolated by Kuhl et al. (2004) were available for the identification of eight kinds of extra chromosomes derived from *A. fistulosum*. Moreover, karyotype analyses of somatic chromosomes in the backcross progeny were conducted to confirm their genomic constitution in a shallot diploid background.

Morphological characteristics of single-alien chromosome deletion lines

After three months in vitro culture of immature embryos, survived seedlings were transplanted in to nursery trays in glasshouse. After six months transplanting, all backcrossed plants were counted for the number of tillers, number of expanded leaves per tiller, and measured for the leaf blade length.

After harvesting, the bulbs of each line were kept separately on the shelf. The shelf-life bulbs of five different deletion types were identified based on the following characteristics: bulb diameter, bulb size, bulb shape and bulb color. Bulbing index (I) was recorded by dividing the maximum bulb diameter by the minimum pseudostem (neck) diameter as described by Brewster (1990).

Analysis of chemical components in single-alien deletion lines

Bulbs of AAF-1F, AAF-4F, and AAF-8F, along with shallot and AAF as controls, were utilized to gauge carbohydrate and cysteine sulfoxide (CSO) contents. The pieces of bulbs were cut and extracted with hot 74% ethanol (final concentration 70% ethanol) and distilled water. The former extract was finally used for the anthrone method and a high-performance anion-exchange chromatography (HPAEC) carbohydrate column to determine the carbohydrate contents, and the latter one a high performance liquid chromatography (HPLC) analysis to investigate the CSO contents.

Application of single-alien deletion lines to genetic analyses

Two genetic maps have been constructed in *A. fistulosum*. The first map was an amplified fragment length polymorphisms (AFLP) map based on backcrosses between two partially inbred lines from the Senju (cv. Saiko) and Kujo (cv. Kujo-Futo) group (Ohara et al., 2005). Recently, Tsukazaki et al. (2008) reported on the development of an SSR map based on 193 markers, which were located on 15 linkage groups and covered a map distance of around 1,500 cM. The map was based on F_2 population originating from a cross between cv. Saiko and cv. Kujo. Five types of single-alien deletions (AAF-1F, -4F, -6F, -7F, and -8F) were utilized to assign the linkage groups of these two maps to chromosomes of *A. fistulosum*.

Genotyping of a chalcone synthase gene, which is related to bulb pigmentation in *A. cepa* (Kim et al., 2005), in shallot, *A. fistulosum*, and the five types of single-alien deletions was performed using Custom TaqMan® SNP Genotyping Assays. PCR plates were read on the SDS 7300 instrument using the end-point analysis mode of the SDS v1.3.1 software package (ABI, FosterCity, CA, USA). Genotypes were determined visually based on the dye-component fluorescent emission data depicted in the X-Y scatter-plot of the SDS software. Genotypes were also determined automatically using the signal processing algorithms in the software.

Results and discussion

Production and identification of shallot - bunching onion chromosome addition lines

First backcross progenies (F_2BC_1) and second backcross progenies (F_1BC_2, F_2BC_2) were produced from backcrossing of amphidiploid (AAFF) and allotriploid (AAF) to shallot (AA). 1114 F_2BC_1 seeds, 91 F_1BC_2 seeds and 163 F_2BC_2 seeds were produced respectively. After immature embryo culture and transplanting, 237 F_2BC_1 plants, 22 F_1BC_2 plants and 24 F_2BC_2 plants were obtained. Number of seeds produced and number of seedlings survived from first backcross combination are greatly higher than second backcross combination. Based on the results from chromosome-specific markers of *A. fistulosum*, chromosome observing and counting (Fig. 2), and karyotype analyses, eight plants carrying 17 chromosomes and sixty two plants carrying 23 chromosomes were identified (Hang et al., 2004). The genomic constitution in the plants was completely identified based on the results from chromosome markers of shallot and karyotype analyses. These two kinds of chromosome additions called monosomic addition lines and single-alien deletion lines, respectively. The results showed that the monosomic addition plants were only produced from second backcrossing. Single-alien deletion plants were mostly produced from first backcrossing. This result will help us to choose the right crossing combination in order to complete these two sets. Single-alien deletion plants were produced easier than monosomic addition plants. An increase in the number of alien chromosomes eases the effect of the deleterious gene found in shallot.

Two complete sets of monosomic addition lines and single-alien deletion lines are very useful for allocating the genes to specific chromosomes of *A. fistulosum*. This genetic information is valuable for genetics and breeding of *A. fistulosum* as well as *Allium* crop in general.

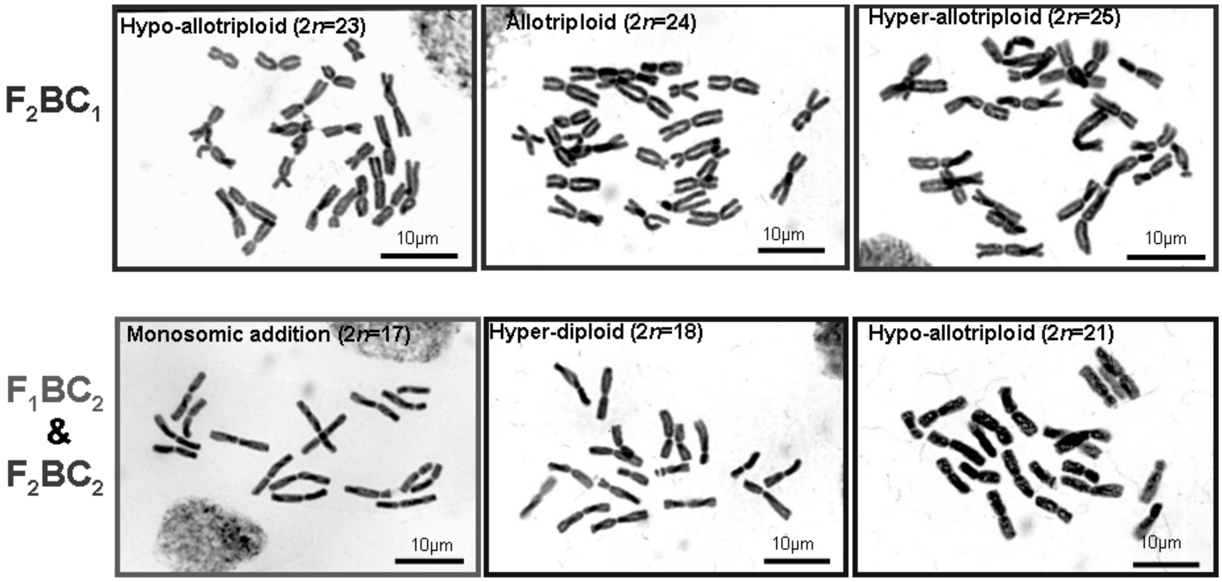

Fig. 2 Somatic metaphase chromosomes of F_2BC_1, F_1BC_2 and F_2BC_2 backcross progenies

Morphological evaluation of single-alien deletion lines

The single-alien deletion lines which showed the vigorous growth were morphologically characterized. Plants of AAF-6F were generated before the other type of single-alien deletion lines; therefore, the data in the seedling stage was not used for comparison. Five types of single-alien deletion lines showed differences from each other in the number of expanded leaves per tiller and length of the leaf blade but not in the number of tillers. Seedlings of AAF-8F had many more expanded leaves (6 leaves per tiller) than the other type of single-alien deletion lines. Regarding leaf blade length, seedlings of AAF-7F grew more vigorously, as expressed in its long leaf blade (217.3 mm). All six single-alien deletion lines conformed to shallot regarding the habit of bulb formation, but they differed from each other and from the parents, the shallot and AAF, in several bulb characteristics. The single-alien deletion line AAF-7F had the largest diameter of the six single-alien deletion types and was bigger than that of the shallot and AAF, while AAF-4F had the smallest diameter. Four types of single-alien deletion lines, AAF-1F, AAF-3F, AAF-4F, and AAF-6F, exhibited reddish-purple skin color and a purple outer scale, as did the shallot and AAF bulbs. On the other hand, yellow skin and light-purple outer scale were observed in the bulbs of AAF-7F. The colors of the bulb skin and outer scale of AAF-8F were also reddish-yellow and pink, respectively.

Qualitative and quantitative analysis of fructan in single-alien deletion lines

Biochemical analyses were conducted three single-alien deletion lines (AAF-1F, AAF-4F, and AAF-8F) and one monosomic addition AA+8F which obtained the number of lines with five or more for bulb characteristics analyses. There was a significant difference in the total sugar content between shallot [73.9 mg/g fresh weight (FW)] and shallot carrying *A. fistulosum* chromosomes, i.e., three types of single-alien deletions (AAF-1F, AAF-4F, and AAF-8F), the monosomic addition AA+8F, and AAF, in which sugars over

200 mg/g FW were detected. There were significant differences in the fructan content with the degree of polymerization (DP) 3 or higher between shallot and shallot carrying *A. fistulosum* chromosomes, i.e., AAF and AAF-1F. While there were no significant difference in the mono- and di-saccharides content between shallot, AAF, single-alien deletions, and AA+8F. Moreover, shallot could not produce fructan with DP 12 or more (Fig. 3), although the single-alien deletion lines, the monosomic addition AA+8F, and AAF produced fructan with DP 20 or more, especially AA+8F, which had the longest chains.

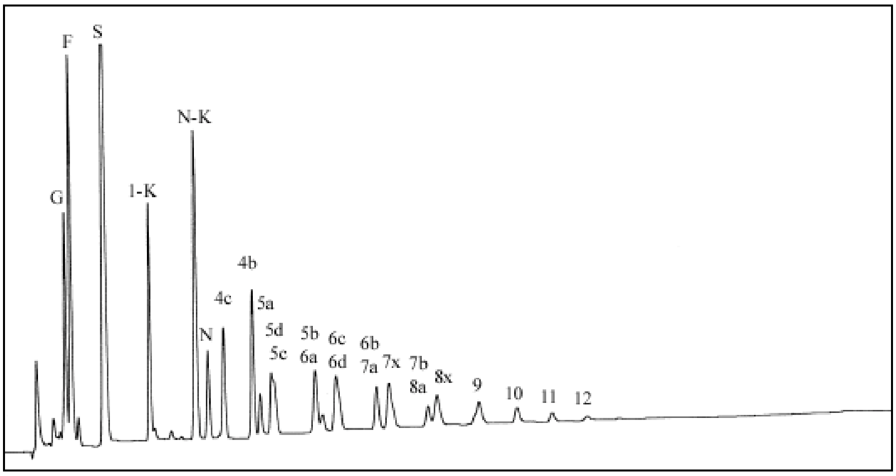

Fig. 3 HPAEC profile of shallot (AA)

G, glucose; F, fructose; S, sucrose;1-K, kestose; N-K, neo-kestose; 1F(1-β-D-fructofuranosyl)m-6G(1-β-D-fructofuranosyl)n sucrose (4a: $m = 2$, $n = 0$; 4b: $m = 0$, $n = 2$; 4c: $m = 1$, $n = 1$; 5a: $m = 3$, $n = 0$; 5b: $m = 0$, $n = 3$; 5c: $m = 2$, $n = 1$; 5d: $m = 1$, $n = 2$; 6a: $m = 4$, $n = 0$; 6b: $m = 0$, $n = 4$; 6c: $m = 3$, $n = 1$; 6d: $m = 1$, $n = 3$ or $m = 2$, $n = 2$; 7a: $m = 5$, $n = 0$; 7x: $m + n \geq 5$; 8x: $n + m \geq 6$). Arabic numbers show the degree of polymerization.

Determination of ACSO content in single-alien deletion lines

The ACSOs were separated with baseline resolution. MeCSO was separated first (retention time, 6.3 min), followed by AlCSO (7.4 min) and PeCSO (8.5 min). There was a great difference in the total ACSO contents between shallot, AAF, the three types of single-alien deletion lines (AAF-1F, AAF-4F, and AAF-8A), and the monosomic addition AA+8F (Fig. 1b). The contents of PeCSO, the primary ACSO of *A. cepa* and *A. fistulosum*, were almost identical in all the examined plants. On the other hand, the shallot showed a significant increase in the contents of AlCSO, the principal ACSO of garlic (*A. sativum*), compared with each single-alien deletion lines. In addition, MeCSO, the major ACSO of Chinese chives (*A. tuberosum*) and rakkyo (*A. chinense*), had a content in shallots that was two to four times as high as that in each single-alien deletion lines, AA+8F, and AAF.

Assignment of linkage groups and a gene to chromosomes of *A. fistulosum*

The 15 linkage groups consisted of SSR markers were assigned to five chromosomes of *A. fistulosum* through the five types of single-alien deletion lines (data not shown). TaqMan® SNP Genotyping Assays using genomic DNAs of shallot, *A. fistulosum*, and the five single-alien deletion lines resulted in assignment of a chalcone synthase gene of *A. fistulosum* to chromosome 4F (Fig. 4). These results have indicated that the single-alien deletion lines developed in this study are very useful for allocating genetic markers to *A. fistulosum* chromosomes.

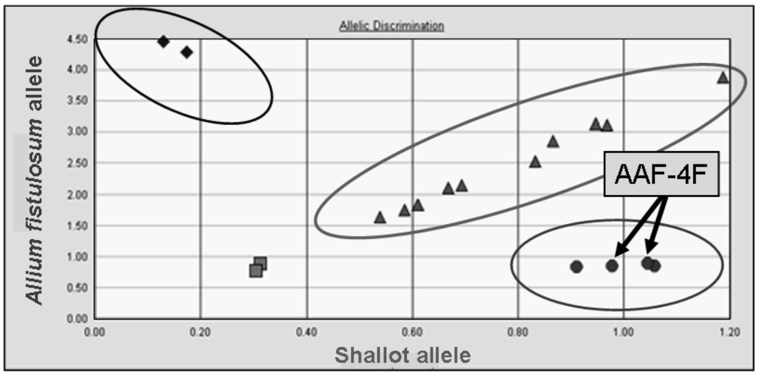

Fig. 4 Bivariate scattergram of relative probe fluorescence from TaqMan genotyping analysis of a chalcone synthase gene of *Allium fistulosum*, shallot, and single-alien deletion lines (AAF-1F, -3F, -4F, -6F, -7F, -8F)
◆, *Allium fistulosum*; ●, shallot and AAF-4F; ▲, AAF-1F, -3F, -6F, -7F, and -8F; ■, Negative control.

Future prospects

The present study has freshly identified three and six types of shallot – *A. fistulosum* monosomic addition lines and single-alien deletion lines, respectively. The two other types of single-alien deletion lines, in which either chromosome 2F or 5F was absent, could not be produced. To facilitate the mapping and chromosomal assignment of genes in *A. fistulosum*, it is necessary that a complete set of the single-alien deletion lines be developed, i.e., production of AAF-2F or AAF-5F. Some of alien-chromosome addition lines of shallot might create a possibility of creating a new shallot variety harboring favorable traits of *A. fistulosum*. The most excellent lines of them will be applied to the practicability test regarding several agronomic traits. Further investigations at field of low latitudes will absolutely be needed to select novel shallot varieties.

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Affection of Magnesium and Mix of Silica & Humic on Photosynthetic and Agronomic Characters in F_1 Hybrid Rice under Low N Fertilizer Condition

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Abstract

This study was conducted to determine the effects of magnesium and a mixed of silica & humic on photosynthetic and agronomic characters of the F_1 hybrid rice (TH5-1) planted under low N fertilizer level (0.27 gN per 0.03 m^2pot) and normal N fertilizer level (0.54 g N per 0.03 m^2pot). The Mg $(NO_3)_2$ fertilizer (T1) were sprayed and a mix of Na_2Si0_2 + humic (T2) were applied to the plant at the tillering stage (14days after transplanting) and panicle initiation stage (15 days before heading).

As T1 treatment at tillering stage, net CO_2 exchange rate (CER) significantly increased in rice plant at both active tillering stage (from 21.3 to 23.0 μmolm^{-2} s^{-1}) and flowering stage (from 19.9 to 21.7 μmolm^{-2} s^{-1}) under low N condition. However, T2 treatment only increased the CER value in rice plant at flowering stage under normal N condition (from 20.1 to 22.8 μmolm^{-2} s^{-1}). The increase in CER was due to the increase in SPAD (an indicator of chlorophyll content) and stomatal conductance. There was non- significant difference in plant height or number of tillers per plant in the F_1 hybrid under treatment and control conditions. Under all N conditions, leaf area and whole-plant dry weight of rice plant increased with T1 but the increase was not significant with T2 treatment. Under low N condition, T1 increased grain yield of rice plant (9.6 to 13.7 g plant^{-1}) much higher than T2 (9.6 to 11.9 g plant^{-1}), mainly due to the increase in number of spikeletes per panicle and filled grain rate. Under normal N condition, grain yield only significantly increased as T2 treatment (from 19.7 to 23.9 g plant^{-1}).

Applying magnesium fertilizer and mix of silica& humic at the panicle initiation stage resulted in the increase CER value at flowering stage under low N condition, but the result was not significant under normal N condition. Under low N, only T1 increased grain yield of rice plant (from 9.3 to 11.1 g plant^{-1}) due to the higher filled grain rate and the higher 1000-grain weight, while under high N condition only T2 increased grain yield (from 16.6 to 18.4 g plant^{-1}) due to the increase in 1000-grain weight. Therefore, magnesium sprayed fertilizer and mix of silica & humic would be used to increase grain yield of rice under low N fertilizer input.

Key worlds: hybrid rice, magnesium, nitrogen, photosynthesis, silica.

I. INTRODUCTION

Nitrogen (N) is one of the most important nutrients for plant growth regulation and biomass production. A large amount of leaf N is located in chloroplast proteins such as stromal enzymes, thylakoid protein and light harvesting antenna complexes (Evans and Terashima, 1987). Nitrogen fertilization is a key input in increasing rice productivity in Vietnam and other Asian countries. In our previous researches, the physiological and morphological characters of F1 hybrid, improved and local cultivars related to nitrogen use efficiency has been demonstrated (Pham et al., 2003, 2005). In hybrid rice, higher leaf N content leads to higher Rubisco activity of the F_1 hybrid, compared parent cultivars, leading to higher positive heterosis in photosynthetic rate at high N levels (Pham *et al*. 2003). Nitrogen use efficiency (NUE) for photosynthetic, dry matter and grain yield was much higher in F1 hybrid than that in inbred and local cultivar, especially at ripening stages (Pham et al., 2007). The introduction of high-yielding cultivars and hybrid rice has greatly increased the prospect of increasing yields, but this increased output was often associated with the intensive cultivation which requires high nitrogen input. The average level of N applied for rice production recorded recently in the Red River Delta, the second largest rice production area in Vietnam, has been at 120 kg/ha/crop (Kurosawa *et al.,* 2004), while in Japan it is approximately 80 kg/ha/crop (FAO, 2002). It is necessary to reduce both amount of chemical fertilizer (N, P, K), pesticide application for maintaining growth and productivity of rice and achieve a more sustainable production system. Role of magnesium, silica and humic to nitrogen use efficiency has been researched not much. Acording to the study by Okamoto (1963), foliage spray of Na_2SiO_3 solution led to the increase of silicified cells, improved growth as a whole, and the acceleration of nitrogen and phosphorus translocation. Foliar fertilizer was reported to increase photosynthesis and grain yield in rice plant (Kuepper, 2003)

II. MATERIALS AND METHODS

The pot experiment was conducted in green house in Hanoi University of Agriculture using TH5-1, a F1 hybrid rice, produced from thermo-sensitive genic male sterile line. The seedling at 3-4 leaf age stage was singly transplanted into a pot containing 5 kg of soil. Total chemical fertilizer applied into one pot with 2 level of nitrogen (N1 and N2) with the same base of phosphorus and potassium:

N1: (0.36g N + 0.36g P_2O_5 + 0.36 g K_2O)/pot (0.03m^2)

N2: (0.72g N + 0.36g P_2O_5 + 0.36 g K_2O)/pot (0.03m^2)

Chemical fertilizer was applied at three stage such as base dressing (30%N + 100% P_2O_5), top dressing at 10 days after transplanting (50%N + 50% g K_2O) and final dressing at 15 days before heading (20%N + 50% g K_2O).

Foliar nutrient application including Magenitra (T1) and mix of NatriSilica and acid humic (T2). Magenitra (11%$N0_3$) was diluted in concentration of 1g/100ml H_2O and sprayed with 0.03 g/pot, Humic-NaH acid (0.03%) was sprayed with amount of 1.7ml per pot. $Na_2(SiO_3)$ (32.2% Na_2O, 46,8% SiO_2) was diluted 10% and applied into soil before transplanting with amount of 0.24 ml per pot. Both T1 and T2 was sprayed at two stage as tillering (15 days after transplanting) and heading (3 – 5 days before heading).

Measurement: At active tillering stage (30 days after transplanting, flowering and dough-ripen and ripening stage, 5 plant of each treatment was randomly selected for measuring photosynthetic and agronomic characters.

Photosynthetic characteristic (CER): Two top-fully expanded leaf of each plant was selected for measuring CO2 exchange rate (CER), transpiration rate (Tr) and stomatal

conductance (gs) using LICOR 6400, at temperature of 30oC, light intensity of 1500 mmol/m2/s and CO2 concentration of 370 ppm.
- Chlorophyll content: The leaf measured photosynthesis were selected for measuring SPAD using SPAD Mirol 502, Japan.
- Specific leaf area (SLA): The leaf measured CER was sampled for measuring leaf area using ANA-GA-5, Japan, then dried at 80oC for 48h for calculating SLA
SLA = Leaf area/ Leaf dry weight
- Agronomy characters: plant high, number of tillers, dry matter (DM)
- Yield and yield component
Statistical analysis: Data was analyzed by SAS program, (1990) after Shinjo (1994). Mean comparisons were conducted by LSD (0.05) based on ANOVA.

III. RESULT AND DISCUSSION

Table 1: Affection of Mg $(NO_3)_2$ and mix of $NaSiO_3$ + Humic applied at tillering on CER in the F_1 hybrid Rice

Time of application	N level	Treatment	CER (µml $m^{-2}s^{-1}$)		
			Active tillering stage	Flowering Stage	Dough-Ripen Stage
15 Days after transplanting	N1	Control	21.3	19.9	11.8
		T1 ($Mg(NO_3)_2$)	23.0	21.7	10.2
		T2 (Silic + Humic)	*21.8*	19.9	12.4
	N2	Control	22.5	20.1	12.2
		T1 ($Mg(NO_3)_2$)	*22.8*	20.3	12.6
		T2 (Silic+ Humic)	23.3	22.8	12.3
	$LSD_{0.05}$		*1.58*	*1.77*	*1.4*
3-5 days before heading	N1	Control	-	18.6	11.0
		T1 ($Mg(NO_3)_2$)	-	21.0	10.5
		T2 (Silic + Humic)	-	21.3	10.3
	N2	Control	-	21.1	11.7
		T1 ($Mg(NO_3)_2$)	-	22.5	11.0
		T2 (Silic+ Humic)	-	22.3	11.7
	$LSD_{0.05}$		-	*1.7*	*1.2*

Note: N1 and N2: 0.36 and 0.72 g per 0.03m^2 pot, respectively.

Under low N condition (N1), as application of T1 (MageNitra) at the tillering stage, the CER value significantly increased at the active tillering (from 21.3µml $m^{-2}s^{-1}$ to 23.0 µml $m^{-2}s^{-1}$) and flowering stages (from 19.9µml $m^{-2}s^{-1}$ to 21 .7 µml $m^{-2}s^{-1}$) but it deceased at dough-ripen stage. Also, application both T1 and T2 (mix of silic and humic) before heading increased significantly increased the CER value at flowering stage (from 18.6µml $m^{-2}s^{-1}$ to 21 .3µml $m^{-2}s^{-1}$). However, under normal N condition (N2), only application T2 at tillering stage significantly increased the CER value at the flowering stage (from 20.1µml $m^{-2}s^{-1}$ to 22.8 µml $m^{-2}s^{-1}$).

Table 2: Affection of Mg $(NO_3)_2$ and a mix of $NaSiO_3$ + Humic applied at tillering on SPAD in F1 hybrid Rice

Time of application	N level	Treatment	SPAD		
			Active tillering stage	Flowering Stage	Dough-Ripen Stage
15 Days after transplanting	N1	Control	41.6	37.0	37.3
		T1 ($Mg(NO_3)_2$)	44.4	39.9	35.2
		T2 (Silic+ Humic)	43.2	38.5	37.9
	N2	Control	43.9	39.2	38.3
		T1 ($Mg(NO_3)_2$)	43.4	39.8	38.9
		T2 (Silic+ Humic)	44.1	41.2	39.5
	$LSD_{0.05}$		*1.3*	*2.0*	*2.1*
3-5 days before heading	N1	Control	-	41.6	39.3
		T1 ($Mg(NO_3)_2$)	-	42.4	38.3
		T2 (Silic+ Humic)	-	43.1	38.7
	N2	Control	-	43.0	39.9
		T1 ($Mg(NO_3)_2$)	-	43.0	39.8
		T2 (Silic+ Humic)	-	43.2	39.9
	$LSD_{0.05}$		-	*1.5*	*0.7*

Note: N1 and N2: 0.36 and 0.72 g per 0.03m^2 pot, respectively.

As application of both T1 (MageNitra) and T2 (mix of silic + humic) at tillering stage significantly the SPAD value under low N condition at the active tillering (from 41.6 to 44.4) and flowering stages (from 37.0 to 39.9) but it deceased at dough-ripen stage. However, only application T1 at heading increased CER at flowering stage under low N condition. This indicated that both magnesium and nitrogen nutrient supplied on young leaf increased chlorophyll content, which cause increased in CER. However, under normal N condition (N2), either application of T1 or T2 at tillering stage not significantly increased the value at all growth stages, but the CER value significantly increased, which indicated that nitrogen use efficiency increased in rice plant.

A significant and positive correlation was observed between CER and SPAD value as treatment at all growth stage, excepted at dough-ripen stage as application at heading (Fig.1).

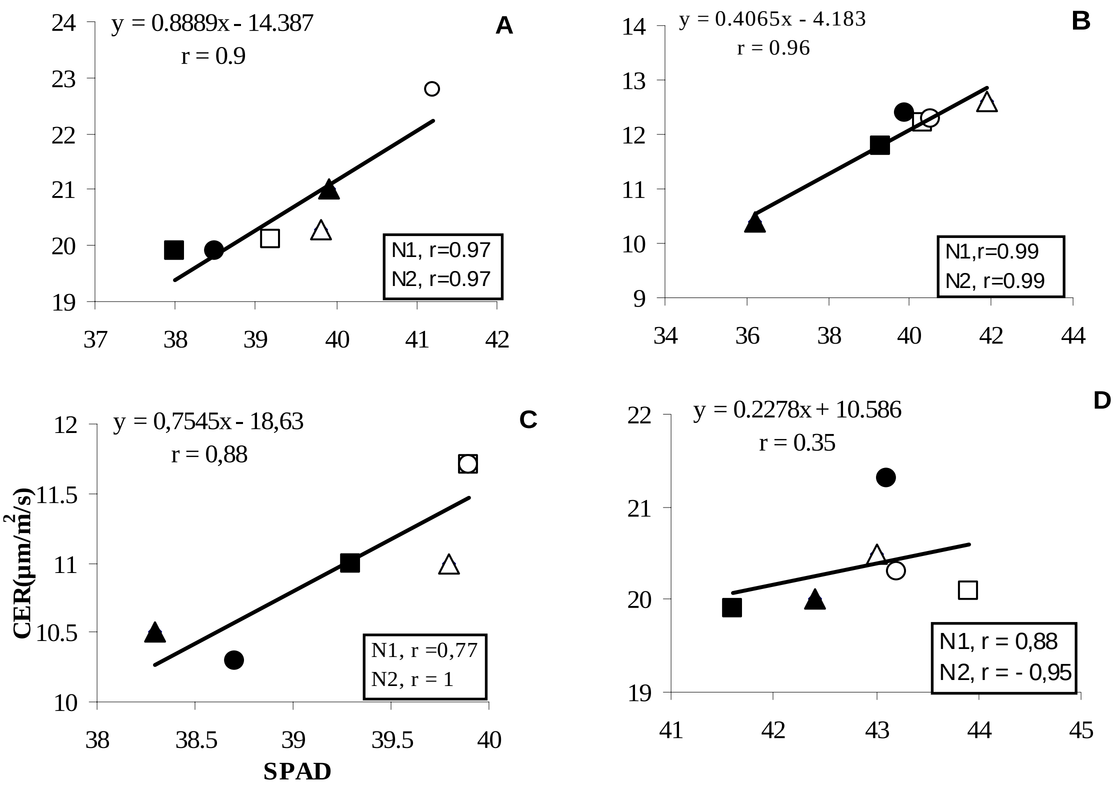

Fig 1. Correlation between CER and SPAD in rice plant at flowering stage (A) and dough-ripen stage (B) as application at tillering and at flowering stage (C) and dough-ripen stage (D) as application at heading.

Specific leaf area, leaf area and dry matter accumulation:

Table 3: Affection of Mg $(NO_3)_2$ and a mix of $NaSiO_3$ + Humic applied at tillering on SLA, Leaf area and Dry matter accumulation in the F1 hybrid

Time of application	N level	Treatment	Active tillering stage		
			SLA (cm^2 g^{-1})	Leaf area (cm^2 $plant^{-1}$)	Whole-plant dry weight (g $plant^{-1}$)
15 Days after transplanting	N1	Control	216.1	687.8	7.7
		T1 ($Mg(NO_3)_2$)	224.5	706.1	7.4
		T2 (Silic+ Humic)	232.6	675.3	6.8
	N2	Control	209.7	909.8	8.4
		T1 ($Mg(NO_3)_2$)	221.2	1139.6	9.3
		T2 (Silic+ Humic)	238.6	833.2	8.3
	$LSD_{0.05}$		46.1	165.8	0.7

There was non-significant in specific leaf area (SLA) and leaf area as treatment T1 and T2 at the active tillering stage under low N condition (Table 3 and Table 4), except SLA at flowering stage significantly increased (162 cm^2 g^{-1} to 191.7 cm^2 g^{-1}) as application T1 at heading stage under normal N condition, and leaf area significantly increased at heading stage (from 909.8 cm^2 $plant^{-1}$ to 1139.6 cm^2 $plant^{-1}$) as application T2. Application T1 at tillering increased whole- plant dry weight at active tillering (from 8.4 g $plant^{-1}$ to 9.3 g $plant^{-1}$) under normal N condition but the increased was not significant under low N condition. In contrary, this value significantly increased at flowering stage from 15.8 g $plant^{-1}$ to 17.5 g $plant^{-1}$) as application T1 under low N condition. Thus the application of T1 at tillering stage increased photosynthesis under low N condition while increased leaf area under normal N condition, which caused increase in dry matter accumulation.

Table 4: Affection of $Mg(NO_3)_2$ and a mix of $NaSiO_3$ + Humic applied at heading on SLA, Leaf area and Dry matter accumulation in the F1 hybrid

Time of application	N level	Treatment	Flowering stage		
			SLA (cm^2 g^{-1})	Leaf area (cm^2 $plant^{-1}$)	Whole-plant dry weight (g $plant^{-1}$)
3-5 days before heading	N1	Control	162.0	759.6	15.8
		T1 ($Mg(NO_3)_2$)	187.1	795.1	17.5
	$LSD_{0.05}$	T2 (Silic+ Humic)	191.7	674.8	16.6
	N2	Control	187.4	1179.7	25.5
		T1 ($Mg(NO_3)_2$)	200.0	1104.3	24.4
		T2 (Silic+ Humic)	168.0	1185.8	25.5
	$LSD_{0.05}$		25	193.3	1.6

Yield components and grain yield:

There were non-significant differences in the numbers of panicles per plant as treatments under both N conditions. Under low N condition, as application both T1 and T2 significantly increased the number of spikeletets per panicles (Table.5). However, under normal N condition the value only significantly increased as application T2 (from 273.1 to 292.9). Under low N condition, the filled-grain rate increased as application T1 at tillering stage (from 57.3% to 79.5%), T1 at heading stage (from 57.1% to 69.3%), T2 at tillering stage (from 57.3% to 66.2%), however, the value only significantly increased as application T2 under normal N condition. Under low N condition, grain yield significantly increased as application T1 at tillering stage (from 9.6 g $plant^{-1}$ to 13.7 g $plant^{-1}$) and at heading stage (from 9.3 g $plant^{-1}$ to 11.1 g $plant^{-1}$). However, under normal N conditions, the increase was only significant as application T2 at tillering stage (from 19.7 g $plant^{-1}$ and 23.9 g $plant^{-1}$).

Table 5: Affection of Mg $(NO_3)_2$ and a Mix of $NaSiO_3$ + Humic applied at tillering on yield components and grain yield in the F1 hybrid

Time of application	N level	Treatment	Ripening stage				
			Number of panicle plant^{-1}	Number of spikelets panicle^{-1}	Filled grain Rate (%)	1000-grain weight (g)	Grain yield (g plant^{-1})
15 Days after transplanting	N1	Control	4.0	228.2	57.3	26.2	9.6
		T1 (Mg$(NO_3)_2$)	3.0	277.6	79.5	27.0	13.7
		T2 (Silic+ Humic)	3.5	273.0	66.2	26.6	11.9
	N2	Control	6.2	273.1	64.3	25.9	19.7
		T1 (Mg$(NO_3)_2$)	6.3	275.1	57.6	26.2	20.5
		T2 (Silic+ Humic)	7.0	292.9	67.2	25.8	23.9
	$LSD_{0.05}$		1.2	18.0	-	0.5	1.7
3-5 days before heading	N1	Control	4.0	228.2	57.3	25.2	9.3
		T1 (Mg$(NO_3)_2$)	3.0	248.3	69.1	27.0	11.1
		T2 (Silic+ Humic)	4.0	212.7	60.6	26.6	9.6
	N2	Control	5.2	273.1	64.3	26.0	16.6
		T1 (Mg$(NO_3)_2$)	5.0	287.0	59.4	26.2	16.2
		T2 (Silic+ Humic)	5.0	271.9	65.3	26.8	18.4
	$LSD_{0.05}$		1.2	22.0		0.3	1.7

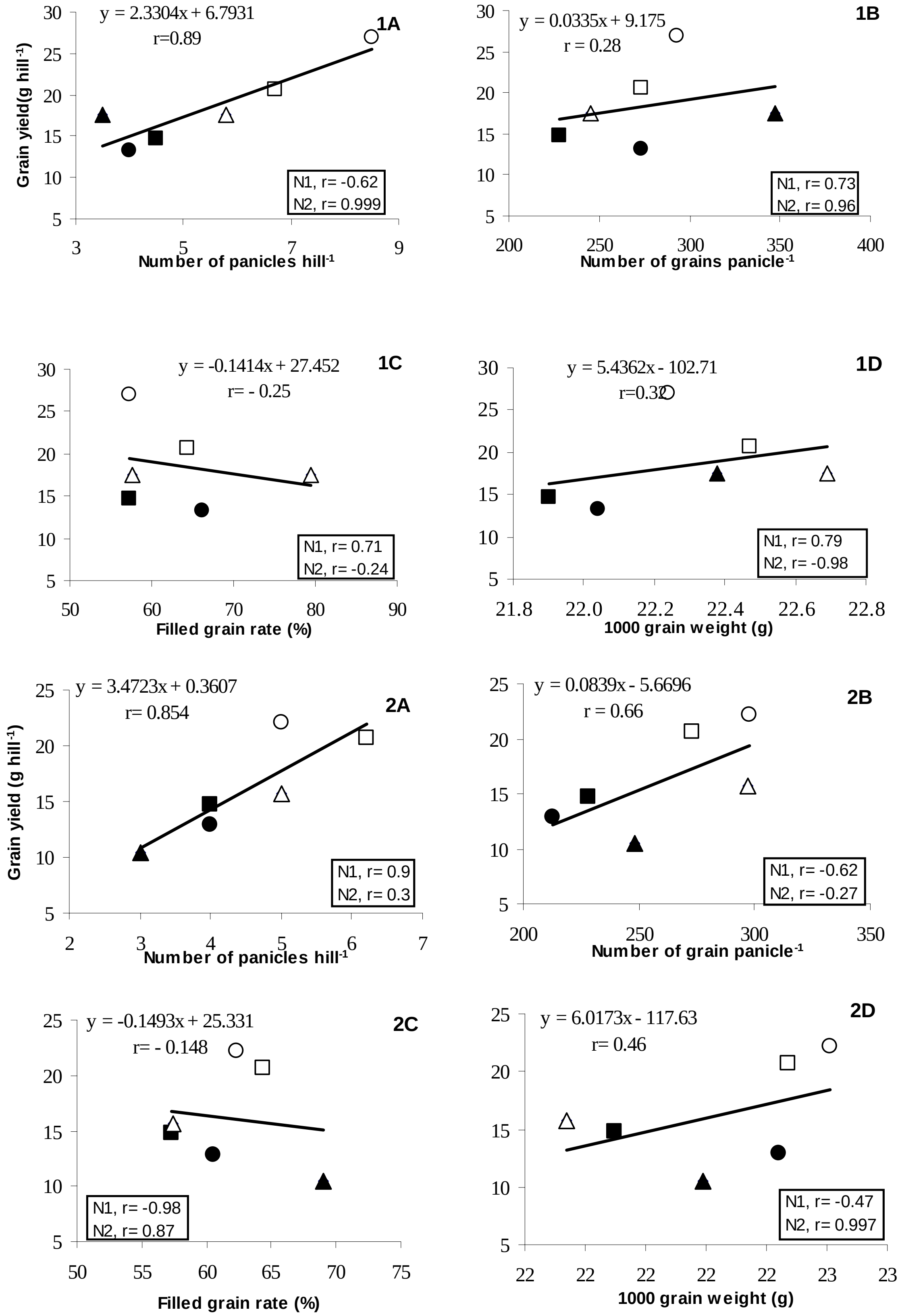

Fig 2. Correlation between grain yield and grain yield components as application at tillering stage (1) and heading stage (2).

IV. CONCLUSION

1. Application of MageNitra at tillering stage increased photosynthetic rate under low N condition due to the increase in chlorophyll content, while it increased leaf area under normal N condition.
2. Under low N condition, application of MageNitra at both tillering and heading stage increased grain yield , due to the increase in number of spikelets per panicle, filled- grain rate and 1000-grain weight.
3. Under normal N condition, application of mix of silic + humic increased grain yield, due to the increase in filled-grain rate.

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Hybrid Rice Cultivation Situation in the Northern Midland Region of Vietnam

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Abstracts:

In the recent years, hybrid rice (HR) areas are rapidly increased in Thai Nguyen, Tuyen Quang and Cao Bang provinces, which located in the center of the Northern Midland Region of Vietnam. HR is considered adopting in this region, demonstrative the heterotic on potential yielding, insensitive farming and diseases resistant. However, main hybrid combinations include Nhi You 838; Boi Tap Son Thanh, Shan you 99; Nhi you 63; Phuc Hung 95; TH3-3 and VL 20…of which TH3-3 and VL 20 are produced in Vietnam.

In both spring and summer season crops, In Thai Nguyen province, HR cultivated areas were increased from 4330 hectares in 2004 to 7230 hectares in 2008. VL 20 was cultivated in 2500 hectares in Thai Nguyen in 2008. It was estimated making up 34.5% of HR cultivated areas in Thai Nguyen. In Cao Bang HR cultivated areas were increased from 4,899 ha in 2006 to 8,115 ha in 2008. The largest HR areas are in Tuyen Quang province of 22,949 hectares and makes up 50.8% of the province' rice crop areas in 2008.

Key words: Hybrid rice, Northern, Vietnam, Thai Nguyen,

Introduction

Vietnam is considered the next "success story" in hybrid rice adoption after China. Starting with about 11,000 hectares in 1992, the same year the hybrid rice program was launched, it reached 600,000 hectares in recent years, most of it grown in the North of the country. Vietnam aims to further increase the hectare for hybrid rice to 70% of the country's total rice area (currently 7.5 million hectares) by 2010, according to the Ministry of Agriculture and Rural Development (MARD). To meet this goal, large enterprises are encouraged to produce hybrid rice seeds to reduce the import volume of this kind of seeds, standing at 13,000 tones at present. In addition, the country will have to increase by 1.5 times the current acreage of rice fields. The Cultivation Department says that domestic enterprises are currently capable of producing between 3,500-4,000 tones of hybrid rice seed each year whereas the country needs between 15,000-18,000 tones.

However; in order to promote hybrid rice production in Vietnam in the future, more effort is required in the following areas: (1) Cost reduction of F1 seeds by deploying technology for doubling the current F1 seed yield; (2) Becoming self-sufficient in F1 seed as early as possible, by supporting domestic seed companies; (3) Development of more hybrid rice varieties with high yield, resistance to major pests and a good grain quality; (4) A strong government commitment and support to the hybrid rice program, in terms of skilled manpower; resources, coordination and monitoring and (5) An intensive training program for hybrid breeding and F1 seed production for staff and farmers.

Materials and method

A survey was conducted in 3 provinces: Thai Nguyen, Tuyen Quang and Cao Bang, which located in the North-Eastern of Vietnam. Of which, Thai Nguyen is center of the region, Cao Bang represents as a highland province and Tuyen Quang as a midland one.

The rice production data was collected at The province' Department of Agriculture and Hand book of Agricultural Statistics, 2006 .

Results and discussions

Hybrid rice production in Vietnam

Vietnam started planting hybrid rice in 1992 with about a limited area of 11,000 ha**.** The average areas of hybrid rice planted was 10^{th} fold increase in 1996, and was about 580,000 ha in the recent years (Table 1). Hybrid rice is planted in both spring and summer season. The most adopted ecological regional area of hybrid rice are located in the North of Vietnam. During period (1992-2006), hybrid rice yield was 18-21 percent higher than the conventional inbred varieties (Hoan, 2001). Hybrid rice yield range 6.2 - 7.2 tones/ha and 4.5-6.5 tones/ha in the spring season and summer season, respectively.

The hybrid rice area has progressively increased, especially in the spring season, accounting for two thirds of the total hybrid rice area in the region. At present, hybrid rice is grown in 31 provinces in North Vietnam and five provinces in the Central Highlands and Central Vietnam, but not in the Mekong Delta due to direct seeding.

Hybrid Rice production in Northern Midland and Highland region of Vietnam

At the present, hybrid rice is planted in the different socio-ecological regions of the country, of which, the Red River Delta and the North Central Coast are major production areas, The north East and west region is the following cultivated areas with 22.93% of HR areas of the whole country in 2006 (Table 2).

Table 1. Area and yield of hybrid rice production in Vietnam (1992-2006)

Year	Area (ha)	Yield (ton/ha)	Area (ha)	Yield (ton/ha)	Area (ha)	Yield (ton/ha)
1992	11094.00	5.77	1156.00	7.20	9938.00	6.10
1993	34648.00	6.75	17025.00	7.02	17623.00	6.05
1994	60077.00	5.84	45430.00	6.26	14647.00	4.54
1995	73503.00	6.14	39598.00	6.35	33905.00	5.91
1996	127743.00	5.85	60416.00	6.71	67327.00	5.07
1997	187802.00	6.38	110802.00	6.56	77000.00	6.14
1998	200000.00	6.54	120000.00	6.70	80000.00	6.30
1999	233000.00	6.47	127000.00	6.50	106000.00	6.43
2000	435508.00	6.44	227615.00	6.50	207000.00	6.37
2001	480000.00	6.48	300000.00	6.60	180000.00	6.30
2002	500000.00	6.36	300000.00	6.50	200000.00	6.00
2003	600000.00	6.26	350000.00	6.45	250000.00	6.00
2004	577000.00	6.35	350000.00	6.45	227000.00	6.20
2005	588000.00	6.50	353000.00	6.50	235000.00	5.56
2006	584200.00	6.32	346000.00	6.50	238200.00	6.15

Source: 2006; Hand book of agriculture statistics.

Table 2. Trend in areas planted with hybrid rice in Vietnam in the year 2000 and 2006

Region	2000		2006	
	Area (ha)	% of total	Area (ha)	% of total
North East and West	109,500	25.21	135,000	22.93
Red River Delta	225,400	51.25	214,000	36.41
North Central Coast	99,500	21.75	225,000	38.23
South Central Coast and Central Highland	7,800	1.79	14,000	2.42
Total	442,200	100	558,000	100

Source: 2006; Crop Division of Ministry of Agriculture and Rural Development.

Table 3. Area of hybrid rice production in Cao Bang, Tuyen Quang and Thai Nguyen provinces.

(Unit: 1000 ha)

Year	Cao bang province			Tuyen Quang province			Thai Nguyen province		
	Total rice planted area	Hybrid rice planted area	%	Total rice planted area	Hybrid rice planted area	%	Total rice planted area	Hybrid rice planted area	%
2004	29.6	-		46.4	22.46	48.4	69.9	4.33	6.2
2005	30.1	-		45.6	24.82	54.4	70.1	3.16	4.5
2006	30.6	4.89	16.0	45.9	22.33	48.6	70.1	5.31	7.6
2007	30.6	5.24	17.1	45.5	21.88	48.1	70.2	6.73	9.6
2008	30.6	8.12	26.5	45.1	22.94	50.9	70.2	7.23	10.3

Recently, in the Northern-Eastern region of Vietnam, the greatest HR cultivated area was in Tuyen Quang province. The average areas of hybrid rice planted was around 48-50% of the total area of rice planted during period (2004-2008). Thai Nguyen province had the highest of total area of rice planted (annual 70,000 ha), however, the average areas of hybrid rice planted was around 6.2-10.3% of the total area of rice planted (2004-2006). In contrast, Cao Bang province is one of the remote high mountainous province in the Northern of Vietnam, but the area of HR was 26,4% of the total rice area of rice planted in the year 2008.

In this region, the main combinations of HR included Boyou 903, Boyou 64, Shan you 99, Nhi you 63, Nhi you 838, TH3-3 and VL 20 of which, TH3-3 and VL 20 was two hybrid rice varieties are produced in Vietnam. The others varieties were imported from China. In 2008 VL 20 variety was planted in Thai Nguyen province of 25,000 ha. It was estimated making up 56,9% of HR cultivated areas in Thai Nguyen.

Major constraints to hybrid rice production in North-East Region of Vietnam

Firstly, the high cost of input was the most concern for the majority of the farmer who have interested in HR cultivation. All of the farmer who live in the mountainous area are ethnic people and the poor people, they can not buy the HR varieties, unless have subsidy from the government.

Secondly, quality of HR are importance for the local farmer. They eat high quality rice as well as sticky rice as their custom.

Thirdly, non-irrigation as well as cold in the beginning of the spring crop season or at the end of summer season is the major constraints to rice production in generation and to HR production in especially. This caused a lower yield of HY varieties. In addition the lately crop season to compare with the Red River Delta region usually occurs.

Conclusion

In view of the above, there are some major recommendations for enhancing large-scale hybrid rice production in the North-Eastern of Vietnam to consider. Reducing the cost of Fl seed, More hybrid rice varieties with high yield, resistance to major pests and good grain quality should be developed. And a strong government commitment and support to the hybrid rice program, in terms of skilled manpower, resources, extension and other related issues. Intensive training program for hybrid rice production for staff and farmers should be doing.

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Temporal Changes of Inorganic-N Concentrations of Surface and Groundwater during a Rice Planting Period in Farming Villages of Northern Vietnam

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Abstract

Ammonium-N and nitrate-N concentrations of surface and groundwater were measured during a spring rice planting period in farming villages in northern Vietnam. The time and amount of chemical N fertilizer applications as basal dressing and topdressing were also investigated. The measurements of the concentration were done 6 times over a 70 day-period after the basal dressing. The depth of the groundwater sampled was from 7-10 m. The chemical fertilizer N application amounts (kg/ha) were 68-90 as basal dressing, and 20-40 as the first and second topdressings, respectively. Basal dressing was done in February, and the first and second topdressings were done in March and April. For surface water, the ammonium-N concentrations were 7-9 mg/L at the first measurements, but temporally decreased to less than 2 mg/L. The concentration, however, increased to some extent after the fertilization, and differed according to the villages' fertilization amount, showing a positive effect of fertilization on the concentration. Infiltration of surface water may have caused the temporal decrease. The nitrate-N concentrations were low overall. From the oxidation-reduction- potential (ORP), nitrification could not occur in the surface water. For the groundwater, the concentrations tended to increase temporally. The groundwater ammonium-N concentration was perhaps created by the infiltration of ammonium-N bearing surface water. From the groundwater's ORP, the nitrification could not occur, as well. The groundwater ammonium-N and nitrate-N concentrations reached 4-5 and 2-3 mg/L maximally. The nitrate-N concentration satisfied the water standard for drinking use, but the ammonium-N concentration did not at each measurement, and therefore use of the groundwater for drinking should be done carefully.

Key Words: rice planting, fertilizer N, nitrate- N, ammonium-N, village, temporal change

１. Introduction

Rice plantings in Vietnam have been greatly changed in recent decades due to the expansion of farmland, introduction of high-yielding rice varieties, and the development of irrigation networks. Through these changes, the number of rice plantings per year has increased from one cropping to double cropping, by which a large amount of chemical fertilizers of N, P and K have been applied. The Red River Delta (RRD) is one of the major rice planting areas along with the Mekong Delta in Vietnam. In the RRD, spring rice is planted first, then summer rice is done, and after that, a winter crop is planted in some areas of the RRD. Though a lot of chemical N fertilizer is applied in the rice plantings, the fertilizer applications were not split over the time period well, but rather concentrated earlier around the time of transplanting. Through that, the surface and groundwater may have been contaminated by inorganic-N, i.e. ammonium-N (NH_4-N) and nitrate-N (NO_3-N), during that period.

There are some studies on the contamination of surface and groundwater by inorganic-N in the RRD (Kurosawa et al., 2004, 2006, 2008), where the positive effects of chemical N fertilizer applications on the concentrations were disclosed. However, these studies handled a temporal change over years, but a short-term temporal change of the concentration during a single rice planting period had not been studied yet.

Therefore, the ammonium-N and nitrate-N concentrations were measured some days after the basal dressing, and every 10- 15 days afterward for surface and groundwater in typical farming villages of the RRD during the rice planting period. The measurements were done for a spring rice planting, since the chemical fertilizer N was applied more in the spring rice planting than in the summer rice planting. In addition, in the spring rice planting season, the amount of rainfall was low (occupying around 20% of annual rainfall), thus, these concentrations were affected rather purely by the fertilizer N applications without being diluted by the rainfall.

From the measurements, the following are aimed to clarify for the villages: when and how much amount of fertilizer N was applied as the basal dressing and topdressings, how intensively the concentrations of ammonium-N and nitrate-N occurred in the surface and groundwater, how they changed over time, and what factors affected the concentrations and the changes, respectively.

2. Materials and methods

2.1 Study area

Two villages (Phu Dong and Dang Xa communes), which are located in the suburban area outside Hanoi City, with a location of 18- 25 km northeast of the center of Hanoi City, were targeted. The area is a flat low-lying area with elevations of less than 10 m. In the villages, irrigation and drainage networks for rice planting are well organized. According to the FAO/UNESCO soil classification system, the main soil type was Endo gleyi- eutric fluvisols.

The farmland areas and annual cropping patterns and areas are shown in Table 1. The area of 2 rice (spring rice- summer rice) plantings occupied most, followed by the area of vegetables only plantings, and then by that of 2 rice plus a winter crop plantings in each village.

Table 1. Area of farmland and annual cropping patterns and its areas in the target communes.

Cropping pattern	Phu Dong commune (ha)	Dang Xa commune (ha)
Agricultural land	507	322
Spring rice- summer rice	310	180
2 rice – a winter crops	47	52
Vegetables only	150	90

Winter crop: maize, sweet potato, tomato and vegetables

Vegetables: cabbage, mustard greens, tomato, chou-fleur, etc.

According to the meteorological data recorded in Hanoi City during 2001 through 2004 (General Statistics Office, 2002 to 2005), the mean seasonal rainfall from May to October (rainy season) and from November to April (dry season) amounted to 1,470 mm and 250 mm, respectively, with 4.9 and 2.9 hours of mean daily sunshine in the corresponding seasons. The mean annual air temperature was 24.5℃, with a monthly average ranging from 17.6℃ in January to 29.6℃ in June. The relative humidity was very high throughout the year, with an annual mean of 79%.

There are two main groundwater aquifers in the RRD. One aquifer is embedded in Holocene sediments, and the other in Pleistocene sediments. The former aquifer is present at a depth of 0.5 to 2 m from the ground surface during the rainy season and at a depth of 2 to 8 m during the dry season. Its thickness ranges from a few meters up to 40 m. The latter aquifer is confined and underlies the former with a thickness of 10 to 100 m (World Bank, 1995).

2.2 Study period and time of water sampling

The study period was from March – May in 2008. During the period, water sampling was done 6 times at 10-15 day intervals, from several days after the basal dressing, to a little more than one month after the second top dressing. The total period for the sampling was 70 days. The basal dressing was done within 20 days before transplanting, the first topdressing was done at the time of early tillering, and the second topdressing was that of panicle initiation. The first measurements of the water were made in March 2008, at 5- 10 days after the basal dressing, and subsequent measurements were done at 10- 15 day intervals, and final measurements was done in May 2008.

The measurements of the surface water were collected from 4 sites at depths of 3- 5 cm in paddy fields, and groundwater measurements were done at 4 sites at depths of 7- 10 m from wells in the respective villages. Each site was fixed in location during the measurements. The wells were located in yards of households. The volume of the water samples collected from respective water sources was 500 mL.

2.3 Measurements of ammonium and nitrate ion concentrations and ORP

Ammonium and nitrate ion concentrations of the water were determined by a spectrophotometer (UV-mini 1240, Shimadzu Co., Ltd), using the Nessler and Cataldo methods, respectively. Ammonium and nitrate concentrations were converted to concentrations of ammonium-N and nitrate-N, respectively, by applying the molecular weight ratio of N to NH_4^+ and NO_3^-.

The pH and ORP of the water were measured by a portable pH meter and an ORP meter (D-50 Series, Horiba, Co. Ltd.), respectively. Since 3.33 mol/L KCl－Ag/AgCl was used as the comparative electrode of the ORP meter, it was necessary to add about 200 mV to the recorded value, which depended on the water temperature in order to convert the recorded value to the value corresponding to the standard hydrogen electrode.

2.4 Investigation of time and amount of fertilizer N applications

The time and amount of chemical fertilizer N application as basal dressing, and first and second topdressings for the 2008 spring rice cultivation were derived through interviews of the farmers in the villages. According to the local farmers, the application amounts from the basal dressing to second topdressing occupied about 90 % of total application amount of chemical fertilizer N.

3. Results and Discussion

3.1 Time and amount of fertilizer N application for rice planting

The surveyed results of the time and amount of chemical fertilizer N applications in spring rice plantings in the villages as basal dressing, and first and second topdressings are shown in Table 2. The basal dressing was applied in late February, the first topdressing was applied in early or middle of March, and the second topdressing was applied in early April for the respective communes.

Table 2. Time and amount of fertilizer N applications as basal dressing, and first and second topdressings in the target communes in 2008.

Commune	Time/ amount of fertilizer N application	Basal dressing	First top-dressing	Second top-dressing
Phu Dong	Time (date)	25th-28th, Feb.	10th – 14th, Mar.	8th -10th, Apr.
	Amount (kg/ha)	70- 90	30- 40	20- 35
Dang Xa	Time (date)	20th-24th, Feb.	5th – 10th, Mar.	5th -8th, Apr.
	Amount (kg/ha)	68- 85	28- 35	20- 30

The fertilizer N application amounts (kg/ha) as basal dressing were 68-90 and the first and second topdressings were 28-40 and 20-35, respectively for the communes. In the period from the basal dressing to the first topdressing, approximately 80% of the total fertilizer N was applied, and the remaining amount was applied at the second topdressing. Thus, the chemical fertilizer N application was concentrated in the early stages of rice growing. In the period between the panicle initiation and flowering stage, no chemical fertilizer N was applied.

The total amounts of the N applied (kg/ha) were 120-165 for the Phu Dong and 116-150 for Dang Xa communes, respectively. The recommended dose of N for rice planting in the RRD is 100- 120 kg/ha. The applied amount of fertilizer N in these villages was higher than that of the recommended level.

3.2 Temporal changes of ammonium-N and nitrate-N concentrations for surface and groundwater

Surface water

The observed ammonium-N and nitrate-N concentrations for surface water of the Phu Dong and Dang Xa communes are shown in Figs.1 and 2, respectively. The dates of each measurement of the concentrations were the same as those of the ORP, which are shown in Table 3. In Figs. 1-2, the plotted values are the averages for all sites at each measurement. Here, during the 1st and 3rd measurements, which were done during March or during March and early April, the concentration of ammonium-N for surface water rapidly dropped from approximately 9 to 1 mg/L, and from 7 to 2 mg/L for Phu Dong and Dang Xa communes, respectively. The concentrations also decreased a little from the 4th to 6th measurements.

Table 3. The ORP value in each of the measurements for Phu Dong and Dang Xa communes.

Commune		Order of measurement					
		1st	2nd	3rd	4th	5th	6th
Phu Dong	Measurement date	Mar.5	Mar.15	Apr.1	Apr.15	May.1	May.15
	Surface water	127	123	218	210	122	207
	Groundwater	196	230	174	198	162	159
Dang Xa	Measurement date	Mar.2	Mar.12	Mar.27	Apr.12	Apr.27	May.12
	Surface water	173	215	113	199	151	246
	Groundwater	158	141	156	145	238	186

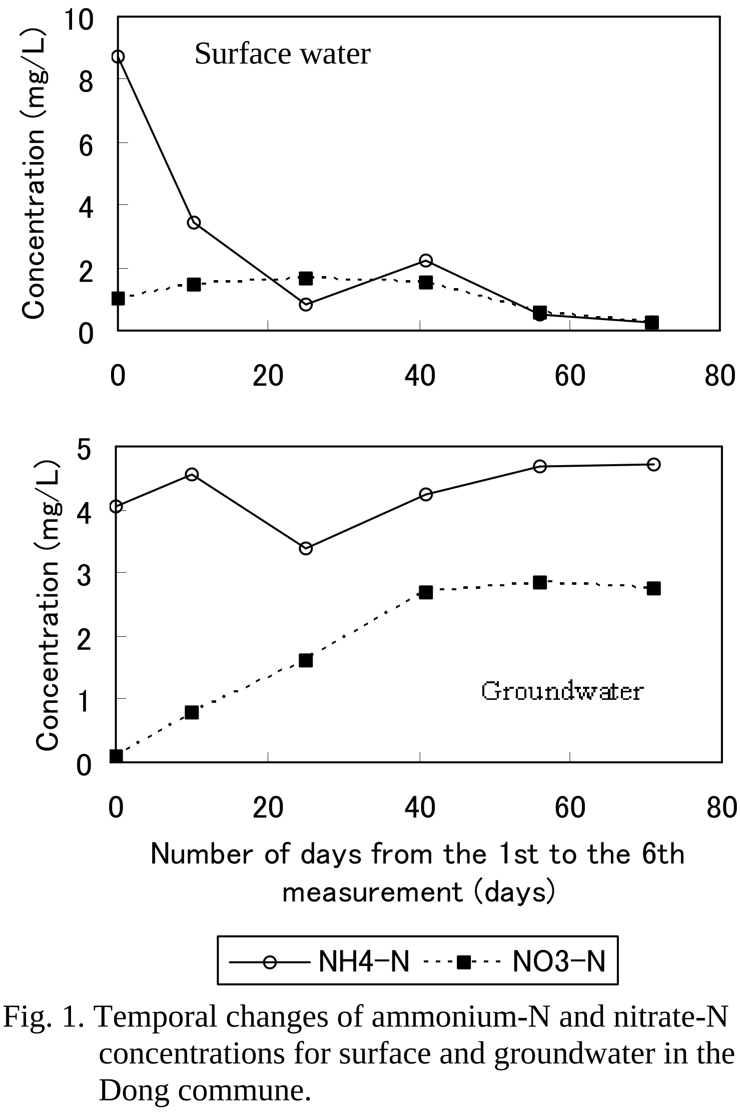

Fig. 1. Temporal changes of ammonium-N and nitrate-N concentrations for surface and groundwater in the Phu Dong commune.

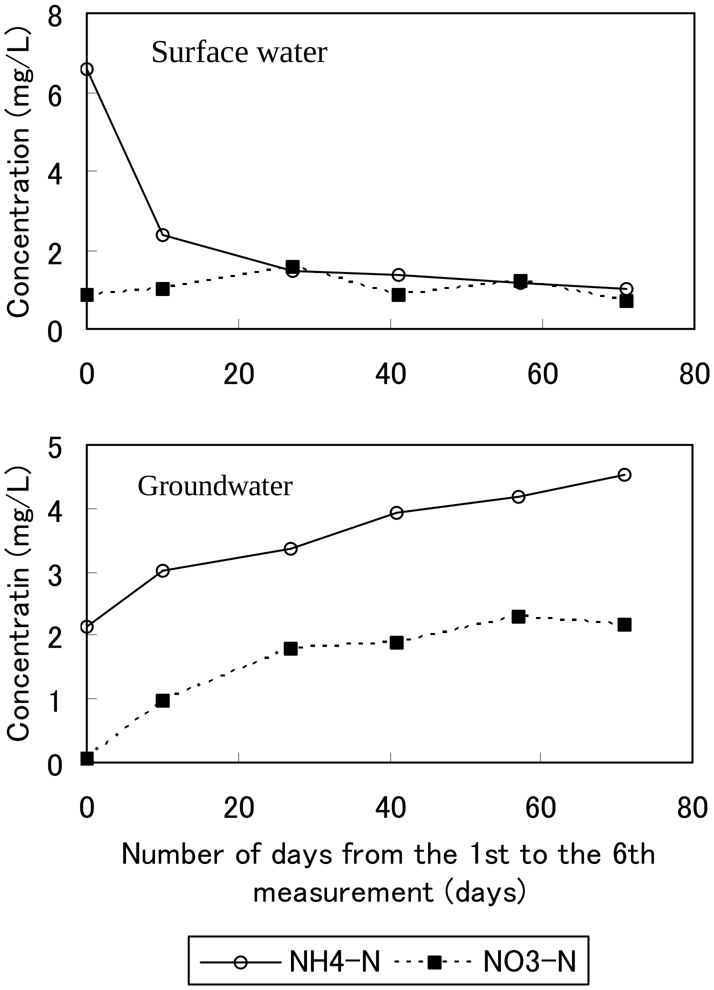

Fig. 2. Temporal changes of ammonium-N and nitrate-N concentrations for surface and groundwater in the Dang Xa commune.

The nitrate-N concentrations tended to increase a little with time from the 1st to the 3rd measurements, and then, the concentration decreased slowly from 3rd to 6th measurements in both communes.

The ammonium-N and nitrate-N concentrations were less than 2.5 mg/L in both communes during the 3rd and 6th measurements, and both concentrations did not differ largely between the communes.

Groundwater

The observed ammonium-N and nitrate-N concentrations for the groundwater are shown in Figs.1 and 2 for the Phu Dong and Dang Xa communes, respectively. According to Figs. 1-2, the ammonium-N concentration was in between 3-5 and in between 2-5 mg/L for Phu Dong and Dang Xa communes, respectively. In the Dang Xa commune, the concentration increased over time from the 1st to 6th measurement, and the increase was observed in the Phu Dong commune from the 3rd to 6th measurements.

The nitrate-N concentration was less than approximately 3 and less than 2 mg/L in the Phu Dong and Dang Xa communes, respectively. In the Phu Dong commune, the concentration increased over time from the 1st to 4th measurements steadily, but the concentration changed only a little after the 4th measurement. However, in the Dang Xa commune, the concentration increased from the 1st to 3rd measurement steadily, and it increased slowly to the 5th measurement, and the concentration showed a decrease a little after the 5th measurement.

The ammonium-N was higher by 1.5-2 mg/L than nitrate-N in concentration at each measurement in both communes, except from the 1st to 2nd measurements in the Phu Dong commune, which showed nearly a 4 mg/L difference.

The ammonium-N concentration in the groundwater was higher than that in surface water except at the 1st measurement for both communes. The nitrate-N concentration in the groundwater was also higher than that in surface water at 4th or later measurements.

3.3 ORP values for the water at each measurement

The measured ORP for surface and groundwater are shown in Table 3 for both communes. Here, the value of each measurement is the average for all sites at every measurement. According to the Table, the ORP was 100 – 250 mV at every measurement, and the concentration was neither consistently larger nor smaller in the surface water than in the groundwater throughout the measurements.

4. Discussion

4.1 Effect of fertilizer N application on the temporal changes of ammonium-N and nitrate-N concentrations

The surface water ammonium-N concentrations at the 1st measurement, made at 5-10 days after the basal dressing, was very high at about 7-9 mg/L in the communes. With this, the effect of basal dressing is conceivable. Around the 2nd measurement, the first topdressing was made, but the concentration was continually decreasing from the 1st to the 3rd measurements, and whether there was an effect of the dressing was difficult to identify. At the 4th measurement, made in the middle of April 2008, the concentrations increased a little from the 3rd measurement in Phu Dong commune, and the trend of increase can be seen slightly in Dang Xa commune. The second topdressing was done between the 3rd and 4th measurement, therefore the effect of the second topdressing on the concentration could be recognized.

Other cases in Figs. 1-2 did not show a high ammonium-N or high nitrate-N concentration at the 1st measurement, and did not show the increase of these concentrations from the 3rd to 4th measurements. Therefore, the effect of basal dressing and/or topdressing on the concentrations was only recognized for the surface ammonium-N concentrations in both communes.

The surface ammonium-N concentrations at the 1st, 2nd and 4th measurements were higher in the Phu Dong commune than in the Dang Xa commune. For this reason, the positive effect of the dressing amount was considered because the every dressing amount was generally higher in the Phu Dong commune than in the Dang Xa commune (Table 2).

At the 5th to 6th measurements, the concentrations were not changed so much after the second topdressing was over. Therefore, only a minor effect of dressing could be recognized at the period of these measurements.

4.2 The cause of the temporal changes of ammonium-N and nitrate-N concentrations for surface and groundwater

Surface water

From the fact that the nitrate-N concentrations were small (nearly less than 2 mg/L) throughout the measurements of the surface water, the strong occurrence of transformation from ammonium-N to nitrate-N (nitrification) was not recognized in the surface water. The level of the ORP backed up this idea, because nitrification occurs mainly when the ORP is 100-330 mV (value by the standard hydrogen electrode) (Florida Rural Water Association, 2004) or about -100 - 130 mV by the recorded (unconverted) value. The ORP shown in Table 3 is out of this range.

The surface water ammonium-N concentrations tended to decrease temporally though it varied slightly. Here, the ammonium-N was considered to be decreased by the infiltration from surface water to groundwater without transforming into nitrate-N strongly in surface water. This trend could be seen in both communes.

Groundwater

The ammonium-N of the groundwater was thought to be created by the infiltration of surface water, which bore the ammonium-N, because according to the groundwater ORP (Table 3), the nitrification could not strongly occur.

From Figs. 1-2, the groundwater ammonium-N concentrations showed an increase over time in both communes, except from the 1st to the 2nd measurements in the Phu Dong commune. In the Phu Dong commune, the basal dressing, which was done later in time than that in the Dang Xa commune, was closer to the period of 1st and 2nd measurements. In addition, the amount of basal dressing was higher in the Phu Dong commune than in the Dang Xa commune. Those helped make the groundwater ammonium-N concentrations at the 1st and 2nd measurements higher in the Phu Dong commune than in the Dan Xa commune.

The nitrate-N concentrations also showed an increase from the 1st to 5th measurements. Here, the creation of nitrate-N concentration may be attributable to the infiltration of surface water even partly, however, the increase from the 1st to 3rd and from the 1st to 4th measurements in the Phu Dong and the Dand Xa communes, respectively, were so steadily, despite of minor occurrence of nitrification in surface and groundwater, that further examination is necessary.

4.3 The level of ammonium-N and nitrate-N concentrations for groundwater compared to water standard.

From the comparison between the concentrations measured for the groundwater and the Vietnamese drinking water standard, the nitrate-N concentrations satisfied the standard (<10 mg/L), while the ammonium-N concentrations exceeded the standard

(<0.05mg/L) by 4 to 9 times. It showed that the groundwater was not appropriate for drinking.

5. Conclusions

The following conclusions were derived from the present study.

1. Fertilizer N applications for the spring rice plantings were 68-90, 28-40, and 20-35 kg/ha as basal dressing, and the first and second topdressings in the targeted communes, respectively. The basal dressing was done in February, the first topdressing was in early – middle March, and the second topdressing was in early April, respectively.
2. For surface water, ammonium-N concentrations were at a high of 7-9 mg/L at 1st measurement, which was made 5-10 days after the basal dressing. After the measurements, the concentrations decreased with time to less than 2 mg/L, but during the measurements it increased to some extent after the dressing, showing the response to the fertilizer N applications. In the commune, where the fertilizer N application amounts were higher than the others, the ammonium-N concentrations were also higher than the others, showing the effect of fertilizer applications on the concentrations. The nitrate-N concentrations were small throughout the measurements, due to minor occurrences of nitrification.
3. For groundwater, ammonium-N concentrations showed an increase over time, which reached 4-5 mg/L maximally, and were higher than that of surface water at later measurements in each commune. The ammonium-N was perhaps created by the infiltration of ammonium-N bearing surface water. Nitrate-N concentration ranged up to nearly 3 mg/L. It showed a steadily increase over time in early measurements, despite of minor occurrence of nitrification in surface and groundwater, therefore, further examination is necessary.
4. Groundwater nitrate-N concentrations were lower than the drinking water standard, but the ammonium-N concentrations were higher than the standard at all of the measurements for both communes. Therefore, it needs said that the use the water for drinking needs to be done cautiously.

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Rice Cultivation on Acid Sulphate Soils in the Plain of Reeds, Vietnam as Affected by Water Environment and Cropping Season.

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Abstract

The Plain of Reeds in Long An province, Vietnam has the lowest altitude in the western part of the plain resulting in seasonal changes in surface water depth within a year. Therefore the reclamation of the region can not rely on tidal water to remove excessive amounts of toxic elements such as Al, Fe and organic acids. The accumulation of these elements increases the EC and decreases the pH of the soil. Because of the seasonal changes in both water quality and solar radiation, rice yields also differ seasonally despite fertilization with fused-magnesium phosphate to increase soil pH and to supply phosphorus.

A rice variety VND 95-20 (which was released by the IAS) has been grown on a Typic Sulfaquept soil of Tan Thanh district, Long An province, for four consecutive seasons. Three phosphate fertilizer sources (Apatite Laocai, Gafsa rock phosphate and single-superphosphate) were applied at five P rates (0, 25, 50, 100 and 100 kg P ha^{-1} on one occasion only) in a split-plot design with P sources as the main plot and P rates randomized in the sub plots. Plant height, number of seeds/panicle, number of panicles/m^2, weight of straw and grain yields were strongly affected by the seasonal changes in water quality (EC, pH, Al). During the rainy season, the rice crop performed very poorly, resulting in a low yield. Crops grown in the dry season after flooded periods performed well and grain yields were two-to-three-fold higher. Grain yields increased with P application rates, being highest for the treatments receiving 100 kg P/ha yearly in two consecutive years. Phosphate source did not affect (P=0.05) grain yield. These results highlight the interaction between environmental factors and potential yield and demonstrate the need for flexible hybrid growth responses to the changing environmental conditions inherent in some farming systems.

Key Words: phosphorus, acid sulphate soils, seasonal change, TP, SSP, RP,

Introduction

The Plain of Reeds in Long An province, Vietnam has a large area of acid sulphate soils with high phosphorus fixing capacity. Water management is one of the best ways to reclaim acid sulphate soils for crop cultivation. However, fresh water is not often available and the drainage system is limited due to low position in the landscape. Since lime is not available in the region, phosphate fertilizers are used to supply phosphorus nutrient and at the same time to increase soil pH.

Phosphorus is an essential plant nutrient and its deficiency restricts crop yields severely that substantial P inputs are required for optimum plant growth. Manufactured water-soluble P fertilizers such as single superphosphate (SSP) and diamonium-phosphate (DAP) are commonly ultilised to correct P deficiencies. In Vietnam, superphosphate is locally produced but the cost of the sulfuric acid import is relatively high which is often a major outlay for resource-poor farmers. In addition, intensification of agricultural production in the countries of the tropics necessitates the addition of P not only to increase crop production but also to improve soil P status in order to avoid further soil degradation. The direct application of phosphate rock (PR), especially where available locally, has proved to be an agronomically and economically sound alternative to the more expensive superphosphates.

The effect of different phosphate sources and rates and seasonal changes toxic elements on grain yield of rice were investigated. The first study was conducted from October 1992 to September 1993 under the collaboration project between IAS/IFDC/IRRI. Two crops had been grown, one in dry season 1992-1993 and one in wet season 1993 where SSP, DAP and thermophosphate (TP) were used as test P sources. Eleven years later, the second study was carried out in four consecutive crops started in 2004 where rock phosphates (Lao cai Apatite from Vietnam, Gafsa RP from Tunisia and SSP were used. This is a joint project.

Materials and methods

The experiments were conducted on an acid sulfate soil of the ‘Plain of Reeds’, Moc Hoa district, Long An Province, Vietnam. The coordinates are 10^{0}40.354’N, 106^{0}00.256’E. The elevation is around sea level (0 m).

The soil is an actual acid sulfate soil: Thionic Fluvisols (FAO/UNESSCO soil classification system) or Typic Sulfaquepts (USDA soil classification system). The soil was a silty clay (14% sand). Sampling in 1994 showed that soil pH H2O was 3.7; exch. Al was 9.5 cmolc kg^{-1}dry season (DS) and 7.4 cmolc kg^{-1}wet season (WS); EC (1:2.5) was 1.4 mS/cm (DS), 0.4 mS/cm (WS). Sampling in 2004 for the second study showed the first two horizons at depths of 0-15 cm and 15-30 cm had pH_{H2O} (1:2.5) 4.48 and 3.72; total acidity (KCl, 1M) 1.5 and 2.89 $cmol_c$ kg^{-1}; organic carbon 3.8 and 2.3 %; Bray I P 27.3 and 6.7 mg kg^{-1}; P sorption capacity at 1000 mg P/kg soil 955 and 857 mg kg^{-1} and ECEC 6.2 and 6.9 $cmol_c$ kg^{-1}, respectively. The jarosite horizon occurs at about 48-60 cm depth.

In the first study (1994-1995), no P, DAP, TP and SSP were used as P sources. The P content is 46.4, 15.5 and 20.5 % P_2O_5, respectively. Phosphorus was added at the rates of 0, 60, 120 and 180 kg P_2O_5 ha^{-1} for each season. As a result the experiment 1 included four P sources at four P rates (4 x 4 = 16 treatments).

In the second study, Lao Cai apatite from Vietnam, Gafsa rock phosphate from Tunisia and local SSP were used as P sources. The P content is 28.8, 31.5 and 20.5 % P_2O_5, respectively. Phosphorus was added at the rates of 0, 25, 50 and 100 kg P ha^{-1} in the first crop. In the second crop, no P was added to all the plots in order to study possible residual effects of PR. In the third crop, the same amounts of P as the first crop were added to the same plots as had been done in the first crop and no P added in the fourth crop. In addition, another treatment received 100 kg P ha^{-1} at the first crop and no more P was added in the following seasons. This treatment is used to follow the residual effect of PR after four seasons. As a result the experiment 2 included three P sources at five P rates (3 x 5 = 15 treatments).

Both experiments were a split-plot design with P sources as the main plot and P rates randomized in the sub plots. The treatments were replicated four times.

Rice varieties IR 50404-2-2-3 and VND 95-20, commonly-used cultivars by the farmers in that area was used as a test crop for the 1^{st} and the 2^{nd} study, respectively. Rice seedlings were transplanted at the row spacing of 15 cm and hill spacing of 15 cm. Three seedlings were put in one hill.

Phosphorus fertilizer was totally applied before transplanting by broadcasting and then incorporating into the soil with a hand hoe to the depth of 10 cm. Nitrogen (urea) and potassium (KCl) were added to the rice crop in adequate amounts to avoid N and K limitations. These fertilizers were split into three applications.

Analysis of variance and mean separation were done using MSTAT-C program (MSTAT Copyright, 1988).

Results

First study

The effect of P source, P application rate, soil depth and cropping season on soil pH $_{H2O}$ at harvest is presented in Table 1. After one application, although TP had a higher soil pH $_{H2O}$ compared with other P sources, the differences were significant at harvest of the second application in the wet season. TP also significantly increased soil pH of the top 5 cm compared with the lower horizon. Application of TP increased 0.19 unit pH of top 5 cm compared with no P added. The differences in pH $_{H2O}$ due to P added was bigger with time. Different P rate did not affect soil pH in the first application but was highest at 120 kg P_2O_5 ha^{-1} at harvest of the wet season.

The most interesting information is in the dry season, the EC of the top 5 cm was very much higher than the below soil and those differences were highly significant ($P<0.01$) (Table 2). In addition, the EC of the soil at harvest of the dry season was almost three fold higher than those in the wet season. This shows the importance of seasonal changes to the environment hence affect crop growth which management practices should put into account.

P fertilisation creates a 'soil-depth effect' on soil pH, exchangeable Al and available P between the 0-5 cm and 5-15 cm depths. Therefore the benefit of P fertilisation would be extended if the fertilizer be incorporated deep into the soil.

Table 1. Effect of P source, P application rate and cropping season on soil pH $_{H2O}$ of an acid sulphate soil of Tan Lap village, The Plain of Reeds at harvest.

Parameter	pH H_2O (1 : 2.5)					
	Dry season			Wet season		
Depth (cm)	0 – 5	5 – 15	Df	0 – 5	5 – 15	Df
P Source						
0P	3.74 ab	3.73	0.05ns	3.88 b	3.75 ab	0.12*
SSP	3.74 ab	3.76	-0.02ns	3.91 b	3.72 b	0.19*
DAP	3.69 b	3.71	-0.02ns	3.96 b	3.71 b	0.25*
TP	3.80 a	3.73	0.07*	4.07 a	3.83 a	0.24*
CV (%)	***3.2***			***3.3***		
P rate (kg P_2O_5.ha^{-1})						
0	3.77	3.73	0.05ns	3.88 b	3.75	0.12*
60	3.72	3.69	0.02ns	3.92 b	3.69	0.22*
120	3.74	3.76	-0.02ns	4.03 a	3.78	0.25*
180	3.78	3.75	0.03ns	3.98 ab	3.78	0.21*
CV (%)	***3.2***			***3.3***		

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Table 2. Effect of P source, P application rate and cropping season on soil EC (1:2.5) of an acid sulphate soil of Tan Lap village, The Plain of Reeds at harvest

Parameter	EC (mS/cm) (1 : 2.5)					
	Dry season			Wet season		
Depth (cm)	0 – 5	5 – 15	Df	0 – 5	5 – 15	Df
P Source						
0P	1.64	0.84	0.8**	0.45	0.53	-0.09*
SSP	1.38	0.86	0.5**	0.47	0.48	-0.01ns
DAP	1.43	0.90	0.5**	0.44	0.47	-0.03ns
TP	1.44	0.89	0.6**	0.48	0.49	-0.01ns
CV (%)	***29.6***			***14.6***		
P rate (kg P_2O_5.ha^{-1})						
0	1.64	0.84	0.8**	0.45 ab	0.54	-0.08*
60	1.34	0.80	0.5**	0.43 b	0.46	-0.03ns
120	1.43	0.86	0.6**	0.49 a	0.50	-0.01ns
180	1.49	0.98	0.5**	0.47 ab	0.48	-0.01ns
CV (%)	***29.6***			***14.6***		

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

The soil had a very high exchangeable Al in the dry season and lower at harvest of the wet season (Table 3). Thermophosphate significantly reduced exch. Al at harvest of the wet season (after two applications) compared to the other two P sources. At all cases, the top 5 cm soil had significant lower exch. Al compared with the subsoil. The differences were up to 3.3 $cmol_c\ kg^{-1}$ after two seasons for TP showing a benefit of P fertilization with TP. Although the study did not statistically analyse the difference between season, a great decrease in exch. Al from dry season to wet season showing a seasonal change effect.

Table 3. Effect of P source, P application rate and cropping season on exchangeable Al grown on an acid sulphate soil of Tan Lap village, The Plain of Reeds

Parameter	**Exchangeable Al ($cmol_c\ kg^{-1}$)**					
	Dry season 92-93			Wet season 93		
Depth (cm)	0-5	5-15	Df	0-5	5-15	Df
P Source						
SSP	9.22	9.92	-0.7*	7.39 a	10.13	-2.73**
DAP	9.80	10.80	-1.0**	7.57 a	10.23	-2.67**
TP	9.01	10.23	-1.22**	6.45 b	9.78	-3.30**
CV (%)	***12.6***			***10.8***		
P rate (kg $P_2O_5.ha^{-1}$)						
0	9.90	9.89	0.01ns	7.42	9.93	-2.51**
60	9.47	10.50	-1.03**	7.48	10.27	-2.79**
120	9.39	9.90	-0.51ns	6.95	9.81	-2.86**
180	9.18	10.55	-1.38**	6.98	10.00	-3.06**
CV (%)	***12.6***			***10.8***		

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Table 4. Effect of P source, P application rate and cropping season on grain yield and weight of straw of IR 50404 grown on an acid sulphate soil of Tan lap village, The Plain of Reeds

Parameter	Grain yield ($kg.ha^{-1}$)		Weight of straw ($kg.ha^{-1}$)	
	Dry season	Wet season	Dry season	Wet season
P Source				
0P	1654 c	818 c	1679 d	1679 c
SSP	4079 b	1329 b	4116 c	2913 b
DAP	4334 b	1333 b	4538 b	2930 b
TP	4840 a	1665 a	5098 a	3429 a
cv (%)	***7.9***	***17.7***	***10.1***	***12.8***
P rate (kg $P_2O_5.ha^{-1}$)				
0	1654 c	818 c	1679 d	1679 c
60	4120 b	1378 a	4024 c	2922 b
120	4277 b	1454 a	4616 b	3096 ab
180	4856 a	1495 a	5112 a	3254 a
cv (%)	***7.9***	***17.7***	***10.1***	***12.8***

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Phosphate fertilization significantly increased grain yield in both seasons (Table 4). There was no significant difference in grain yield between DAP and SSP. Among P sources, TP gave highest grain yields compared with other P sources. In the dry season, grain yield increased with P rate, highest at 180 kg P_2O_5 ha^{-1}. Similar trend was seen with straw yield.

Second study

There was no significant different in soil pH $_{H2O}$ among P source nor P rate in the 1st dry season but it did in the 2nd wet season (Table 5). Bray I-P significantly increased with P rate. Total acidity significantly decreased with P rate in both season.

Table 5. Effect of P source, P application rate and cropping season on soil pH H2O (1:5) and Bray I-P of an acid sulphate soils of Tan Lap village, The Plain of Reeds.

	Dry season (2004-2005)		Wet season (2005)	
Treatment	pH_{H2O} (1:5)	Bray I-P (mg/kg)	pH_{H2O} (1:5)	Bray I-P (mg/kg)
P Source				
Apatite	4.26	36.9	4.30	28.8 b
Gafsa	4.24	47.0	4.26	34.9 ab
SSP	4.19	52.7	4.24	41.2 a
LSD			7.87	
P rate				
0	4.20	36.1 b	4.24 b	27.2 c
25	4.23	40.9 b	4.26 b	32.5 b
50	4.24	48.7 a	4.25 b	39.9 a
100	4.29	52.7 a	4.33 a	40.1 a
100*	4.20	49.2 a	4.24 b	35.3 b
LSD		**5.01**	**0.05**	**3.88**
CV %	***2.17***	***13.19***	***1.57***	***13.4***

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Table 6. Effect of P source, P application rate and cropping season on soil exchangeable Al and total acidity of an acid sulphate soils of Tan Lap village, The Plain of Reeds.

Treatment	Dry season (2004-2005) Exch Al	Dry season (2004-2005) Total Acidity	Wet season (2005) Exch Al	Wet season (2005) Total Acidity
	(cmolc kg^{-1})		(cmolc kg^{-1})	
P Source				
Apatite	3.24	4.81	3.30	4.72
Gafsa	3.31	4.96	3.26	4.64
SSP	3.27	5.39	3.32	5.11
P rate				
0	3.29	5.30 a	3.29	5.08 a
25	3.26	5.28 a	3.30	5.05 a
50	3.29	4.93 a	3.23	4.80 a
100	3.25	4.44 b	3.37	4.39 b
100*	3.28	5.30 a	3.30	4.81 a
LSD		0.47		0.35
CV%	***3.74***	***11.24***	***9.58***	***8.86***

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Table 7. Effect of P source, P application rate and cropping season on weight of straw of VN 95-20 grown on an acid sulphate soils of Tan Lap village, Long An province from 2004-2006

Treatment	Dry season 04-05	Wet season 05	Dry season 05 – 06	Wet season 06
P Sources				
Apatite	7.50	4.61	5.67	4.24
Gafsa	7.71	4.65	5.37	4.17
SSP	7.42	4.67	5.51	4.13
LSD	8.60 ns	10.0 ns	50.6	30.38
P rates				
0	7.15	3.89 c	5.27 b	3.12 d
25	7.47	4.63 b	5.49 ab	3.75 c
50	7.63	4.64 b	5.37 b	4.54 b
100	7.91	4.95 ab	5.76 a	4.96 a
100*	7.54	5.12 a	5.69 a	4.52 b
LSD	ns	0.39	0.32	0.43
cv%	***8.60***	***10.05***	***7.11***	***2.3***

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Dry weights of straw were significant different as affected by P rate (Table 7) at the second season onwards. This also shows the residual effect of P from the first dry season as no P added to the dry season. Grain yield did not differ among P sources (Table 8). Wet season had much lower grain yield compared with the dry ones. Grain yield increased with P rate.

Table 8. Effect of P source, P application rate and cropping season on grain yield of VN 95-20 grown on an acid sulphate soils of Tan Lap village, Long An province from 2004-2006

Treatment	Dry season 04 – 05	Wet season 05	Dry season 05 – 06	Wet season 06
P Sources				
Apatite	6.75	3.18	6.63	1.69
Gafsa	7.01	3.26	6.68	1.67
SSP	6.86	3.24	6.32	1.78
LSD	4.08 ns	8.81 ns	0.40	0.14
P rates				
0	6.88	3.09 b	6.15 c	1.53 c
25	6.99	3.13 b	6.64 b	1.62 bc
50	6.78	3.24 ab	6.59 b	1.88 a
100	6.80	3.46 a	6.95 a	1.86 a
100*	6.93	3.22 b	6.40 bc	1.69 b
LSD	ns	0.24	0.30	0.13
cv%	***4.08***	***8.81***	***5.6***	***9.4***

In a column and for each item, means followed by the same letter are not significantly different at P<0.05 according to DMRT

Treatment received 100 kg P ha^{-1} for four consecutive crops (2 years) had a significant lower yield compared with the one received 100 kg P ha^{-1} each year showing that 100 kg P ha^{-1} is not sufficient for phosphate capitalisation.

Conclusion

Since the Plain of Reeds is located in the lowest altitude of the landscape resulting in seasonal changes in surface water depth within a year. Therefore the reclamation of the region can not rely on tidal water to remove excessive amounts of toxic elements such as Al, Fe and organic acids. The accumulation of these elements increases the EC and decreases the pH of the soil. Phosphate fertilisation (sources and rates) effectively reduced Al toxicity and acidity, an alternative reclamation method to replace water treatment where fresh water is not available;

P fertilisation creates a ‘soil-depth effect’ on soil pH, exchangeable Al and available P between the 0-5 cm and 5-15 cm depths. Among P sources, TP significantly increased grain yield and nutrient uptake compared with SSP and DAP. P rates had positive effects on grain yield, crop growth and soil properties.

After 10-11 years of continuously cultivated and ameliorated with phosphate fertilizer, grain yield had increased from 3 to more than 6 tonnes ha^{-1} in dry season and from <1 to 3 tonnes ha^{-1} in wet season. Grain yield increased with P application rates, highest at treatment received 100 kg P/ha yearly in two consecutive years. The less significance found among P sources could be due to a high P availability in the soil of the second study after applying phosphate fertilisers for many years.

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Numerical Modeling of Nitrogen and Phosphorus Runoff in a Flat Low-Lying Paddy Cultivated Area

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Abstract Chiyoda basin is located in Saga Prefecture in Kyushu Island, Japan, has a total area of approximately 1,100 ha, and is a typical flat and low-lying paddy-cultivated area. As other agricultural lands, increasing the crop production is one of the main objectives of farmers. In order to do so, they prefer to put more fertilizers, especially nitrogen and phosphorus. However, the redundant nutrients arising from fertilizer load can easily have negative impacts on the water environment and ecosystem. Therefore, it is necessary to evaluate and manage the total nitrogen (TN) and total phosphorus (TP) load in this area. This study presents a mathematical model of TN and TP runoff during an irrigation period in Chiyoda basin in order to elucidate the pollutant fluxes that accompany water transportation in paddy fields and drainage canals, and to evaluate the transfer of pollutants from the study area to the Chikugo River. First, the water flow was simulated by a continuous tank model and the accuracy of the model was then evaluated by comparing the simulated water levels with observed ones during an irrigation period. The observed and simulated water levels were in good agreement, indicating that the proposed model is applicable for drainage and water supply analyses in flat, low-lying paddy-cultivated areas. Second, the TN and TP runoff during an irrigation period was simulated based on the TN and TP loads that were determined by observed data in paddy fields. For TN runoff, the simulated results and observed data were in good agreement whereas for TP runoff, the simulated results were higher than the observed data. However, if the settled TP within the paddy tank was calculated as 6%, then the simulated results and the observed data were in good agreement. We concluded that the TN runoff from paddy field to the drainage canal system was not affected much by the sediment related process. The present study could provide farmers and managers with a useful tool for controlling the water distribution in an irrigation period, and the TN and TP loads in the downstream area as well as the Chikugo River.

Keywords Irrigation period, irrigation requirement, total nitrogen, total phosphorus, tank model, gate drainage canal.

Introduction

Integrated nutrient management (INM) has been recognized as an effective management practice for the reduction of nutrient losses from farmland, and is also relevant generally to the notion of environmental-friendly agriculture (Cho *et al.*, 2008). However, solving the nutrient-management problem is not simple. In agricultural systems, it may be necessary to achieve the ultimate goal of obtaining nutrient balance (Cho 2003). Moreover, the efflux of nitrogen (N) and phosphorus (P) from agricultural lands is considered to be a major contributor to the accelerated eutrophication of rivers and reservoirs around the world (Kim *et al.*, 2006). During the irrigation period, the flat low-lying, paddy-cultivated areas are loaded so there are many types of nutrient resources such as fertilizer, rainfall, circular irrigation, and so on. Therefore, in Chiyoda basin, it is necessary to elucidate the pollutant fluxes that accompany water transportation in paddy fields and drainage canals, and to evaluate pollutant removal from the study area to the Chikugo River.

In the present study, a continuous tank model was used to simulate the water flow in the paddy fields and canal system during the irrigation period. Next, the TN and TP runoff from paddy fields to the drainage canal system were simulated.

Materials and Methods

1. Study area

Chiyoda basin is located in Saga Prefecture in Kyushu Island, Japan. It is a typical flat and low-lying agricultural area surrounded by the Jobaru River to the west and the Tade River to the east, as shown in **Fig. 1**. The total basin area is approximately 1,100 ha, which is mostly covered with paddy fields. The excess water during flood events is removed from the paddy fields to the secondary drainage canals, and then from the secondary canals to the main drainage canal, which has a length of 7.2 km. Finally, the excess water is discharged from the main drainage canal to the tidal compartment of the Chikugo River using a gate and the pump drainage system. All canals are used for both irrigation and drainage purposes.

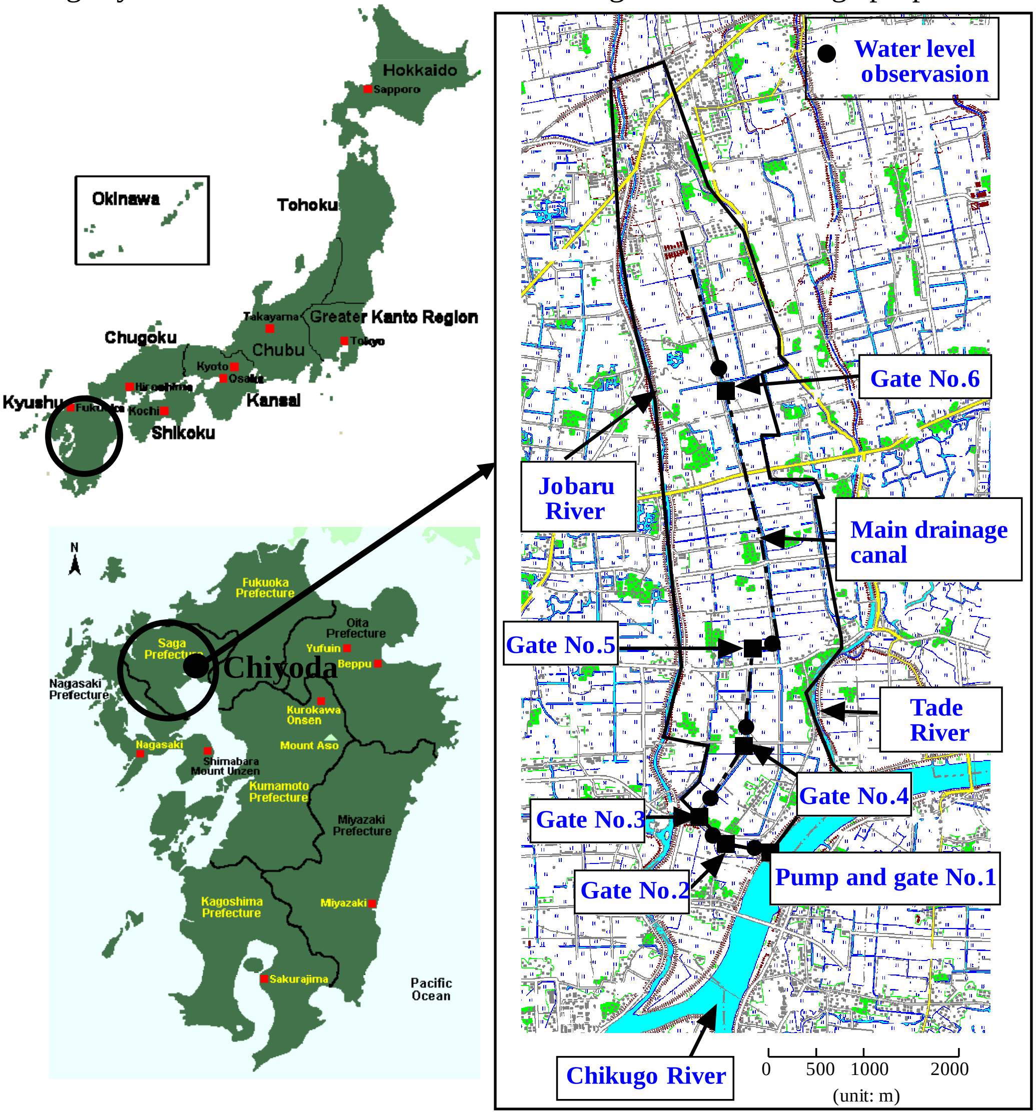


Fig.1 Location of Chiyodadrainage basin.

2. Data acquisition

In order to evaluate the applicability of the proposed model in the present study, water level sensors were set up in June 2005, and have been observed at the upstream of check gates since then. The water level data from June 2007 to October 2007 were used for the verification of the proposed model. The water levels at the Chikugo River were also observed and used as the downstream boundary condition of the model. Secondly, the daily TN and TP concentrations were observed at the downstream end of the main drainage canal. In order to take the daily water sample, one automatic sampling machine was set up at this location. In addition, the water samples at the outlet of paddy fields and along the main drainage canal were taken once per 20 days interval. The water sample at the upstream end of the main drainage canal was also taken once per 20 days in order to determine the TN and TP concentrations in irrigation water supply. All of the water samples and TN and TP concentrations were analysed in the laboratory under standard condition. These observation points are shown in **Fig.2**.

3. Modeling of water flow and runoff nitrogen and phosphorus

Considering the characteristics of Chiyoda basin and the purpose of this study, a continuous tank model (Hiramatsu *et al*., 2004) was adopted because it has a simple model structure and high performance. In the authors' model (Chinh *et al.*, 2008), the paddy fields and adjacent small canals were divided into "paddy tanks," and canals were divided into segments called "river tanks." Connecting the paddy tanks and the river tanks to each other, the flow discharge and direction at each connection branch were calculated by hydraulic equations using the differences between water levels in the tanks at both ends of the branch.

By dividing paddy fields and canals into paddy tanks and river tanks based on the topography and land use, the drainage network model of Chiyoda basin was obtained, as depicted in **Fig. 2**. The basin was analyzed by this model in which the paddy fields were divided into 15 tanks, the secondary drainage canals were divided into 10 river tanks, and the main drainage canal was divided into 14 river tanks.

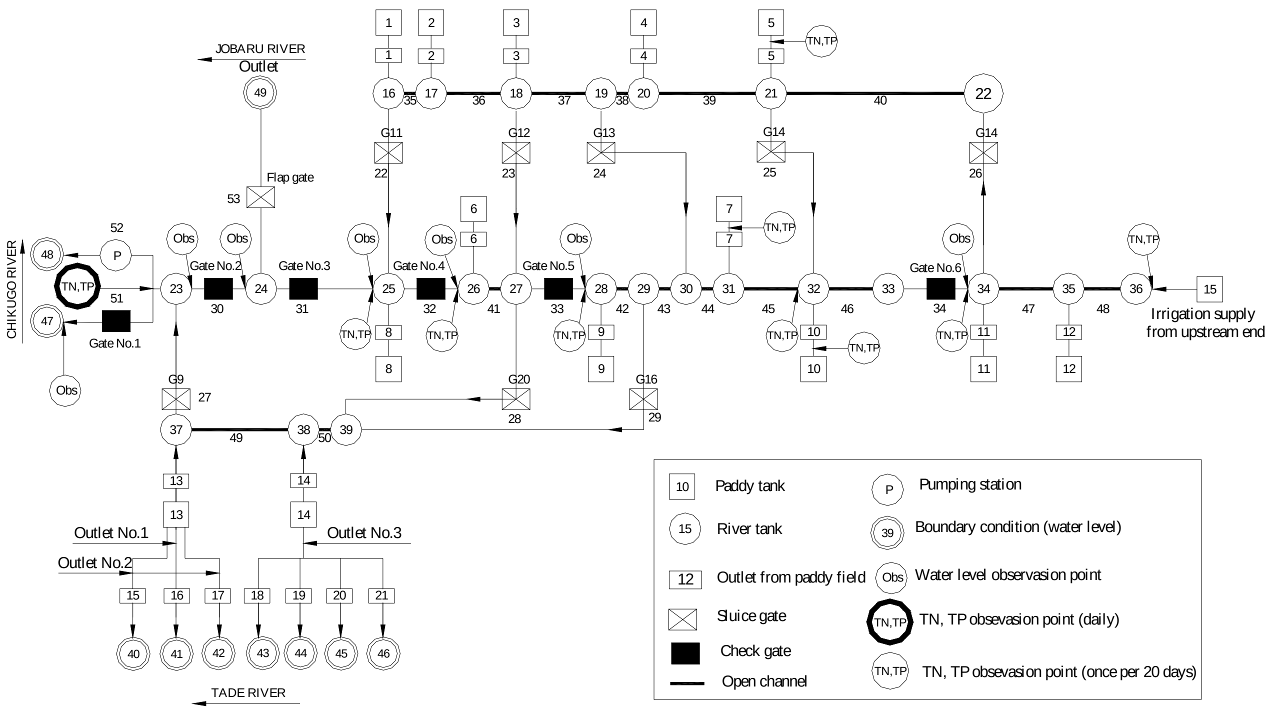


Fig. 2 Drainage network model of Chiyoda basin.

Therefore, there were 24 river tanks in total. The interfaces between the paddy tanks and the river tanks are drainage structures: 21 outlets from paddy fields to drainage canals or rivers, 8 sluice gates from the secondary drainage canals to the main drainage canal, 5 main check gates located in the main drainage canal, 1 gate, 1 pump and 1 flap gate located at the downstream end.

a) Determination of water level and flow rate

This model was numerically solved to determine the water levels in the paddy tanks and the river tanks, and the flow discharges at every connection branch.

Assuming that the water level in each tank is uniformly varied, the variation of the water volume $V_{(i)}$ in tank i is described by the following continuity equation, which is a basis equation for calculating the water flow.

$$\frac{dV_{(i)}}{dt} = Q_{\mathrm{in}(i)} - Q_{\mathrm{out}(i)} \tag{1}$$

In equation (1), $V_{(i)}$, $Q_{\mathrm{in}\,(i)}$ and $Q_{\mathrm{out}\,(i)}$ are a water volume, an inflow to tank No.i and an outflow from tank No.i, respectively. The drainage network model in Chiyoda basin had 39 tanks, resulting in the simultaneous first-order ordinary differential equations with 39 unknown variables. These equations were numerically calculated by the Runge-Kutta-Gill method. The flow rate Q at each connection branch was calculated by hydraulic equations using the differences between water levels in the tanks at both ends of the branch. Weirs, gates and open channels were assumed for hydraulic treatment of the connection branch, as shown in **Fig. 2**.

b) Determination of TN and TP runoff

As the modeling of water flow, TN and TP runoff were also numerically solved to determine the TN and TP load rates in the paddy tanks and the river tanks, and the TN and TP release rates at every connecting branch.

The total loads of TN ($LTN_{(i)}$) and TP ($LTP_{(i)}$) in the paddy tanks and the river tanks are described by the following equations, which are the basis equations for calculating the TN and TP runoff.

$$\frac{dLTN_{(i)}}{dt} = TN_{\mathrm{in}(i)} - TN_{\mathrm{out}(i)} \tag{2}$$

$$\frac{dLTP_{(i)}}{dt} = TP_{\mathrm{in}(i)} - TP_{\mathrm{out}(i)} \tag{3}$$

In equations (2) and (3), $LTN_{(i)}$, $LTP_{(i)}$;$TN_{\mathrm{in}\,(i)}$, $TP_{\mathrm{in}\,(i)}$; snd $TN_{\mathrm{out}\,(i)}$, $TP_{\mathrm{out}\,(i)}$ are total loads of the TN and TP; TN and TP load rates to tank No.i; and TN and TP release rates from tank No.i, respectively. The water flow network model in Chiyoda basin had 39 tanks, resulting in the simultaneous first-order ordinary differential equations with 39 unknown variables for each TN and TP. These equations were numerically calculated by the Runge-Kutta-Gill method together with water flow equations.

TN and TP effluent loads are mainly from fertilizer input, water irrigation supply, rainfall, and release loads from neighboring tanks.

Kato (2005) showed that not all the TN loads in applied fertilizers would be released in the runoff process. Some would be absorbed by plans and disappear by volatilization and denitrification. In the paddy fields, the disappearance rate of TN was set at 60% in the irrigation period. Therefore, TN and TP effluent loads, which are the remainder after subtracting absorption from the disappearance rates, were determined by the following equation:

$$TN_{\mathrm{in}(i)} = (TN_{\mathrm{Load}(i)} - TN_{\mathrm{Dis}(i)})A_{(i)} \tag{4}$$

$$TP_{\mathrm{in}(i)} = (TP_{\mathrm{Load}(i)} - TP_{\mathrm{Dis}(i)})A_{(i)} \tag{5}$$

where $A_{(i)}$ is area of paddy tank No.*i*. $TN_{Load(i)}$ and $TP_{Load(i)}$ are the TN and TP load rates per unit area from fertilizer, rainfall, and irrigation water supply to paddy tank No.*i*.

$$TN_{\mathrm{Load}(i)} = TN_{\mathrm{Fer}(i)} + TN_{\mathrm{Rain}(i)} + TN_{\mathrm{Irr}(i)} \tag{6}$$

$$TP_{\mathrm{Load}(i)} = TP_{\mathrm{Fer}(i)} + TP_{\mathrm{Rain}(i)} + TP_{\mathrm{Irr}(i)} \tag{7}$$

$TN_{Fer\ (i)}$, $TP_{Fer\ (i)}$, $TN_{Rain\ (i)}$, $TP_{Rain\ (i)}$, $TN_{Irr(i)}$, and $TP_{Irr(i)}$ are the TN and TP load rates per unit area, from fertilizer, rainfall, and irrigation water supply to paddy tank No.*i*. the TN and TP disappearance rates per unit area ($TN_{Dis(i)}$, $TP_{Dis(i)}$) depend on many factors such as soil characteristics, dissolution rate of TN or TP from fertilizer, growing stage of rice, weather conditions, and ponded water depth in the paddy field. In this study, the TN and TP concentrations at the paddy outlets were observed.

Therefore, these values could be used as the TN and TP concentrations in the paddy tanks after subtracting the disappearance rates. Consequently, instead of equations (4) and (5), the $TN_{in\ (i)}$ and $TP_{in\ (i)}$ effluent loads that could be obtained from measurements are described by the following equations:

$$TN_{\mathrm{in}(i)} = V_{(i)} \times CTN_{\mathrm{Obs}(i)} \tag{8}$$

$$TP_{\mathrm{in}(i)} = V_{(i)} \times CTP_{\mathrm{Obs}(i)} \tag{9}$$

where $V_{(i)}$ is the volume of water that was determined by equation (1) and $CTN_{Obs(i)}$ and $CTP_{Obs(i)}$ are the observed concentrations of TN and TP at the outlet of paddy tank No. *i*. By employing this process, the difficulty in the determination of the TN disappearance rate could be overcome.

Results and discussions

First, the accuracy of the proposed model was evaluated by comparing the simulated results with the observed water levels. The variation of water levels in river tanks 23, 24, 25, 26, 33 and 34 are shown in **Fig. 3**.

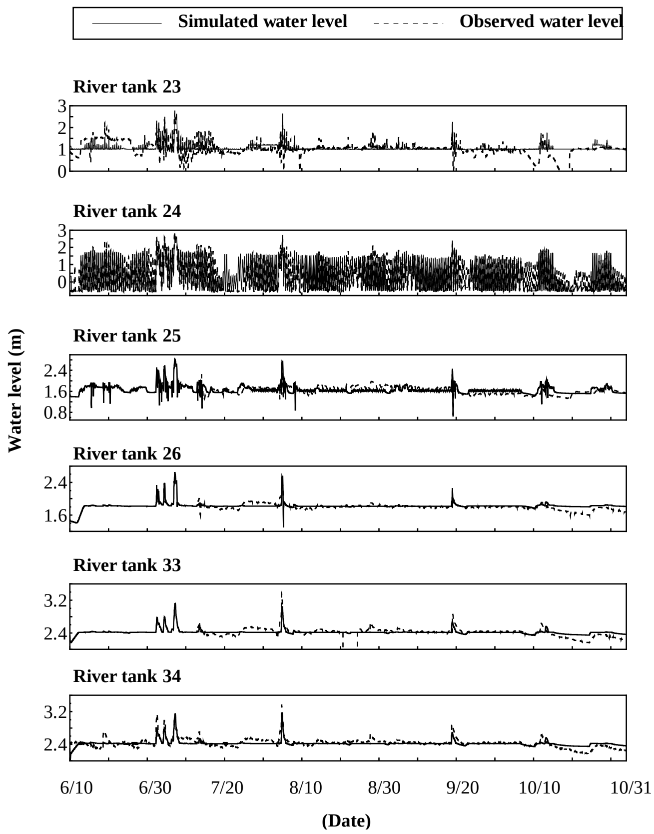


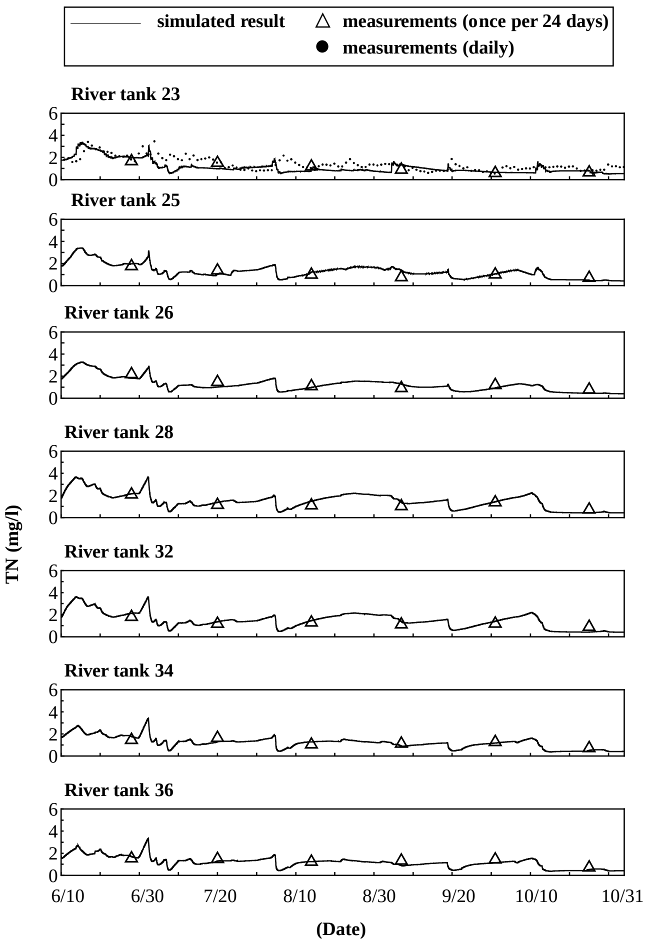
Fig. 3 Comparison of simulated results and observed water levels.

These figures show that the observed and simulated data are in good agreement. It was concluded that the Chiyoda basin model was successfully constructed by using a continuous tank modeling.

Second, the TN and TP runoff from paddy fields to the drainage canal system were simulated. The accuracy of the model was evaluated by comparing the simulated result of TN and TP concentration with the observed data.

a) For TN concentration and runoff:

The simulated results are in reasonable agreement with the field measurements, as shown in **Fig. 4**. According to the farming activities, the fertilizers were loaded once in the beginning of the rice season (June 10). During the puddling stage (from June 10 to June 25), the ponded water depth in paddy fields was maintained at 3 cm. The field experiment data showed that about 42% of applied N from fertilizer was dissolved by this water layer. Therefore, the TN concentration in paddy tanks and river tanks were very high. TN concentration in paddy field ranged between 4.0 and 7.0 mg l^{-1}. In this stage, about 25% of the dissolved TN was released in the runoff process; the remainder was absorbed by soil and plants and disappeared by volatilization and denitrification. Cho (2003) and Kato (2005) reported that the disappearance rate ranges from 60% to 80% of the dissolved TN. **Fig. 4** shows that in the beginning of the shallow water stage (July 5), the TN concentration increased rapidly because of heavy rainfall, then it decreased because the TN dissolution rate also decreased 0.63%.



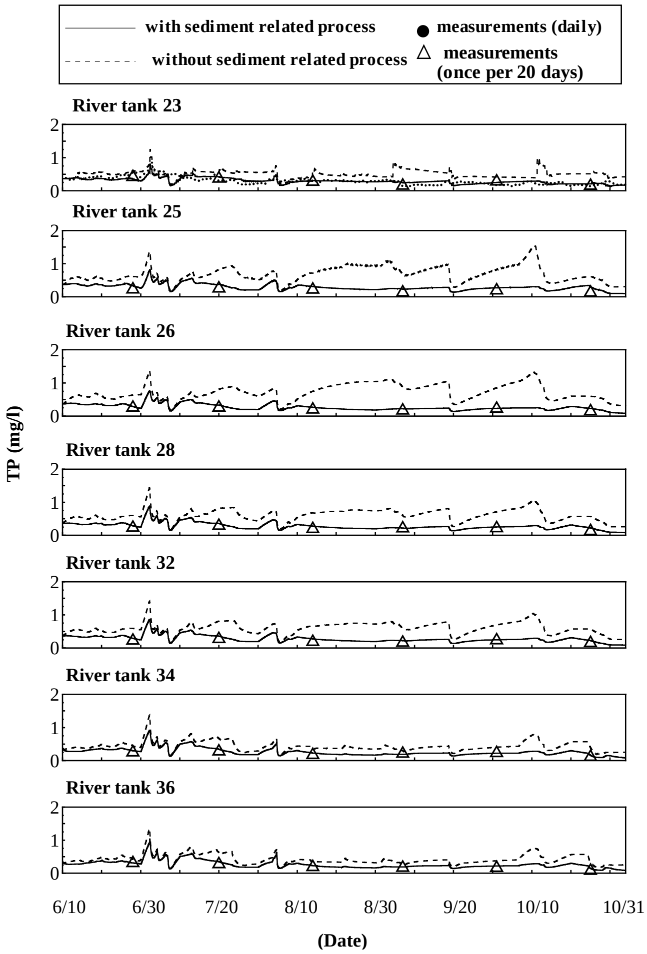


Fig. 4 Total nitrogen concentration in river tanks along main drainage canal and downstream end of main drainage canal.

Fig. 5 Total phophorus concentration in river tanks along main drainage canal and downstream end of main drainage canal.

In the middle drainage stage, most of the water was drained from paddy fields to drainage canals so that the TN concentration decreased rapidly. The TN concentration increased during the deep water stage because the TN dissolution rate from fertilizer increased. Moreover, the irrigation water that contained TN load was supplied continuously from drainage canal to paddy fields. Finally, in the harvesting preparation stage, TN concentration in paddy tanks and river tanks decreased gradually due to most of the dissolved TN run out at the end of rice season.

b) For TP concentration and runoff:

If TP runoff was considered as TN runoff, then the simulated results of TP concentration in river tanks were higher than the measurements, as shown in **Fig. 5**.

This phenomenon could be explained by the fact that the total effluent load of TP would not be conveyed by the water flow. Some of the load would have settled inside of the interface between the paddy tanks and river tanks. Therefore, in paddy tank No.*i*, the remainder after subtracting the settled TP was determined by the following equation:

$$TP_{\mathrm{out}(i)} = Q_{\mathrm{out}} \times (1-\alpha) CTP_{\mathrm{Obs}(i)} \quad (10)$$

where α is the settling coefficient of TP;$CTP_{\mathrm{Obs}(i)}$, the observed concentration of TP in paddy tank No.*i*; and Q_{out}, the discharge of structure.

The α coefficient was determined by the trial and error method. In the case of α = 6%, the relative error (mean absolute error divided by mean measured data) is the smallest, and the simulated results of TP concentration in river tanks and measurements are in good agreement. Moreover, the amplitude of the model output almost matches the measured value. Therefore, it could be concluded that 6% of the effluent load of TP was settled within paddy tanks and transported by the sediment related process throughout the structures.

The TP concentration in the puddling stage was not as high as the TN concentration, because TP dissolved more slowly than TN.

c) Evaluation of water quality in main drainage

The irrigation water quality in the drainage canal and the pollutant load from Chiyoda basin to the Chikugo River could be evaluated by comparing the simulated results and the standard of TN concentration in the irrigation water. As presented in **Fig. 4**, during the puddling and transplanting stages (from June 10 to July 1), the TN concentration in the main drainage canal was higher, namely, 1.0 mg l^{-1} (as the standard of TN concentration in the irrigation water in Japan); in other growing stages of rice, TN in the main drainage canal was within the standards.

Conclusions

TN and TP runoff was simulated by using numerical modeling during an irrigation period from June to October 2007 in Chiyoda basin, which is a typical flat and low-lying paddy-cultivated area, for calculating the water flow and TN and TP runoff. First, the water flow model was simulated and then evaluated by comparing the simulated water levels with observed ones. The results showed that the observed and simulated water levels were in good agreement, indicating that the proposed model was applicable for flat, low-lying, paddy-cultivated areas. In order to meet the requirements for water distribution, this water flow model was constructed by considering the related factors such as rice growing stage, evapotranspiration, infiltration, farming activities. Second, TN and TP runoff were simulated and investigated. For TN runoff, the simulated results and observed data are in good agreement; for TP runoff, the simulated results are higher than the observed data. However, if the settled TP within the paddy tank was calculated as 6%, then the simulated results and the observed data are in good agreement. It was concluded that TN runoff from paddy field to the drainage canal system was not affected much by the sediment related process, whereas for TP runoff, this process should be considered. The pollutant load from Chiyoda basin to Chikugo River was estimated by utilizing the TN and TP concentrations at the outlet of the main drainage. These results could provide farmers and managers with a useful tool for controlling the water distribution in an irrigation period and the TN and TP loads in the downstream area as well as the Chikugo River.

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The authors wish to acknowledge the Chikugo River Basin Irrigation and Drainage Project Office, Kyushu Regional Agricultural Administration Office, the Ministry of Agriculture, Forestry and Fisheries of Japan for the acquisition of the in situ measurement data of the water levels in the main drainage canal. We appreciate the helpful cooperation in modeling the drainage network in Chiyoda basin provided by Gijutsu Kaihatsu Consultant Co., Ltd., Fukuoka, Japan. Partial financial support for this study was provided by JSPS Grants-in-Aid for Scientific Research (B) (project number: 16380163 and 19380138). We would also like to thank all of the project members for their invaluable discussions.

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Heavy Metal Contamination of Soil in Wastewater-Irrigated Paddy Field in a Suburban Area of Hanoi, Vietnam

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Abstract

The present paper deals with the heavy metal contamination of soil in the paddy field subjected to the irrigation water polluted with wastes from various industrial plants in Hanoi. Soil samples were taken at different distances (0-50 m) from the edge of the paddy field. The retention and potential mobility of heavy metals were assessed based on the contents of total and fractionated heavy metals in the soil and their leachability. The concentration of the fractionated heavy metals was determined by selective sequential extraction method. The average concentration of the metals in the soil was in the order: Cu (202 mg kg^{-1}) > Zn (192 mg kg^{-1}) > Cr (185 mg kg^{-1}) > Pb (159 mg kg^{-1}) > Ni (45 mg kg^{-1}) > Cd (4 mg kg^{-1}). The heavy metal concentrations in the soil exceeded the permissible level of the Vietnamese standard for Cd, Cu, Pb and Zn. The results of selective sequential extraction procedure indicated that dominant fractions were oxide, organic and residual materials for Cd, Ni, Pb and Zn, and organic and residual materials for Cr, and an organic material for Cu. Leaching tests with deionized water and acid solutions indicated that the ratio of leached metal concentration to total metal concentration in the soil decreased in the order: Cd > Ni > Cr > Pb > Cu > Zn. By leaching with deionized water and acid solutions, all heavy metals were released fully from exchangeable fraction, and Cd and Ni were fully from carbonate and oxide fractions.

Key words**:** Vietnam, Paddy soils, Heavy metal, Selective sequential extraction, Leaching.

INTRODUCTION

There are two rivers, the To Lich and Kim Nguu Rivers, in Hanoi City, and water from these rivers is used to irrigate suburban agricultural land. Along the rivers, various industrial plants are located and wastewater from these plants has degraded the water quality of the rivers, because of poor facilities to treat wastewater and a rapid increase in industrial plants in recent years. The paddy field site for the present study is located in Thanh Tri District, the southern part of Hanoi City. The district occupies 63.27 km^2 and its 40 % is farmland. This farmland area is most productive but is highly contaminated with heavy metals (Ho et al., 1998), because highly polluted water from the two rivers is irrigated to the farmland (Nguyen et al., 2007). Although Hanoi City government conducted the monitoring of heavy metals in river water, groundwater, sludge from rivers and canals, vegetation, aquatic life (Klank et al., 2006), assessment on the heavy metal pollution of paddy fields and its influence on rice have not been performed. The present paper deals with the heavy metal contamination of soil in a suburban area of Hanoi.

The objective of this study is to examine the heavy metal contamination of paddy soil and rice subjected to the irrigation water, polluted with wastes from various industrial plants that are located along the To Lich and Kim Nguu Rivers in Hanoi City. The retention and potential mobility of heavy metals were assessed based on the contents of total and fractionated heavy metals in the soil and their leachability.

MATERIALS AND METHODS

Soil samples

The sampling of soil was conducted on December 3 to 6, 2005. The sampling site is located in Thanh Tri District of Hoang Liet Commune in Hanoi City (Fig. 1). Soil samples were collected from the depths of 0-20 and 20-40 cm at the locations of various distances from the road: 0, 3, 6, 10, 20 and 50 m (Fig. 1). The soil samples were ground after air drying, and sieved with an opening of 1 mm.

Chemical and physical properties of the soil

The value of pH was measured using soil suspension with soil-water ratio of 1:2.5 in weight. Organic carbon was determined by the Tyurin method and organic matter content was obtained by multiplying by the coefficient of 1.724 (Committee of Soil standard methods for Analyses and Measurement, 1986). Cation exchange capacity (CEC) was measured by the method proposed by Muramoto et al. (1992).

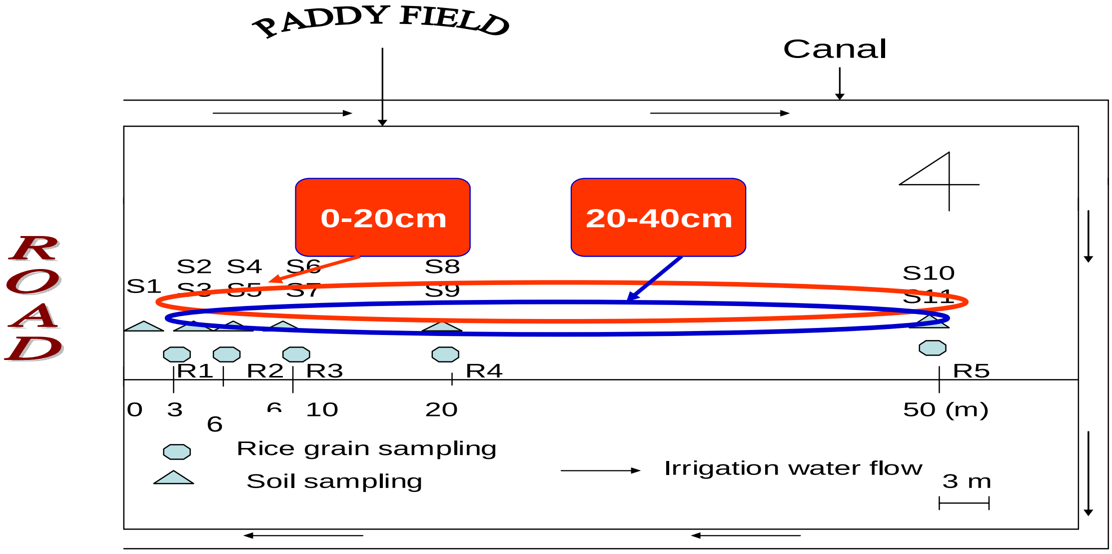

Fig. 1. Location of sampling site for soil and rice grain

Determination of total metal concentration

For total heavy metal analysis, the solid was digested with a mixture of hydrofluoric, nitric and perchloric acids. The resulting solution was then analyzed by atomic absorption photometer (SOLAAR 2S, Thermo Electron Corporation).

Selective sequential extraction (SSE) of heavy metals

The SSE methods were adopted from Tessier et al. (1979), Li and Li (2001), and Yong et al. (2001).

Leaching test

Batch leaching tests were used to determine the heavy metal leachability of soil samples (USEPA, 1987). The leaching solutions used were deionized water (pH 5.5), nitric acid (HNO_3), acetic acid (CH_3COOH) at pH 4 and 1M ethylene diamine tetra acid (EDTA).

RESULTS AND DISCUSSION

Properties of the soil

The chemical and physical properties of the soil samples are shown in Table 1. The $pH_{(H2O)}$ and $pH_{(KCl)}$ was in a range of 8.1 to 8.7 and 7.3 to 7.9, respectively. The organic matter content and CEC were higher in the surface soil (0-20 cm) than in the subsurface soil (20-40 cm). The exchangeable Ca and Mg were predominant, and the surface soil exhibited higher total cation concentration than the subsurface soil. These can be explained in terms of the higher accumulation of organic suspended solids from the irrigation water in the surface soil than the subsurface soil. The clay fraction ranged from 12.7 to 51.2%, being classified as loam or silt loam.

Table 1. Chemical and physical properties of the soil samples taken at different distances from the road

Location	Distance from the road (m)	No	Depth (cm)	pH (H2O)	pH (KCl)	OM* (%)	CEC ($cmol_c$ kg^{-1})	Exchangeable cation ($cmol_c$ kg^{-1})				
								Ca	Mg	K	Na	Total
1	0	S 1	0-20	8.4	7.8	3.6	12.7	23.7	1.8	0.1	0.2	25.8
2	3	S 2	0-20	8.3	7.6	3.3	11.7	10.6	3.0	0.5	0.3	14.3
		S 3	20-40	8.2	7.3	2.2	8.6	5.4	2.1	0.3	0.2	8.0
3	6	S 4	0-20	8.2	7.8	3.6	13.1	9.9	3.6	0.5	0.4	14.3
		S 5	20-40	8.2	7.5	2.4	8.8	5.4	2.6	0.4	0.2	8.6
4	10	S 6	0-20	8.3	7.9	3.3	12.3	9.0	3.6	0.5	0.4	13.5
		S 7	20-40	8.3	7.6	2.1	8.6	5.7	3.1	0.4	0.2	9.5
5	20	S 8	0-20	8.7	7.8	3.2	12.3	8.3	3.6	0.6	0.4	12.9
		S 9	20-40	8.3	7.5	2.5	9.9	6.3	3.6	0.6	0.3	10.7
6	50	S 10	0-20	8.2	7.7	3.9	8.7	7.4	3.6	0.5	0.6	12.1
		S 11	20-40	8.1	7.6	2.9	7.6	7.1	3.6	0.6	0.3	11.5

* OM. Organic matter

Table 2. Total heavy metal concentration in the soil samples taken at different distances from the road

Location	Distance from the road (m)	No	Depth (cm)	Cd	Cr	Cu	Ni	Pb	Zn
				(mg kg^{-1})					
1	0	S 1	0-20	7.5	201	270	58	195	310
2	3	S 2	0-20	4.5	195	225	56	175	256
		S 3	20-40	4.0	190	245	40	160	165
3	6	S 4	0-20	4.5	195	220	51	165	200
		S 5	20-40	3.5	178	190	40	155	165
4	10	S 6	0-20	4.5	195	192	50	165	183
		S 7	20-40	3.0	166	175	37	145	163
5	20	S 8	0-20	4.0	193	190	48	160	175
		S 9	20-40	2.9	165	165	36	140	163
6	50	S 10	0-20	4.0	192	190	46	155	165
		S 11	20-40	3.0	162	155	32	130	162
*BGL**				*0.16*	*62*	*73*	*34*	*32*	*115*
*TCVN***				*2*		*50*		*70*	*200*

* Background levels of heavy metals in agricultural soils of Tu Liem District of Hanoi, Vietnam (Ho et al., 1998)

** Vietnamese standard (7209-2002: MOSTE of Vietnam, 2002) for heavy metal concentration in agricultural soils

Heavy metal concentration in the soil

Total heavy metal concentrations in the soil samples are shown in Table 2. The average concentration of the heavy metals was in the order: Cu (202 mg kg^{-1}) > Zn (192 mg kg^{-1}) > Cr (185 mg kg^{-1}) > Pb (159 mg kg^{-1}) > Ni (45 mg kg^{-1}) > Cd (4 mg kg^{-1}). The metal concentration was higher in the surface soil than the subsurface soil for all locations and metal types, because heavy metals in river water were supplied in greater amount into the surface soil than the subsurface soil.

Compared with the background level of heavy metals in the soil that has not been subjected to polluted irrigation water (Ho et al., 1998), heavy metals in all locations of the study site exhibited higher concentration, and the total concentrations of Cd, Cu and Pb exceeded the permissible level of the Vietnamese standard (TCVN 7029-2002) for agricultural soil (Cd: 2 mg kg^{-1}; Cu: 50 mg kg^{-1}; Pb: 70 mg kg^{-1}). These indicate that the excess heavy metal concentrations in the soil are mainly due to the application of polluted irrigation water to the paddy field.

Heavy metal association with soil fractions

The distribution of heavy metals in soil profiles is continuously altered by both anthropogenic activities and natural turnover in rock-soil-plant systems. The toxicity and mobility of heavy metals are related to their chemical form, and hence the total heavy metal content in a soil matrix alone does not provide adequate information on their bioavailability and eco-toxicology. Heavy metals are associated with various soil components in different forms, and these associations have been indicated to affect the mobility of metals in the soil as well as their bioavailability (Ahumada et al., 1999). Water soluble heavy metals and those retained through exchangeable phases exhibit high mobility and are readily taken up by crop plants. The mobility and bioavailability of metals precipitated with carbonates, occluded in Fe-Mn oxides or complexed with organic matter depend on the physical and chemical properties of the soil (Rubio et al., 1994).

The heavy metals retained through different phases were identified for eleven soil samples in Table 1 using selective sequential extraction (SSE). The results obtained are presented in Fig.2 for various heavy metals. The relative proportion of heavy metal associated with six phases was different by the type of metals, but was similar for all soil samples. The oxide, organic and residual materials were predominant for Cd, Ni, Pb and Zn, the organic and residual materials were for Cr, and the organic material was for Cu. The water-soluble, exchangeable and carbonate fractions were much smaller in percentage compared with other fractions in all heavy metals.

Potential leachability of heavy metals

The potential release of heavy metals from the soil due to changes in water and soil environment was assessed using the batch leaching tests. Weak acid and strong complexant solutions are commonly used to determine trace-metal mobility in sediments (Sahuquillo, 2003). In our tests, nitric and acetic acid solutions (pH 4) and EDTA solution were used as weak acid and a complexing agent, respectively. For the assessment of heavy metal release from the soil samples, the repeated washings (5 times) of the samples with above solutions, based on the batch leaching tests, were employed. Figure 3 shows the change in the leached metal concentration with the number of washing for the soil sample No.1 in Table 1. The leached concentrations of all metals increased substantially with increasing the number of washing for all solutions. The leached metal concentration after five washings was in the order: Cr > Ni > Pb > Cu > Zn > Cd for all solutions. The EDTA treatment gave higher leached metal concentration than the deionized water and acid treatments. After five washings, the leached metal concentration reached almost a plateau for Cd, Zn, Cu, Pb and Ni while still tended to increase for Cr. The leaching tests with repeated washings were also conducted on the soil samples other than the soil sample No.1 in Table 1 and similar results were obtained (not shown here).

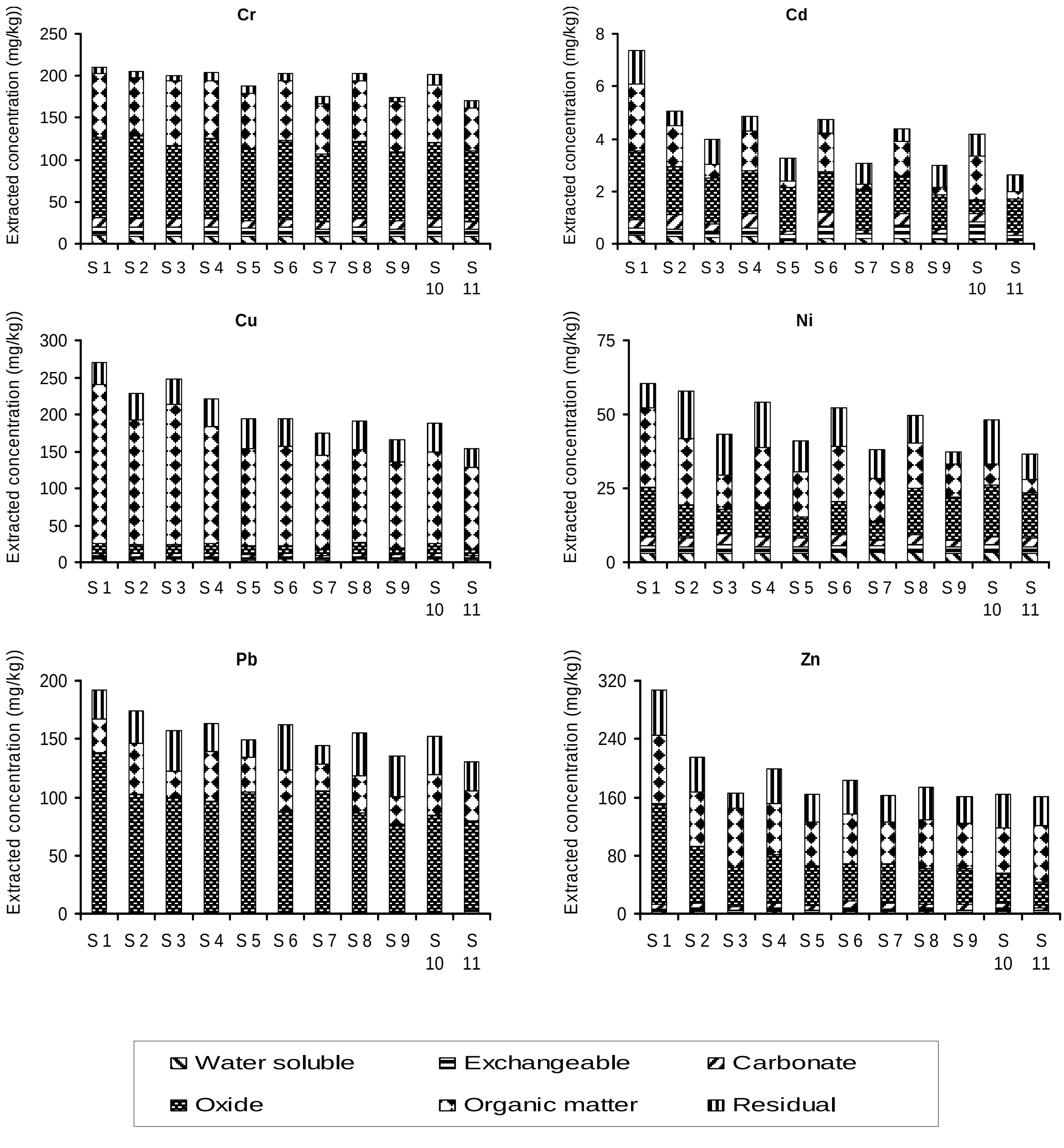

Fig. 2. Heavy metal extracted via selective sequential extraction (SSE) from the soil samples taken at different distances from the road.

The leached heavy metal concentration thus determined for all soil samples were plotted against the total metal concentration for the respective leaching solutions (Fig. 4). The treatments with deionized water, nitric acid and acetic acid exhibited similar patterns, and for most metals the leached metal concentration was almost constant for the change in the total metal concentration, while the EDTA treatment gave higher leached concentrations than other treatments.

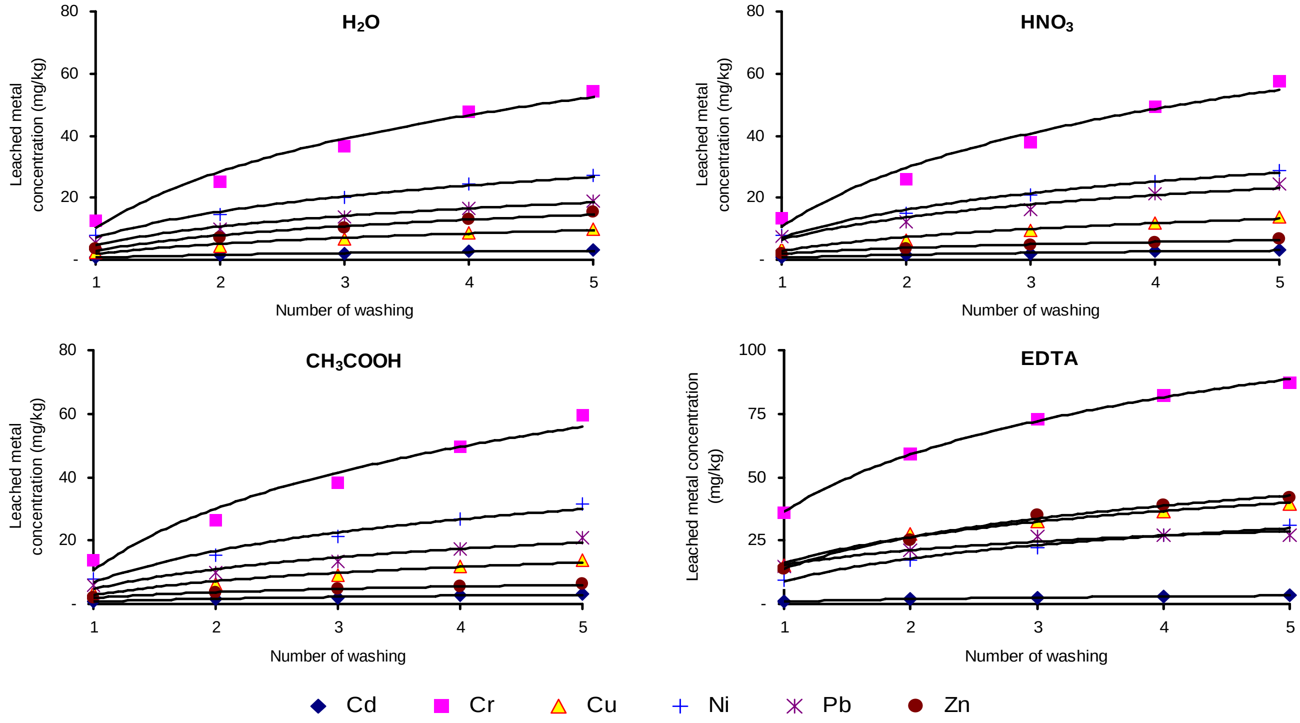

Fig. 3. Changes in the concentration of leached heavy metals by repeated washings with deionized water and the solutions of nitric acid, acetic acid and EDTA.

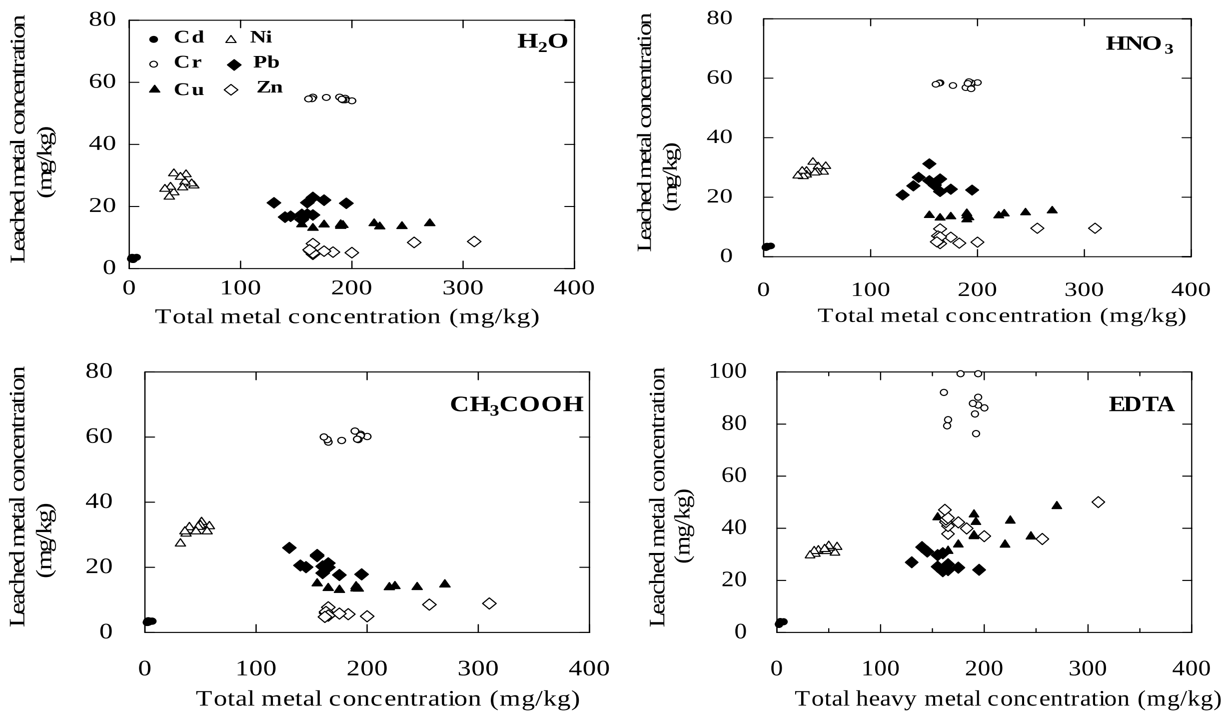

Fig. 4. Correlation between total heavy metal concentration in the soil samples and the concentration of heavy metals leached with deionized water and the solutions of acetic acid, nitric acid and EDTA.

The ratio of the leached metal concentration to the total metal concentration in Fig.4 could be a useful index for the leachability of heavy metals in the soil. The ratio was obtained for the plotted data of the respective heavy metals, and the average of the ratio was calculated. Figure 5 shows the average of the ratio for the respective heavy metals and leaching solutions. The ratio decreased in the order: Cd > Ni > Cr > Pb > Cu > Zn for the treatment with deionized water, nitric and acetic acid, and in the order: Cd > Ni > Cr > Zn > Cu > Pb for the EDTA treatment. The bar in the figure indicates the range of the ratio for all soil samples. The EDTA treatment gave higher leachability than other treatments for Cd, Cr, Cu and Zn. This can be explained by the fact that EDTA possesses high complexing capability, and extracts higher amount of metals in organically- and oxide-bound fractions compared to the deionized water and acid solutions (Fig.6). The ability of this chelant to bind metal ions in extremely stable complexes can be utilized not only for desorption of sorbed ions, but for the dissolution of insoluble metal compounds as well (Palma and Ferratelli, 2005).

Fractionated heavy metals and potential leachability

As described previously, the heavy metal leaching by repeated washings with deionized water, acid and EDTA solutions is capable of releasing metals retained through exchangeable, carbonate, oxide and organic phases. In order to examine the extent of heavy metal leaching from these phases, the concentrations of the metals leached with different solutions were compared with the sequentially fractionated heavy metal concentrations in Fig.2. The results are shown in Fig.6. The figure represents the average of heavy metal concentrations of all soil samples. For Cd, Cr, Ni and Pb, the deionized water and acid treatments gave similar leachability: Cd and Ni were released fully from the exchangeable, carbonate and oxide fractions, and partly from the organic fraction; Cr and Pb were fully from the exchangeable and carbonate fractions, and partly from the oxide fraction. Copper was released fully from the exchangeable and carbonate fractions, and Zn was fully from the exchangeable fraction by deionized water and acid treatments. The EDTA treatment gave similar results for Cd, Cr, Ni and Pb, but additional release from the organic fraction for Cu and from the carbonate and oxide fractions for Zn. Less leachability for Pb and Cu is consistent with the findings that Pb and Cu are strongly retained by iron-oxides and organic matter (Brummer, 1986; Livens, 1991).

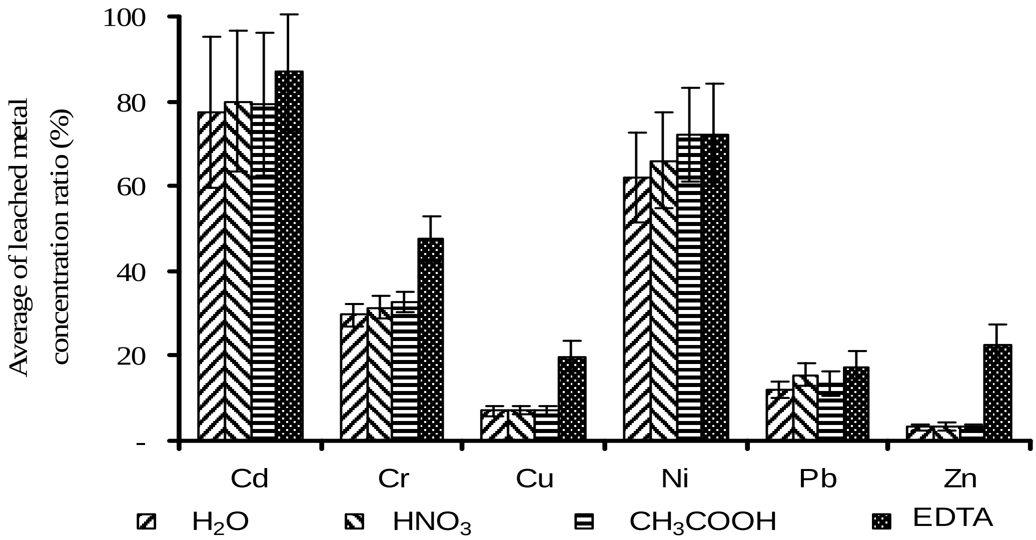

Fig. 5. Ratio of leached metal concentration to total metal concentration in the soil samples

These results suggest that the heavy metals retained through the phases other than water-soluble fraction can be released when paddy soil is exposed continuously to irrigation water, enhancing the bioavailablity of heavy metals to plants. Bioavailability for soils is defined as the fraction of the total amount of a heavy metal in a soil that can cause an effect, positive or negative, on an organism (Pierzynski et al., 2005). At equal concentrations some heavy metals are more likely to cause an effect than others, and for a given heavy metal the likelihood of an effect will vary depending on the soil containing the heavy metals. The bioavailability of heavy metals retained through various phases generally decreases in the order: water soluble > exchangeable > carbonate > oxides > organic > residual, and the heavy metals in the water soluble, exchangeable and carbonate fractions exhibit high mobility and bioavailability to plant uptake (Kashem and Sing, 2001).

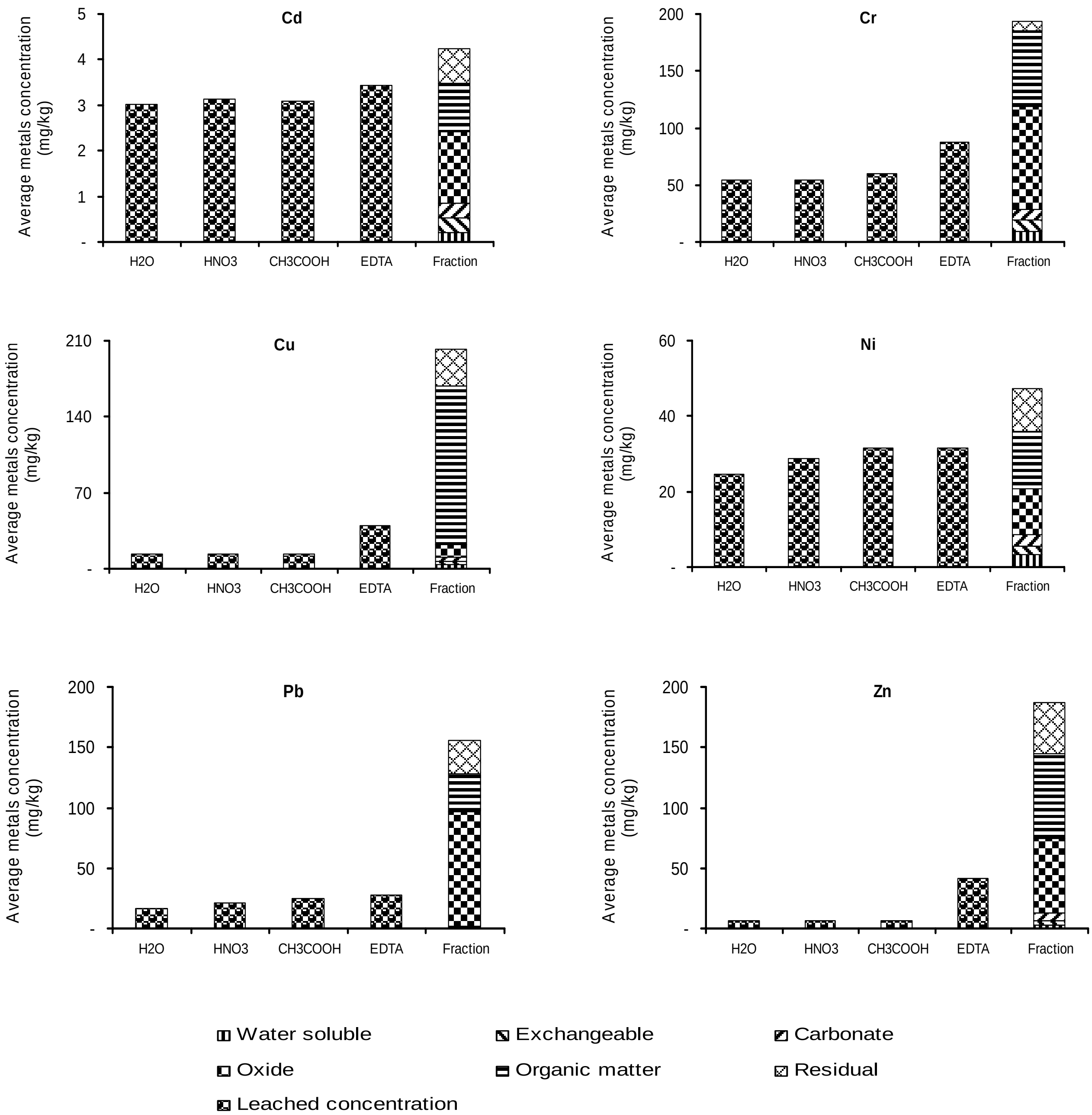

Fig. 6. Comparison between the concentrations of metals leached with different solutions and sequentially fractionated metal concentration.

CONCLUSIONS

The concentrations of Cd, Cu and Pb in the soil exceeded the permissible level of Vietnamese standard for agricultural soil. In SSE analysis, dominant fractions were oxide, organic and residual materials for Cd, Ni, Pb and Zn, organic and residual materials for Cr, and organic material for Cu. The proportion of water-soluble, exchangeable and carbonate fractions was much smaller than other fractions for all metal types.

The ratio of the leached heavy metal concentration to the total metal concentration decreased in the order: Cd > Ni > Cr > Pb > Cu > Zn for the treatment with deionized water, nitric and acetic acid, and in the order: Cd > Ni > Cr > Zn > Cu > Pb for the EDTA treatment. The EDTA treatment gave higher leachability than other treatments for most metal types. By the leaching tests with deionized water, and the solutions of nitric acid, acetic acid, and EDTA, heavy metals were released fully or partially from the exchangeable, carbonate, oxide and organic fractions in the soil samples.

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Outbreaks of Insect Pests in the Tropics: A Case Study of the Coconut Beetle

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Brontispa longissima; invasive pest; outbreak; palm; tropics

Introduction

The coconut hispine beetle, *Brontispa longissima* Gestro (Coleoptera: Chrysomelidae) is a serious pest of coconut and other palms. The larvae and adults of *B. longissima* were found in folded leaflets of palms and they feed on the leaf tissues (Fenner, 2003). Infestation of this beetle turns the leaves brown and decreases the fruit production. Sustained heavy attack may cause tree death (Kalshoven, 1981; Fennner, 2003). This beetle is believed to be native to Papua New Guinea and Indonesia (Rethinam and Singh, 2007), but it has been invading into other countries (Stapley, 1973; Chiu et al., 1985; Voegele, 1989; Fenner, 2003). In late 1990's, this beetle found in Mekong Delta in Vietnam and Maldives, and they have spread to Southeast Asian countries and outbreaks were reported from there (FAO, 2004). So far, many studies have focused on the control of this beetle. However, mechanisms of which this beetle outbreaks have been rather neglected. In this paper, we review life history and behavior of this beetle in the Tropics. Then, we discuss relationship between this beetle and host plants, and effects of weather conditions on populations of this beetle.

Life history and Behavior of *B. longissima*

Female beetles deposit brown flat eggs on the surface of the host palms. It is usually observed that 1-4 eggs are laid in a cluster (Zhou, 2004). The eggs are normally attached on the leaves with the secretion. Life time fecundity per female was ca. 120 eggs (Kalshoven, 1981; Zhou, 2004). Based on the life history data of Wiriya (2007), the intrinsic rate of natural increase, r was 0.021 at 27°C (Birch, 1948). Zhong et al. (2004) showed that lower development threshold is 11.08°C and thermal constant 966.2 degree days. Mean longevity of adult beetle is 165 days (Zhou et al. 2004). All life stages of *B. longissima* occur within folded leaflets before they have opened. When the leaflet opens, the beetle leaves it and seeks another younger leaflet (Brown and Green, 1958; Fenner, 2003). This leaf beetle species appear to be well protected by the host plants through its lifetime (Brown and Green, 1958). Although this species mainly attacks coconut palm, infestation on ca. 50 species of other palms are reported (Fenner, 2003; Wu et al., 2006).

Outbreak mechanisms of *B.longissima*

It is known that outbreaks of invasive pests may occur when their natural enemies are rare or absent in invaded area (Dharmadhikari et al., 1977). It has been reported that *B.*

longissima was controlled by introduced natural enemies from the native area. Tahiti had suffered severe depredations of this beetle in 1960 and the pupal parasitoid of this beetle, *Tetrastichus brontispae* Fer., was introduced from the Caroline Islands in 1964. As a result of that, the parasitoid brought the beetle under control (Stapley, 1973). In Western Samoa, the beetle was accidentally introduced in 1980 and outbreak occurred. Then, several beneficial insect species including two parasitoids such as *T. brontispae* and the larval parasitoid *Asecodes* sp. were released and they kept the beetle well under control (Voegele, 1989). In Taiwan, the beetle was first detected in 1975. *Tetrastichus brontispae* was introduced in 1983 and it was believed to be an effective biological control agent of the beetle (Chiu et al., 1985). These facts suggest that the outbreaks of this species in invaded area are mainly attributed to the absence of natural enemies. However, outbreaks of this species were reported not only from the area where they were accidentally introduced but also from the native area (Kalshoven, 1981). Thus, we discuss factors of the outbreaks other than the absence of natural enemies in the following sections.

MacArthur and Wilson (1967) used the terms *r*- and *K*-selection to explain the evolutionary processes in particular environments. According to their explanation, *r*-selection occurs in uncertain and variable environments and *K*-selection under more stable environmental conditions (Stenseth, 1987). Several authors compared life cycle traits between *r*-strategists, species under *r*-selection and *K*-strategiests, speices under *K*-selection. *r*-strategists generally have a shorter generation time and higher fecundity which lead to higher *r*, higher host specificity and lower investment in defense. Outbreak species often have those traits of *r*-strategists (Pianka, 1970; Southwood, 1977; Wallner, 1987). For example, Hunter (1991) compared life cycle traits of outbreaking and nonoutbreaking species of Macrolepidoptera feeding on northern hardwood trees. He showed that diet breadth and fecundity of outbreaking species are greater, and outbreaking species also appear to be better defended against predators.

Outbreaks of some agricultural pests, such as the twospotted spider mite, *Tetranychus urticae* Koch, the cotton aphid, *Aphis gossypii* Glover or the diamondback moth, *Plutella xylostella* have been documented frequently (Talekar and Shelton, 1993; Deguine et al., 2000; Cullen, 2006). *r* value is 0.29 at 25°C for *T. urticae* (Kondo and Takahuji, 1985), 0.42 at 25°C for *A. gossypii* (Murai and Tsumuki, 1996) and 0.23 at 26°C for *P. xylostella* (Sarnthoy et al., 1989). Such high *r* values may support the idea that *r*-strategists tend to outbreak. Nakano et al. (1997) compared *r* values between the serious pest species, Sumatran phytophagous lady beetles, *Epilachna vigintioctopunctata*, *E. septima*, and *E. dodecastigma*, and less abundant species, *E. enneasticta*. They found that the serious pest species have higher *r* values than the less abundant species. In contrast, life history strategy of forest pest seems more complex: *r* values of some forest outbreaking pests are high as agricultural pests, but some species are not. For example, *r* value ranges from 0.264 for the leucaena psyllid, *Heteropsylla cubana* (Rauf et al., 1990) to 0.078 at 25°C for the spruce bark beetle, *Ips typographus* (Wermelinger and Seifert, 1999). Compared to those *r* values of forest pests, 0.021 at 27°C for *B. longissima* (calculated from Wiriya, 2007) is rather small. Outbreaks of these forest pests with small values of *r* may be explained by some factors other than high reproductive potential. For example, outbreaks of *Ips typographus* in southern

Norway during the period 1971-1981were caused partly by an extensive windblow and partly by drought (Bakke, 1989). Frequent outbreaks of *B. longissima* should be explained by extrinsic factors.

Relationship between *B.longissima* and host plants

As described above, tightly folded palm leaflets seem to protect *B. longissima*. Besides, they provide lifetime food resources to the beetle. This beetle completes its life cycle on a tree so that immature mortality would be low: The larvae normally stay in the same folded leaflets until pupation. When a frond opens, the larvae in leaflets of the opening frond may move to the new uplight frond in the same tree.

Leaf abscission possibly caused by weather stress or feeding damage is known as one of the causes of mortality in herbivores. Especially, sedentary insects should experience greater mortality as a result of leaf abscission than should species that can readily move to other leaves (Faeth, 1987). Although dispersal ability of larvae of *B. longissima* seems low, the mortality related to leaf abscission of host plants can be neglected in this beetle. Leaf abscission of a coconut frond has seldom been observed and a new frond normally develops monthly.

A new frond of coconut palm may hide the beetle from people since it locates the crown of tall palm tree. Coconut palms can grow to be up to 30 meters and it is hard to detect the beetles from such heights. Also, symptoms of them occurred within the folded leaflets are difficult to detect. People normally recognize the infestation of this beetle after the number of the beetles becomes quite large and damaged leaflets open to show conspicuous symptoms. In other words, it is not until at outbreak level that people normally recognize this beetle. This beetle should require longer period to obtain the outbreak level than other species of high *r* values. Such concealments may provide the beetle enough time to increase their population size.

Effects of weather conditions

In the area *B. longissima* outbroke, it was suspected that dry periods favor the development of this beetle because no outbreak occurred in the regions with high rainfall (Kalshoven, 1981). In Darwin and nearby areas, heavy damage is usually most noticeable in the end of the dry season (Fenner, 2003). Similar effect of dry weather on insect population was observed in another hispine beetle, *Promecotheca reichei* Baly in Fiji. Outbreaks of this indigenous pest of coconut occurred frequently and extensively in the area of small rainfall, while outbreaks were very rare and seldom extensive in the area of great rainfall (Taylor, 1937). Although the mechanism of which humidity or rainfall affects the development of this beetle has not elucidated yet, the climatic conditions appear to be factors of outbreaks of these beetles. Also, difference of suitable or optimal humidity range between the beetle and natural enemies may explain frequent occurrences of these beetle outbreaks within rather dry season or area.

Other weather conditions frequently observed in the Tropics such as extreme temperature or strong wind may decrease the population size of not pests but of their natural enemies and cause outbreaks of pests (Dharmadhikari et al., 1977; Godfray and Chan, 1990). Thus, it is suspected that introduced natural enemy cannot control the pests in the area of unfavorable weather condition.

So far, *B. longissima* was controlled by introduced natural enemies in some area such as Tahiti (Stapley, 1973), Western Samoa (Voegele, 1989) or Taiwan (Chiu et al., 1985). However, it was also reported that the population of the beetle was not suppressed by introduced natural enemies in some parts of Southeast Asia, and it is speculated that some climatic conditions may affect the survival of the natural enemies. Besides, even in the area where this beetle is well under control, there is possibility that some climatic conditions lead to reiterant outbreaks. Further study is required to elucidate the effect of climatic condition on the population dynamics of this beetle.

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Hybrid Rice Production in the Red River Delta, Vietnam

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1. Introduction

The Red River Delta (RRD) is one of the two biggest rice basins in Vietnam. Annual volume of paddy output is recorded at about 6.5-7 metric tons- sources of food for more its population (more than 20 millions) and for export. Agricultural land in the RRD accounts for about 8% of total agricultural land of the country, and has declined due to the industrialization and modernization with rate of about 3% annually during the period 1990-2006. Meanwhile, population grew at rate of 1.5% annually. The characteristics of a transforming economy, global climate changes which caused adverse weather, have made it more difficult and risky for agricultural production as well as rice production, i.e. crop failures. Hence, food security is set as one of the top goals for the sustainable socio-economic development in the country.

Being faced with food security pressure, farmers in the RRD have been concerned with high yield rice varieties. Hybrid rice was first grown in 1990, and hybrid rice area of the RRD accounts for about 40-50% total hybrid rice area of the country, and about 20% of total rice area in the region. Some provinces where hybrid rice area accounts for around 60% of total rice area are Nam Dinh, Ninh Binh. In Nam Dinh, paddy yield (hybrid) is as high as 7.3 tons/ha. In reality, hybrid rice production in the RRD has benefited farmers and consumers. However, there have existed controversial debates on hybrid rice development related to economic and technical aspects. Hence, it is necessary to have objective and scientific views on hybrid rice production, especially economic benefits, in order to propose sound measures for hybrid rice production development in a sustainable way and achieve potentials in rice production of the RRD.

2. Objectives and methodology

Objectives

- Evaluate the need of hybrid rice production and assess economic benefit of hybrid rice at farm level in the RRD
- Propose sound recommendations to develop hybrid rice in the RRD and to achieve higher economic benefit in hybrid rice production.

Methodology

Descriptive statistics is used with key indicators showing economic benefits of hybrid rice production, such as paddy yield, gross output (GO), Intermediate cost (IC), Mixed Income (MI), Profit (Pr). Economic analysis is used to evaluate the current level of rice production (in terms of economics), factors affecting hybrid rice production. Other methodologies used are group discussion and PRA.

3. Results and discussion

Overview of hybrid rice production in the RRD

The RRD covers 10 provinces and cites where hybrid rice is grown, but at different rate of adoption (Table 1).

Table 1. Hybrid rice area in provinces in the RRD

Province/city	Period 2003- 2005		Period 2005 - 2007	
	Area (Ha)	Hybrid rice adoption rate (%)	Area (Ha)	Hybrid rice adoption rate (%)
The RRD	222,870	19.00	250,200	20.50
Hanoi & Ha Tay	9,950	4.70	15,200	8.00
Vinh Phuc	6,420	8.50	6,500	8.90
Bac Ninh	4,900	5.80	4,500	5.50
Hai Duong	3,700	2.50	1,800	1.30
Hai Phong	15,900	17.00	16,000	17.60
Hung Yen	3,000	3.20	1,200	1.40
Thai Binh	26,000	15.00	31,000	18.50
Ha Nam	25,000	33.00	28,000	37.00
Nam Dinh	94,000	58.00	95,000	59.00
Ninh Binh	34,000	41.00	51,000	62.00

Sources: Center for testing of seeds, and author's computation

Ninh Binh and Nam Dinh register highest adoption rate of hybrid rice, which are 62% and 59%, respectively. Farmers in these provinces applied hybrid rice early in 90s and have attained quite high level of rice farming techniques, not only in producing paddy grain but also F1 seed. Meanwhile, in Hai Duong and Hung Yen provinces, inbred rice dominated with more than 96% area, and hybrid rice is not widely applied due to poor seed sources (unstable supply from China). Overall, hybrid rice area has increased regionally but adoption rate is around 20%, hence, potentials for hybrid rice production is still prevalent.

Rice production, however, is organized at farm households individually, who each have averagely about only 0.32 ha for rice production. Hence, sustainable hybrid rice production development should be concerned with area enlargement and economic benefit improvement.

Economic analysis of hybrid rice production at farm level

A farm household survey was conducted in Nam Dinh, Thai Binh, and Hai Phong, focusing on both Spring and Summer rice seasons. Results are presented in table 2.

Table 2. Economic benefit of inbred and hybrid rice (applied for a hectare, 2007)

Indicators	Unit	Spring			Summer		
		Hybrid (A)	Inbred (B)	A/B(%)	Hybrid (C)	Inbred (C)	C/D(%)
1.Yield	Ton/ha	7.04	6.43	109.5	6.2	5.4	114.8
2 GO	Mil. VND	14.20	12.85	110.5	14.00	11.42	122.6
3.IC	Mil. VND	4.90	4.30	113.9	4.70	4.20	111.9
4. MI	Mil. VND	9.25	8.50	108.8	9.20	7.20	127.7
5. Pr	Mil. VND	3.70	2.70	137.0	4.00	1.80	222.2
6. GO/IC	‘000 VND	2.89	2.98	96.9	2.97	2.71	109.6
7. MI/IC	‘000 VND	1.88	1.97	95.4	1.95	1.71	114.0
8. Pr/IC	‘000 VND	0.75	0.62	120.9	0.85	0.42	202.4
9. MI/ working day	‘000 VND	45.00	38.80	115.9	47.00	35.00	134.3

Sources: Calculated on the basis of farm household survey data

Table 2 shows that all economic benefit indicators of hybrid rice are advantageous over those of inbred rice in both seasons. A working day engaged in hybrid rice could be paid with 47,000 VND and 45,000 VND in summer and spring seasons, respectively, meanwhile these figures are 35,000 VND and 38,800 VND (Table 2).

4. Recommendations for hybrid rice development in the RRD

Analysis shows that there is great potentials for hybrid rice production in the RRD in terms of area enlargement and economic benefit improvement, as compared with inbred rice. In order to promote hybrid rice production in a sustainable manner in the RRD, following recommendations are proposed:

- Government investment on research and breeding of domestic hybrid rice should be strengthened in order to meet requirement of seed demand in both seasons (Spring and Summer). Up to now, Vietnam has imported about 70% of total seed for production annually and spent about 20 million USD. Therefore, domestic rice production is heavily dependent of imported seed sources in terms of quantity, quality and price. Imported seed price was sometimes double domestic seed price which discourages farmers to apply hybrid varieties. Ministry of Agriculture and Rural Development set target to meet about 70% seed demand by domestically produced seed by 2010. Research institutes such as Rice Research Institutes, Universities and researchers have created successfully hybrid varieties such as VL20, VL24, TH3-3, TH3-5 (Hanoi University of Agriculture), which are advantageous over imported varieties, such as short growing time, good grain quality, as well as less susceptibility to bacterial leaf blight diseases in Summer season. The key issue is domestic seed supply, hence, it is crucial to organize seed production systems, breeding and transfer of new varieties in wide scale production under support of Government.
- Enhance agricultural extension programs focusing on hybrid rice to improve farmer’s practices in production. Also, rice area planning must be designed soundly and favorably for farmers to apply advanced technologies in hybrid rice production.
- Encourage seed companies to involved actively in hybrid rice production program; regulate seed companies such that they are responsible for seed quality

provided for farmers, such that farmers-seed customers- are not worried to invest on hybrid rice.

- Continue implementation the policy of irrigation fee abolition, develop market of agricultural inputs, especially chemical fertilizers and crop protection chemicals.

5. Conclusions

The RRD has much potential to develop hybrid rice production in both area and application of technologies in intensive farming. However, hybrid rice production depends on farmer's decision. At present, to increase economic benefit and develop hybrid rice production, immediate measures should be taken are to (i) enhance capacity of domestic seed production by promoting research and development of hybrid rice varieties and by organizing production and quality management system of seed, to ensure good quality of seed with favorable price and timely distribution for farmers, and (ii) strengthen agricultural extension activities to improve farmer's knowledge and skills in hybrid rice production.

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Abstract

This study devotes to find out and measure the production efficiency and its determinants of rice production in the selected areas, the Mekong River Delta, Vietnam. The study used stratified sampling method for data collection. For the cross-sectional data obtained for the year 2004-2005, Cobb-Douglas production function was found to be adequate representation of data.

The empirical results indicated that there was an inversed proportion of rice productivity when amount of seed was overused; currently, farmers do not apply lining sow method; they usually sow by hand with high density that is favorable for leaf-eating pest appearance. Coefficient of pure N fertilizer was significant in Summer-Autumn crop that indicated amount of N fertilizer used efficiently; coefficient of pure P fertilizer was not significant in both crops. Agrochemical cost included herbicide, pesticide and others; the change of pesticide influenced Winter-Spring rice productivity at significant level 5%, but not affect Summer-Autumn rice productivity; herbicide and treatment chemical cost were not significant in all crops. The farmers did not apply correct amount of agrochemical affecting productivity decreased. Therefore, to take efficient precaution of pests, the households have to carry out ''4 corrections'' principle (correction of chemical use, correction of time, correction of dosage, concentration, correction of methods).

Key Words: Efficiency, Agricultural production, Determinants

1. INTRODUCTION

1.1 Rationale of the Study

Agricultural production plays an important role to the gross domestic product with 20% of GDP in average. In 2004 gross domestic products in the Mekong River Delta (MRD) was 81,349 billion VND, increased 11.15% compared to 2003. Rice production is the highest contributors in agricultural production in the MRD.

Due to its importance, rice has been expanded widely when people's standard of living has been improved. However, rice producers have to face risks in their production mainly due to the price market fluctuation. Moreover, epidemic diseases also cause much damage to the producers. The market price of rice output usually varies because of instable supply. Agents who involve in the distribution channels of rice products might be private middlemen, agents or state-owned firms. The competitions among these agents are sometimes very severe.

In fact, the producers in this sector in the MRD have also faced similar difficulties and constraints in recent years. Therefore, to understand in detail the current situation of rice production of farmers in the MRD, this research is performed to assess the rice production situation.

This study devotes to find out and measure the production efficiency and its determinants of rice production in the selected areas, the MRD, Vietnam. The results of this research are the basic data to the following researches of rice, and this is also an important case study relating to the agricultural economic development in the MRD.

1.2 Objectives of the Study

1.2.1 General Objective of the Study

To analyze the production efficiency and its determinants of rice production in the selected areas, the MRD, Vietnam; and, provide policy recommendations for increasing its production efficiency.

1.2.2 Specific Objectives of the Study

- To analyze the efficiency of rice production in the MRD in recent years;
- To provide solutions and recommendations for increasing complete efficiencies of rice production in the MRD.

1.3 Research Questions

The research aims to analyze the current situation and efficiencies of rice in the MRD. This research is helpful for policy recommendations to develop rice production. The research should find the answers for the following questions:

(1) What are the current situations and efficiencies of rice production in the MRD?

(2) What are solutions to increase efficiencies of rice production in the MRD?

2. METHODOLOGY

2.1 Data Collection

- Primary data: Direct household interviews were carried out to get the data of the production costs, the advantages and disadvantages of rice production and consumptions in the MRD.

Generally, because of the similar of natural and rice production conditions of provinces, the ways to get the data are homogeneous, and the analysis is not detailed for each province, but it is considered in general for the whole region.

- Secondary data: It was collected from the agricultural offices and departments, the authorities of different levels, the agricultural extension service staff, heads of the agricultural clubs and effective farmers in the MRD.

The interview contents include: (1) The general information of the household and production characteristics; (2) Costs of rice production inputs; and (3) Other information: knowledge, rice cultivation practices, investment demands and farmers' opinions about credits, the markets of the input and output factors of rice products, etc.

2.2. Research Methods

The following research methods were used in the study:

2.2.1 Descriptive Statistics

Descriptive statistics was used to describe the current situation of rice production and consumption. The research used these statistic tools to process and analyze data:

- Confidence interval estimation and testing to estimate research criteria (mean, proportion, etc.).
- Hypothesis testing to test the reliability of the confidence and the dimension of collected data.

- Multiple regression and correlation to analyze the impacts of socio-economic factors.
- Criteria ranking to identify the main and direct factors influence the results of rice production and consumption.

2.2.2. Cobb-Douglas Production Function

This research will use the Cobb-Douglas production function to analyze and identify input factors that influence the productivity, output and the efficiency of rice. Cobb-Douglas production function is carried out by analyzing the primary data on the software LIMDEP.

The Cobb-Douglas production function of rice is illustrated as the following:

$$\ln Y = \alpha_0 + \alpha_1 \ln x_1 + \alpha_2 \ln x_2 + \alpha_3 \ln x_3 + ... + \alpha_{10} \ln x_{10} + \text{N-year}$$

Where:

Y: Household paddy yield in each crop

i: Correlation coefficient i of the independent variable Xi (i = 1, 2, ..., 10)

X_1: The amount of seedling per ha (kg/ha)

X_2: The amount of the used pure N (kg/ha)

X_3: The amount of the used pure P (kg/ha)

X_4: The amount of the used pure K (kg/ha)

X_5: Cost of herbicide (VND/ha)

X_6: Cost of insecticide (VND/ha)

X_7: Cost of pesticide, fungicide (VND/ha)

X_8: Cost of hired labor (VND/ha)

X_9: Cost of home labor (VND/ha)

X_{10}: Cost of irrigation per ha (VND/ha)

N-year: Dummy variable of income

3. BACKGROUND OF THE STUDY AREA

3.1 The Natural Conditions

The MRD is the main area of the food grain production and the biggest granary of Vietnam with approximate four million ha of the natural areas. There are 13 provinces and cities in which 3 cities are under control of province and 1 city is under control of government, 13 towns are under control of the provinces, 92 suburban districts, 3 urban districts, 115 wards, 102 towns and 1,199 communes.

The MRD locates in the tropical zone. It characterizes by a strong monsoon influence (the South West monsoon is in rainy season and the North East monsoon is in the dry season). The rainy season starts from May to November and the dry season starts from December to the next April. The average temperature is 27.7^0C; the average humidity is 85%.

In short, with the natural conditions in the MRD is suitable to develop the tropical crop plants and animals, especially rice cultivation, fruit gardens and different types of cattle and poultry. Thus, the agricultural products in the MRD are plentiful and diversified.

3.2 The Socio-economic Characteristics

The MRD is a suitable zone to grow food grain crops, garden fruits and aquaculture with high export outputs. The average economic growth rate (1996-2003) was approximately 8.4% (lowest in 1997 with 6.1% and highest in 2003 with 10.6%). The industrial output in 2003 at fixed price of 1994 was 38,347,091 billion VND, 19.63% increase compared to 2002. The agricultural output in 2003 at the fixed price of 1994 in the MRD reached 49,859,638 billion VND, 4.8% increase compared to 2002.

The average population of the MRD was 16,964,814 people in 2003 and 10,251,437 people in working age. 80% of the population is working in the agricultural sector. The average area per capita was 2,372m^2/person and 3,877 m^2/labor.

At the end of the 2003 in the MRD there were 4,806 secondary and high schools (increased 4.25% compared to 2002) with 101,780 classes (increased 1.27% compared to 2002). The numbers of the teachers of the secondary and high schools were 3,338,328 (decreased 0.5% compared to 2002). There were 5,590 doctors (in 2002) and 24,957 hospital beds (increased 3.54% compared to 2001) for the whole area of the MRD.

4. RESULTS AND DISCUSSIONS

4.1 The General Information of Production

The MRD was the main area of the agricultural production with high ratio (approximate 38% compared to production value). However, the agricultural value has a downward trend because of the economy restructure - decreasing agricultural contribution in GDP, and increasing the contribution of industrial and service in GDP. Thanks to the natural conditions, agricultural productions are still the strength of the MRD, especially rice, garden fruits and husbandry productions. The main crop plants are food grains, garden fruits and different types of vegetables. Among these, rice production is dominant. The main rice crops are Winter-Spring crop, Summer-Autumn crop and Winter crop. There are combined farming system such as rice-shrimp, rice-fish and 2 rice crops and 1 crop of vegetables.

The main plant of the MRD is food grain plant, especially rice with very high proportion in the cultivation as well as the annual output. The rice equivalent output accounts for 47.43% of the whole output, but the rice output is higher with over 50% of the rice output of the whole country. Especially Winter-Spring rice crop contributes the highest output. However, the highest proportion of the rice cultivation is in Summer-Autumn rice crop with 66.23%.

4.2 Current Situation of Rice Production Households

4.2.1 Overview of Rice Production Households

The survey shows that most of the householders are quite old with average age of 45.1 years old. This denotes that these people have much experience in rice production. Especially, the average number of years that they have planted rice is 26.4 years. Generally, the education levels of rice production households are low. Especially, elementary level is 43.5%. This is the reason why households' capacities of approaching rice production science-technology are not high.

From the survey, the average area is 1.63 ha per household, minimum 0.1 ha per household and the maximum 32.4 ha per household. The average area of studied households are 0.73 ha higher than the cultivation area of the households in MRD. Rice production depends on farming seasons which are Winter-Spring and Summer-Autumn crop. The average productivity is 7.446 tons per ha in the former and 4.774 tons per ha in the latter. Moreover, some farms cultivate the third crop but its productivity is not high, about 3 tons per ha. Hence, majority of households often cultivate vegetable instead of rice in the third crop for increasing their income.

4.2.2 Analysis of Rice Production Efficiency of Serveyed Households

From table 2, in the MRD, total cost per ha of Winter-Spring crop is 119,993 VND lower than that of Summer-Autumn crop. However, production cost structure is not much different between two crops.

Table 2. Average cost items per ha of rice

Items	Winter-spring			Summer-autumn		
	Volume	Cost (VND)	Ratio (%)	Volume	Cost (VND)	Ratio (%)
I. Material cost		***2,531,630***	***56.0***		***2,206,251***	***56.2***
- Seed (kg)	221.39	363,906	8.1	244.08	347,198	7.5
- Fertilizer (kg)		1,175,668	26.0		1,137,031	24.5
- Agrochemical		565,099	12.5		564,018	12.2
- Irrigation		97,595	2.2		146,345	3.2
- Hired machine		329,362	7.3		411,659	8.9
II.Labour cost (days)	61.57	***1,986,533***	***44.0***	62.20	***2,031,905***	***43.8***
- Family labour	40.19	1,205,700	26.7	40.98	1,229,400	26.5
- Hired labour	21.38	780,833	17.3	21.22	802,505	17.3
Total cost		**4,518,163**	**100.00**		**4,638,156**	**100.00**

Source: surveyed data, 2004-2005

Lucrative possibility per ha of a crop: with the average rice price is about 30,000VND/bushel. After paying tax and agricultural fees, the income per ha of household is 4,451,840 VND as the following

- Average productivity: 6,110 kg per ha.
- Average rice price: 1,500/kg/ bushel (20kg)
- Average sales: 9,165,000 VND/ha
- Production cost: 4,578,160 VND/ha
- Agricultural tax and fees: 135,000 VND/ha

Net income: 4,451,840 VND/ha.

4.2.2.1 Winter-Spring crop

Households consider Winter-Spring as the main crop of a year, so they often pay much special attention to this crop.

Material cost

Preparing soil works: Because winter-spring is followed a full water season, the soil is soft with silt enriched, but farmers usually have to plough and lift soil to ensure that germ and wild grass are exterminated. Hence, preparing soil cost is not different between households and between studied areas. Therefore, this cost is considered in inter-relational analysis.

Seeding and seeding cost: After being soaked, mixed and kept with growing chemical, the seed is mixed with anti-insect chemical, and then sowed. Although households are advised to use lining sow method, they haven't applied this method because of spending much time and using little seed that make them not to believe. Hence, amount of seed used here is quite a lot, 221.39 kg/ha. Almost households use seed that produced from previous crop, just very few of them use new seed. With sowing density is high, seed cost approximates 10.99% of total cost.

Fertilizer cost: Farmers put down fertilizer three times a crop: 7-10 days after sowing, 25-30 days after sowing and pre-earring dressing. Urea, NPK 20-20-15, NPK 16-16-8, DAP are popular kinds of fertilizer used. Generally, amount of urea used is much more than other kinds of fertilizer (about 12.21%). Phosphate is used very little. There are only some households using phosphate fertilizer as basic, 15-20 kg/ha, and approximating a small proportion of total invesmental cost.

Agrochemical cost: In general, Winter-Spring crop disease situation is quite less, so farmers only use insecticide when they see appearance of pest in their field. They often use pesticides to take precaution against diseases, so fungicide, insecticide cost are much more than other kinds of chemical substance.

Irrigation cost: There is not any surveyed household participating co-operatives, but they always pay attention to irrigation works, co-operating in irrigation at the same time. Hence, there is not any case that field of the household affected by the other. Moreover, this crop has advantage of high water season and low-lying land that is easy to get water from rivers or canals. Therefore, they are not necessary to pump water. For example, the average Winter-Spring irrigation cost in Thot Not district accounts 2.95% of total cost.

Labor cost. There is not big difference in working days between sites. Hired labor mainly is invested in ploughing, lifting and harvesting because farmers have to hire machines, and need more labors. Other task takes advantages of available family labors.

4.3.2.2 Summer-Autumn

Material cost

Seed cost: Steps of seed process are the same as Winter-Spring crop. In this crop amount of seed used is much more than, but rice price is lower, so seed cost is lower than Winter-Spring crop.

Fertilizer cost: Although Winter-Spring crop farmers is consider less important, farmers invest a lot more fertilizer in this crop. Because of less favorable weather and land, some households use amount of fertilizer 4 times more than in Winter-Spring crop to make verdant luxuriant. Generally, households have tendency to use mixed fertilizer such as NPK 20-20-15 or 16-16-8 rather than the others.

Agrochemical cost. In Summer-Autumn crop, wild grass grow rapidly, so farmers have to spend much more on herbicides cost than Winter-Spring crop.

Irrigation cost. In Summer-Autumn crop, because of low water and hot climate, fields need much water. Hence, irrigation cost takes a larger proportion than Winter-Spring crop.

Hired machine cost. This cost, which spend mainly for ploughing, lifting and harvesting takes a large proportion of total cost. There is not difference in hired machine costs and the way of cultivation between areas, so hired machine costs are mostly the same in areas.

Labor cost. Number of working days used is more than Winter-Spring crop because of much wild grass and pest, so it takes a lot of labor in Summer-Autumn crop.

4.2.3 Analysis of Impacts of Technology Efficiency

4.2.3.1 Analysis of Cobb-Douglas function

Table 4. Cobb-Douglas function result

Independent variables	Winter-Spring crop	Summer-Autumn crop
Intercept	6.3328***	1.4384***
N	0.1868***	0.2413***
P	0.0415ns	0.0445ns
K	-0.0093ns	0.0841***
Pesticide	-0.0204**	0.0095ns
Disease chemical	-0.0048ns	0.0022ns
Herbicide	-0.0047ns	0.0052ns
Irrigation cost	0.0057ns	0.0070ns
Available labor	0.0709**	0.0588***
Rent labor	0.2515***	0.1128ns
Amount of seed	-0.1320***	-0.5433***
R square (R^2)	0.5757***	0.9352***
Sig.F	0.0001	0.0001

Notes:

**** Significant at 1%* ** Significant at 10%*

*** Significant at 5%* *ns: insignificant*

R-square of production function is 0.5757 in Winter-Spring crop and 0.9352 in Summer-Autumn crop. It indicates that there is 57.57% variation of Winter-Spring productivity, and 93.52% variation of Summer-Autumn productivity caused by inputs such as amount of rice seed, fertilizer (pure N, P, K), herbicide cost, ...

Sig.F value of Winter-Spring crop and Summer-Autumn crop are smaller than 5%. This indicates that input factors (independent variables) generally affect productivity variation (dependent variable) in both crops.

Amount of seed. Coefficient of seeding amount is significant at 1% in both crops. When amount of seed increases 1%, productivity of Winter-Spring crop decreases 0.1320%, and productivity of Summer-Autumn decreases 0.5433% (with unchangeability of other factors). It indicates that there will be an inversed proportion of rice productivity when amount of seed is overused. Currently, farmers have not applied lining sow method. Usually, they sow by hand, so sowing density is dense, and favorable for leaf-eating pest appearance. Hence, if there are not effective methods to prevent pests, rice productivity may go down.

Amount of fertilizer. Coefficient of pure N fertilizer is significant in both crops. If farmers raise 1% of N fertilizer amount, then rice productivity increases 0.1868% in Winter-Spring crop, and 0.2413% in Summer-Autumn crop as well (with unchangeability of other inputs). Coefficient of pure K fertilizer is significant in Summer-Autumn crop that indicates amount of K fertilizer used efficiently. Coefficient of pure P fertilizer is not significant in both crops.

Agro-chemistry cost. Agrochemical cost includes herbicide, pesticide and others.

The change of pesticide influences Winter-Spring rice productivity at significant level 5%, but it does not affect Summer-Autumn rice productivity. Pesticide is mainly used for precaution, so amount of pesticide used is similar between the households. If pesticide cost raises 1% in Winter-Spring, rice productivity will decreases 0.0234% when other input factors are constant.

Herbicide and treatment chemical cost are not significant in all crops. It indicates that they do not affect rice productivity because farmers use herbicide before sowing seed, and some of them occasionally use herbicide one time more. And, disease treatment chemical is used for prevention as well. Hence, herbicide cost is generally not different between areas, so it does not affect rice productivity.

According to afore analysis, farmers do not use correct amount of agrochemical that affect rice productivity decrease. Therefore, in order to take efficient precaution of pests, the households have to carry out “4 corrections’’ principle (correction of chemical use; correction of time; correction of dosage, concentration; and correction of methods).

Labor cost. While home labor is significant in both crops, hired labor is only significant in Winter-Spring crop. Thereby, Winter-Spring productivity increases 0.0708% and Summer-Autumn productivity increases 0.5881% when home labor increases 1%. Also, Winter-Spring productivity increases 0.2515% when hired labor increases 1%. It indicates that farmers should pay more attention to their field such as taking care of it, shooting up the bank, timely finding out decay, and having suitable treatment. Moreover, thank to regularly shooting up, pest will not have condition to develop.

Irrigation cost. Irrigation cost is not significant in both crops due to some reasons. There is not difference in natural conditions; the same water amount is pumped out or pumped in at the same time when necessary. Therefore, the productivity changes are not caused by irrigation costs. Perhaps, the number of surveyed questionnaires is not enough to conclude that irrigation cost affects rice productivity.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Cobb-Douglas model evaluation indicates that inputs such as amount of seed, fertilizer, agricultural chemistry, labor, and water costs affect to rice yield. In the crop of Winter-Spring, only the input of N fertilizer is significant in analyzing result. The input of N fertilizer correlates directly with rice yield that also indicates the effective of Winter-Spring crop. In the crop of Summer-Autumn, the input of N fertilizer is also significant and correlative with rice yield. In other words, N fertilizer is effectively used in the crop of Summer-Autumn.

In the crops of Summer-Autumn, costs of land excavation, seed, are significant to the analysis. Seed cost is directly proportional with net income, or it is possibly efficient in the crop of Summer-Autumn. Land excavation cost is inversely proportional with net income, or this cost is impossibly efficient to the income of farmers.

5.2 Recommendations

Seed of rice is still basic factor for increasing productivity, so we need to develop investment of seed sector. Rice of previous crop should not be used as the seed for new crops. Seed supply and test systems could be early built for studying and creating good seed that is suitable for every crop. A specializing area of rice cultivation should be schemed to take advantages of technology and production.

In Vietnam, the supply of pesticide and herbicide is a lot more than the demand. Varieties of pesticide and herbicide are good for farmers in choosing them. However, there are some problems about pesticide and herbicide such as counterfeit goods, under-qualified goods, under weighted packing that might affect users. Therefore, staff of agriculture extension services should reinforce trainings and offer farmers full information of insects, diseases, techniques and measures of preservation that help them use efficiently insecticide, pesticide and herbicide.

With a lot of kinds of chemical fertilizer selling widely in the market, the farmers are so confused of using fertilizer for their rice crops. Therefore, the farmers should be conducted the helpful technology of fertilizer use in order to help farmers to save costs, protect environment, and avoid in damaging their rice yield when they overuse too much fertilizer.

The prices of fertilizer and pesticide were very unstable. The high price of fertilizer and pesticide made the production costs increase. The government should have policies to control the prices of fertilizer that make farmer assured in their production.

Anti-pest rice seed varieties should have been paid more attention. The farmers need to understand all kinds of rice diseases and pests in every area, and the cycles of disease and pest development that can be efficiently preserved by integration measures.

Labor in rural is a lot, but the number of specialized staff is few. Therefore, they should be trained to improve their knowledge that can help them increase their production efficiency.

Irrigational work plays an important role of rice cultivation, so we need to build and maintain flood control dikes for watering and protecting rice crops.

With manual harvest, it makes costs quite high, so it decreases farmers' profit. The costs are mainly the labor hired in harvest works. Therefore, harvesters should be encouragingly used for decreasing costs and improving income of farmers.

Besides, to improve efficiency of rice production, agricultural extension service networks could be widely developed with varieties of reasonable sample: training on IPM; technology conduction at home; experiment on new rice seed; shows of new technologies, development of agricultural extension on TV, radio etc. that help farmers improve their cultivation technology.

We should find and have contract with strong and stable rice buyers, at least during the period of 5 to 10 years. This is the basis for direction of active production, modern investment, and efficiency improvement of processing factories. It may make farmers assured to invest in their fields actively. Moreover, If businessmen are dynamic in competition, farmers will get more profits. The government is able to have rice projects that suit the production practice. It also makes researchers assured to study applied technologies that supply qualified rice for buyers' demands.

Based on the analysis the recommendations are given for concerned people to think of pushing up the development of MRD with its potentials.

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Structural Changes in Economic Efficiency of Rice Farming and Farm Household Economy: A Case of Lac Dao Commune, Van Lam, Hung Yen Province, the Northern Vietnam

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Abstract

This paper discusses a typical model case in the Red River Delta, where the farming practice and farm household economy have dramatically changed under the rapid economic growth and industrialization. The agriculture of the Red River Delta has been well known as a highly labor intensive farming with plenty of population and small-scale operated farmland. With such a characteristic, therefore, it has been considered that the development of further diversified farming helps the farmers in improving their income and living standard.

However, the farmers' livelihood strategies in the Red River Delta are in fact remarkably diverse under the current economic growth and the place of agricultural sector at their livelihood strategies has also been unstable. To clearly understand such an actuality in rural economy and society, we take an example of Lac Dao commune.

Key Words: industrialization, livelihood strategy, farm household economy, rice farming, Red River Delta

Introduction

Since the transition of the economic system so-called *Doi Moi* in 1986, particularly after year 2000, Vietnamese economy has made a remarkable and rapid progress. For example, the GDP per capita in year 2005 reached by US 638 dollars, which was 5.4 times as high as that of year 1990. Industrialization – growth of manufacturing industry sector – in both urban and rural areas seems to be a dominant factor that has caused such a conspicuous economic progress.

Before year 2000, almost all previous studies on farm household economy of Red River Delta concluded on emphasis that further diversification and intensification of farming practice is necessary for farmers to improve their income and living-standard of future [1][2]. We also supposed that such a conclusion must be valid. But contrary to most of the researchers' prediction, it seems that the current situation has not become true so far.

Therefore, the purpose of this study is to discuss the livelihood strategies of farm households in the Red River Delta under industrialization and rapid economic growth, based on the case of Lac Dao commune. In addition, we attempt to examine how the farm organization in both technical and human aspects, the profitability of agriculture, and the over -all farm household economy have been changing.

For the purpose mentioned above, at first, we shortly explain the data and methods employed for this study in the following section. And next, we investigate the changes in socio-economic characteristics and farmers' livelihood strategies of the research site. Then, we discuss the present situation of farming activities, particularly rice farming practice in the research site.

Material and Methods

1) Data

The following primary and secondary data were collected and analyzed in this study.

The primary data consist in two different sets of data series collected at different times between 1995 and 2008. The survey in 1995 was conducted by Prof. Dr. Cho's research team. At this first survey, 100 farmers selected by stratified sampling responded to the interview. The second survey in 2008 was conducted to have interview with the same farm households at the survey in 1995. Due to time constraints at the survey, however, only 31 farm households were interviewed for the data collection and comparatively analyzed in this study. In the both field surveys, the data were collected by making use of same questionnaire blank.

The secondary data were collected by the released official statistics on socio-economy of Lac Dao commune. Some credible information from an interview of the vice-director of agricultural cooperatives of the commune was also made of use as another secondary data. The interview was conducted on 25 Sep., 2008.

2) Methods

In this study, descriptive statistics was primarily employed to analyze the data and to discuss the structural changes in rural economy over all and the farm household economy of the research site.

Result

1) Location

Lac Dao commune is located at the most northern part of Hung Yen province, sharing the provincial border with Bac Ninh province. The commune enjoys an easy access from Hanoi city and Hai Phong city, which are the big consumption markets of the country. A paved provincial road (Route 388) leading to National Highway No. 5 and a railway to the both big cities are passing in the commune (see Figure 1 and Figure 2). Only 40 minuets' trip by motorcycle takes the inhabitants to Hanoi capital.

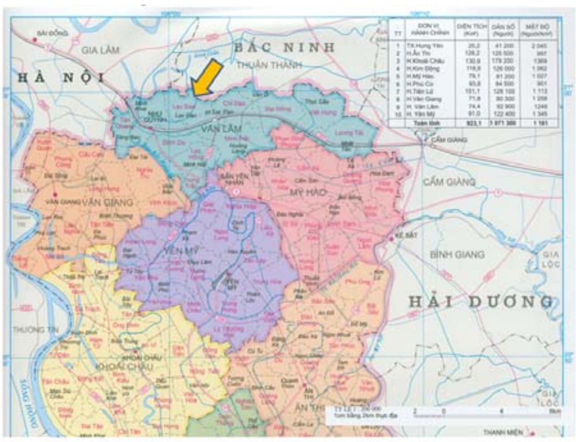

Figure 1 Location of Lac Dao commune

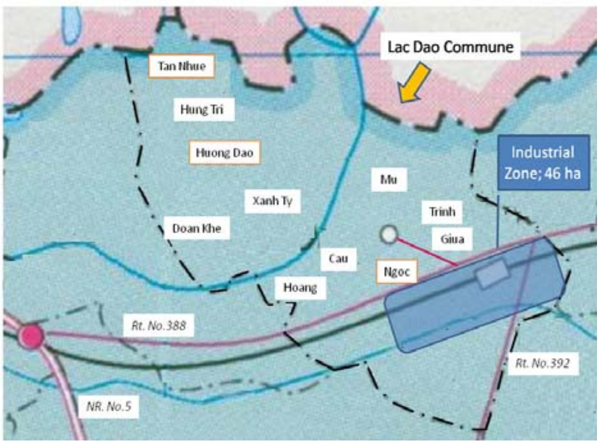

Figure 2 Enlarged map of Lac Dao commune

2) Key information on socio-economy

In 2008, the total area of natural land is 839 ha, of which 416 ha is occupied by agricultural land, 90 ha by industrial sites, and 330 ha is for other purposes of use respectively. In comparison with the land use in 1998, 90 ha of agricultural land have been converted into industrial sites.

The total population in 2008 is 13,500, increasing 1,000 people from the population in 1998. Labor population has also increased by 5,600 in 2008 (see Table 1). Those increases have been caused by not a social increase but a natural increase.

3,160 households exist in the commune in 2008, of which 2,900 households posses farm land and the left is landless. At the time of survey in 1995, all households more or less used to possess farm land. In short, the emergence of landless households is one of the recent distinctive social changes of this commune. Besides the fact pointed out above, it must be noticed that 1,500 households of 2,900 farmland holders have no longer engaged in any faming activities.

Total GDP and GDP per capita of the commune in 2007 recorded 138.3 billion VND and 10.3 million VND, respectively. In particular, the GDP per capita increased by more than 10 times as high as that of 1998 nominally. By seeing the share of GDP by industrial sector between 1998 and 2007, it is obvious that the swift growth of industry and service sectors for the recent ten years has strongly pushed up the economy in the commune. As a consequence, with favorable geographic and social conditions of this commune, 90 hectare of farm land in total has converted into and industrial site including 46 ha of industrial park (see Figure 2 and The BOX).

Table 1 Some key information on socio-economy of Lac Dao commune

Category	Year 2008	Year 1998
Land resource (ha)		
+ Total natural land	839	839
+ Agricultural land	416	504
+ Industrial site	90	0
+ Land for others	330	330
Population (people)		
+ Total population	13,500	12,500
+ Labor population	5,600	4,900
Household		
+ Total number of household	3,160	—
+ The household owing farmland	2,900 (92 %)	— (100 %)
GDP		
+ Total GDP (billion VND)	138.3 (2007)	—
- Agriculture (%)	34.5	65.0
- Industry (%)	20.2	} 35.0
- Service (%)	45.4	
+ GDP per capita (million VND)	10.3 (2007)	1.0

Source: Interview with the vice-director of Lac Dao commune (dated on 25 Sep. 08)

Note: (—) indicates that the data were not available from the interview.

***The BOX*- Chronology of industrialization in Lac Dao commune**

- *Year 2000-01*: The first manufacturing company came and started negotiations for land acquisition.
- *Year 2002*: The first company completed construction of the plant.
- *Year 2003*: Provincial govt. settled a policy to actively invite manufacturing companies in the district.
- *Year 2004*: next 20 companies settled in this commune.
- *Year 2005-06*: Other two companies settled each year.

3) Livelihood strategy of farm households

3)-1 Typology of farm households by livelihood strategy

In order to analyze farmers' livelihood strategies under the current conditions of regional economy, as mentioned above, the data collected from the interview with 31 farm households by the field surveys in 1995 and 2008[1]. Those informants were selected from three different villages in the commune, namely Tan Nhue, Huong Dao, and Ngoc (see Figure 2).

Table 2 shows the typology of the informants by livelihood strategies, applying the theoretical categories released by World Bank [3]. According to the result, it is found that there were two remarkable changes in livelihood strategies among the farm households. One was the decrease in farm-oriented households and the other was emergence of labor-oriented households. In particular, it must be noticed that the number of farm, market-oriented households has reduced from twelve in 1995 by four in 2008 and nine labor-oriented households have newly appeared after the previous survey.

Table 2 Typology of farm households by livelihood strategies

	Year	Farm-oriented household			Labor-oriented	Migration -oriented	Diversified	Total
		Market-oriented	Subsistence -oriented	Total				
Number (household)	1995	12	3	15	0	0	16	31
	2008	4	1	5	9	0	15	29
Percentage (%)	1995	39	10	48	0	0	52	100
	2008	14	3	17	31	0	52	100
	2000 a)	38	4	41	18	1	37	100

Source: Field survey in 1995 and 2008, and World Development Report 2008 (p. 79)
Note: Farm-oriented household: more than 75 percent of total income from farm production.
Farm, market-oriented household: more than 50 percent of agricultural production sold on market.
Farm, subsistance-oriented household: less than or equal to 50 percent agricultural production sold on market.
Labor-oriented household: more than 75 percent of total income from wage or nonfarm self-employment.
Migration/ transfers-oriented household: more than 75 percent of total income from transfers/ other non-labor sources.
Diversified household: Neither farming, labor, nor migration income source contributes more than 75 percent of total income.
a) The figure shows the result caluculated national statistics data (WDR 2008, p. 79)

3)-2. Comparison of gross income by the type of livelihood strategies

Table 3 shows the income level by category of livelihood strategies. It is a logical result that the mean of total gross income at every category increased between 1995 and 2008 with an economic growth. A noteworthy fact, however, is that income differentials among the households have enlarged much widely, especially in the category of farm-oriented household. It is guessed that various types of farm household in

Table 3 Comparison of gross income by type of livelihood strategies

Category	No. of household		Total gross income (nominal figures)							
	Year 1995	Year 2008	Year 1995				Year 2008			
			Mean	Min	Max	Max/ Min	Mean	Min	Max	Max/ Min
Unit	HH	HH	Million VND			time	Million VND			time
Farm-oriented	15	5	10.24	4.94	24.47	5	184.72	11.30	665.62	59
/Market-oriented	12	4	11.10	4.94	24.47	5	228.07	20.94	665.62	32
/Subsistence-oriented	3	1	6.85	5.27	7.94	2	11.30	11.30	11.30	…
Labor-oriented	0	9	—	—	—	—	107.25	36.00	181.38	5
Diversified	16	15	15.43	8.33	35.61	4	74.30	22.80	174.73	8
Whole	31	29	12.92	4.94	35.61	7	103.50	11.30	665.62	59

Source: Field survey in 1995 and 2008
Note: — = not available.

[1] In the survey in 2008, two informants of 31 farm households were too old to give the interviewer reliable information of household economy. And, of the left 29, one household has become landless and other two have no longer engaged in faming activities nevertheless they have kept holding farmlands.

terms of farming scale and intensity have begun to arise among this category[2].

3)-3. Comparison of household expenses by type of livelihood strategies

It is easy to understand that the increase in the households' income makes their living standard better. Table 4 shows the households' expenses by type of livelihood strategies. At each category, the nominal average expenses in 2008 have become 9 to 17 times as high as that of 1995 besides farm, subsistence-oriented household. It seems that the disparity of expenses among the households is getting somewhat wider, but it is of course not as much as income differential.

Table 4 Comparison of household expenses by type of livelihood strategies

Category	No. of household		Total household expenses (nominal)							
	Year 1995	Year 2008	Year 1995				Year 2008			
			Mean	Min	Max	Max/ Min	Mean	Min	Max	Max/ Min
Unit	HH	HH	Million VND			time	Million VND			time
Farm-oriented	15	5	3.50	0.91	7.31	8	53.60	7.68	136.05	18
/Market-oriented	12	4	3.69	0.91	7.31	8	65.09	26.11	136.05	5
/Subsistence-oriented	3	1	2.74	2.40	3.28	1.4	7.68	7.68	7.68	…
Labor-oriented	0	9	–	–	–	–	57.92	27.03	202.72	8
Diversified	16	15	4.19	1.65	10.26	6	36.93	13.05	76.80	6
Whole	31	29	3.85	0.91	10.26	11	46.32	7.68	202.72	26

Source: Field survey in 1995 and 2008

Note: – = not available.

3)-4. Farming resources of household by livelihood strategies

The development of individual farm households depends on the quantity and quality of family labor and farmland that each household holds to some extent. According to Table 5a which shows human and land resources as of 1995 by livelihood strategies, the number of family members and family labor exceeded five and three people respectively at every category. Among all categories, farm-oriented households, especially market-oriented households, were slightly advantageous in term of number of labor force.

Table 5a Farming resources of household by type of livelihood strategies in 1995

Category	Human resources			Land resources		
	Number of family	Number of labor force	Age of household head	Land holding assigned	of which paddy field	Total land operated
Unit	person		yrs old	m^2		
Farm-oriented; 15	5.3	3.3	50.2	2,532	2,495	2,724
/ Market-oriented; 12	5.2	3.4	51.6	2,525	2,489	2,725
/ Subsistence-oriented; 3	5.7	3.0	44.7	2,560	2,520	2,720
Labor-oriented; 0	–	–	–	–	–	–
Diversified; 16	5.5	3.1	47.6	2,373	2,181	3,085
Whole; 31	5.4	3.2	48.8	2,500	2,333	2,910

Source: Field survey in 1995

Note: – = There is no correspondent.

Land holding assigned and Total land operated include cultivation pond.

Labor force is the adult aged 18 – 60 years old.

Regarding the land resources, in all categories of livelihood strategies, the total operated land exceeded the land assigned through renting-in of extra farmland from agricultural

[2] Under the recent governmental policies which encourage large-scale commercial farms over the country, it is suggested that the number of those farms specialized in producing profitable crops and/ or livestock is increasing even in the commune.

cooperatives. It means that farming activity generated a leading income for the livelihood of villagers at that time. Particularly, the diversified households which held relatively abundant family member, small land, and young household heads were active in procurement of land resources from the outside.

Now, Table 5b shows farming resources as of 2008 by categories of livelihood strategies as well Table 5a. Compared Table 5a and Table 5b, the most surprising fact is remarkable decline of assigned land and total operated land of farm households. The total operated land on average in 2008 has reduced by 2,070 sq. meters, which was 2,910 sq. meters in 1995. Such a sharp decline of farmland has been caused by the practice of equalized inheritance to all independents and half-forced expropriation of farmland for industrial sites.

Table 5b Farming resources of household by type of livelihood strategies in 2008

	Human resources			Land resources		
Category	Number of family	Number of labor force	Age of household head	Land holding assigned	of which paddy field	Total land operated
Unit	person		yrs old	m^2		
Farm-oriented; 5	5.0	2.8	62.4	1,468	1,468	2,116
/Market-oriented; 4	4.5	3.0	57.5	1,512	1,512	2,322
/Subsistence-oriented; 1	7	2	82	1,296	1,296	1,296
Labor-oriented; 9	4.4	3.6	59.0	1,635	1,355	1,337
Diversified; 15	4.3	2.9	58.9	1,846	1,796	2,357
Whole; 29	4.4	2.9	60.7	1,723	1,534	2,070

Source: Field survey in 2008

Note: Land holding assigned and Total land operated include cultivation pond.

Labor force is the adult aged 18 – 60 years old.

The next important fact is the inversion of scale of assigned land holding category by category. In 2008, the diversified household has become the biggest holder of assigned farmland, whereas the farm-oriented households become the smallest assigned farmland holder. Therefore, the farm-oriented household is the biggest leaseholder of farmland to maintain their farm-scale.

Another important fact is a change in behavior of labor-oriented households. Their operated land is smaller than the assigned land, which shows a possibility that a part of labor-oriented households has behaved as a land lessor. Through these facts, it is considered that a farmland market by lease contact among farm households has developed and actively worked in Lac Dao commune. In fact, according to the vice director of the commune, 30 per cent of total agricultural land has been moving among farmers by lease contract with the rent of 50 - 60 *kg of paddy/ crop/ sao*.

4) Changes in agriculture, rice farming, and its efficiency

In the past, most farm households in Lac Dao commune used to practice a common diversified farming with a highly intensive land use. It generally comprised two crops of rice and winter upland crops in paddy field and small-scale pig keeping in the garden. However, as shown above, after 90 hectares of paddy field was converted into the industrial sites, the farming activities in this commune have been gradually put backward and the faming system has getting exclusive. So, this section gives some pictures on recent agriculture in the commune by farming sub-sectors.

4)-1. Vegetable and fruits farming sub-sector

In this sub-sector, a sharp recession happened. The total planted area of winter vegetable crops reduced by 72 ha in 2008 from 252 ha in 1998.

4)-2. Pig keeping sub-sector

This sector has also experienced a big structural change. Though many farm households used to keep a few heads of pigs in the past, only a half number of farm households keep raising pigs in this time. In order that producers gain a satisfactory profit from this business sector, it is considered that over 10 heads of fattening pig are necessary to be kept at one time with adopting improved feeding techniques. Therefore, it seems to be not easy for ordinary farmers to earn a high profit from this sub-sector due to limited capital and appropriate knowledge.

4)-3. Rice farming sub-sector

Rice farming sub-sector also shows remarkable changes. Mechanization is the most impressive change in the commune. Now, 58 units of farm tractor, which are privately possessed, work for land preparation and transportation in the commune. The tractors cover all paddy field in the commune and the owners serve custom works under the management of agricultural cooperatives. And two threshers and 10-15 milling machines are available in each village with enough capacity that every farmer can enjoy the service on time. Transplanting and harvesting have not mechanized yet. However, the farmers can easily employ enough labor force with the wage payments of 60,000 to 90,000 VND (equivalent for 3.5 to 5.3 USD) a day. Therefore many farmers in the commune are willing to engage in off-/ non-farm jobs even during the busiest time of rice cultivation.

Table 6 Machanization of rice farming in the commune

Number of machines for rice farming	Note
- Farm tractor (s): 58 units (in the commune) - Tresher (s): 2 units (in each village) - Milling machine (s): 10-15 units (in each village)	A farm tractor has a capacity, covering 20 ha of land preperation in 10 days.

Source: Interview of the vice-director of the agricultural cooperatives

The second biggest change of rice cultivation is the increase in chemical fertilizers and pesticide application. The expense for chemical materials is 155,000 VND per sao on average, accounting for 57.2 % of the total material cost of rice cultivation.

Applying new varieties such as *Khang Dan, Q4, and Q5* brings the farmers much higher yield comparing to *CR 203* in the past. Beside such high yield verities, farmers have started applying high quality of rice varieties like *Bac Thom 7* and some other glutinous rice, which is suit for alcohol processing to get higher added value.

As a consequence, with the decrease in the cultivated paddy field, the total rice production per farm household decreased in the commune. But, on the other hand, with the downsizing of family members (see Table 5a and 5b) and the decline in feed demand by the withdrawal from pig keeping, rice production leaves a surplus for sale for many farm households.

Table 7 Changes in rice cultivation techniques, land condition and productivity in the commune

	1995	2008
Variety applied	*CR 203*	*Khang Dan* *Q4, Q5* *Nep (glutinous rice)*
Chemicals use		
- Expense for chemicals	---	155,000 VND/ sao
- Share of payment for chemicals against total material cost	---	57.2%
Farmland accumulation		
- Number of parcel	7.2 plots	3.8 plots
- Average distance from residence	---	550 m
Total rice production per farm houshold	1,826.2 kg	1,402.0 kg
- Spring rice	1,003.0 kg	756.0 kg
- Summer rice	823.2 kg	646.0 kg
Yield		
- Spring rice	0.48 kg/ m^2	0.63 kg/ m^2
- Summer rice	0.32 kg/ m^2	0.53 kg/ m^2
Cultivated area per farm houshold		
- Spring rice	2,081 m^2	1,161 m^2
- Summer rice	2,493 m^2	1,162 m^2

Source: Field survey in 1995 and 2008

Note: --- means the data are not available.

Conclusion

In this report, we showed a case in Red River Delta where the farming practices is going to be extensive under the condition of rapid economic growth and industrialization. It seems that once miserable full-time farm households have already disappeared from our informants at least. And a lot of part-time farmers are generated in this commune. They say that over two-thirds of total farm households in the commune engage in stable off-/non-farm jobs. Particularly, the young generations do not feel involved in farming activity so much anymore. Some of them strongly watch for a chance to release their farmland with favorable terms. It seems that this is the time for all villagers and local government to make a common picture of well-balanced development, taking economy, communal society, and their own living environment of the future into consideration.

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Development of Vegetable Marketing Channels in Vietnam- A Brief Consideration

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Abstract

It has been crucial issue how to merchandize the enhanced produce after the market oriented renovation in Vietnam. Along with the penetration of market economy, the agricultural cooperative takes an initiative to bind a contract with the processing product export company to solve the problem. On the other hand, middle scale intermediary merchant deals with the remote shipping of agricultural produce.

Recently in order to cope with the enlarged demand for vegetable in urban area and also export demand the vegetable farmers need their marketing channels to sell in a adequate condition such as fair price and good treatment.

We take some examples to show the situation of marketing channels in rural Vietnam to encounter the penetration of market economy.

1. Marketing under contract organized by agricultural cooperative.
2. Middle scale intermediary shipping to the remote area.
3. Marketing under contract with frozen vegetable export company.

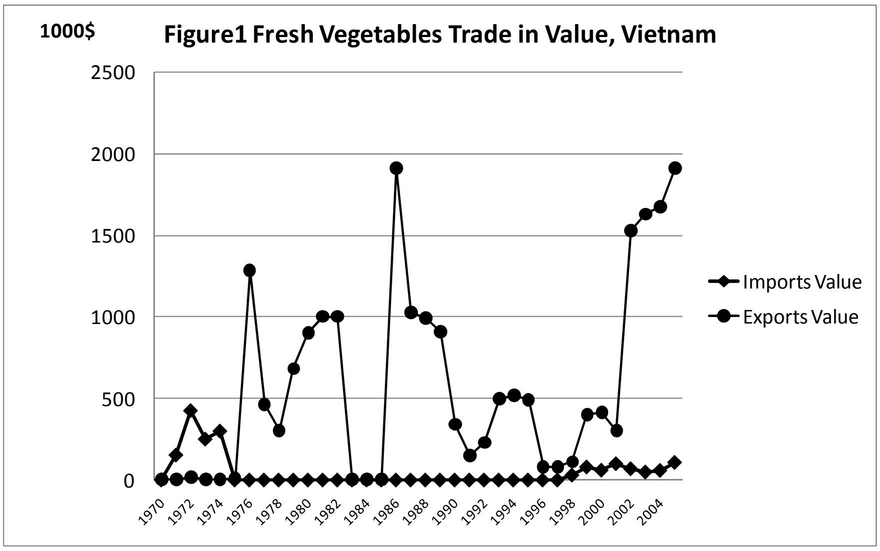
Key words; marketing, contract, cooperative, frozen vegetable, migratory vegetable

Introduction

Under the long period of socialistic planned economy, the activities of private merchant were so phlegmatic that marketing system has not been well established in Vietnam. So it has been crucial issue how to merchandize the enhanced produce after the market oriented renovation. It was observed that vegetable marketing systems especially in Red River Delta faced several problems; for example, localized marketing activities to a small region around the city, wide fluctuation of market price, high transportation cost in proportion as a market area, no standard in quality and shape for commodity vegetable, underdeveloped intermediary and shipping organization, and etc.[1]

Recently, domestic market conditions have changed dramatically from both physical and social aspect in Vietnam. The road conditions have improved rapidly and refrigerators and cold storages have introduced in many distribution channels. From the view points of social condition, the supermarkets are developing in the big city and credit dealing in the transaction becomes prevailed. Vietnam used to export a large quantity of fresh vegetable in late 1980's but the export had stagnated in the 1990' and then it became vigorous again for recent decade (Figure1). On the other hand, along with the trade liberalization vegetables import increased from the surrounding country like China, Thailand and so on.

However, upgrading agricultural market institution such as market control law, wholesale market regulations and price stabilization system is relatively behind these situations.



Source: FAOSTAT

Material and Methods

In order to observe recent marketing situations, we classified the vegetable marketing channels into indirect and direct marketing channels according to the analysis by Hung and Hien [2].

Indirect marketing channel can be classified into two types, (1) wholesale at home or at the field, and (2) wholesale at markets. The home/field marketing is done in two ways (1a) middle scale middlemen collect vegetables for big wholesalers transporting to remote area. And (1b) most vegetables are collected by small middlemen for sale at near market.

Direct marketing between vegetable growers and consumers or commercial buyers can be classified into two types (3) selling directly to consumers at retail market or on the streets and (4) selling to processing or export company and to shops/restaurants.

We take some examples to show the changing situation of marketing channels in rural Vietnam to encounter the penetration of market economy.

1. Marketing channel between vegetable processing company and agricultural cooperative (type 4)
2. Marketing channel between farmer and the middle scale intermediary shipping vegetables to the remote area (type 1a)
3. Marketing channel under the contract with frozen vegetable export company (type 4)

Result

1) Contract channel with vegetable processing company

Agricultural and Rural Development Department (ARDD) of Nam Dinh province has been promoting a constructive policy for the improvement of agricultural production such as irrigation system reconstruction, supply production materials including nursery and seed, animal hygiene control, agricultural extension service and so on. Adding to this, they introduced new varieties of ground nuts and potato and built the storage of potato sets.

Nam Cuong Agricultural Cooperative in Y Yen district (Table1) concluded a contract with Dong Giao Company, Ninh Binh under the direction of ARDD of Nam Dinh in 2002. And then, the cooperative concluded a contract with LUVECO Company located in the same province of Nam Dinh without a complicated rigmarole. Under the contact, farmers in Nam Cuong Cooperative produce sweet corn, baby corn, baby cucumber and mini-tomato.

Table1 Planted area of vegetable and bean in Nam Dinh ha

	2000	2004	2005	2006	2007
Whole Province	14,328	19,369	19,940	22,556	19,850
Nam Dinh	182	289	236	316	320
My Loc	597	477	253	397	312
Vu Ban	1,349	1,949	2,137	2,355	1,926
Y Yen	2,997	3,824	3,373	3,888	2,932
Nghia Hung	1,538	2,615	2,753	3,265	2,701
Nam Truc	1,118	2,039	2,129	1,815	1,338
Truc Ninh	1,024	1,579	1,619	2,037	1,900
Xuan Truong	914	858	843	887	843
Giao Thuy	1,701	2,350	2,752	2,983	2,689
Hai Hau	2,908	3,389	3,845	4,613	4,889

Source: Namdinh Satistical Yearbook, 2007

The roles of Nam Cuong cooperative under the contact are as follows;

1. Conclusion of a contract; the contract is renewed every crop season. Before the renewal of contract the Cooperative surveys the expectation crop acreage to all the member farmers. According to this survey the Cooperative conclude a contract with the processing company.
2. Supply of agricultural material and substitute work service; the vegetable processing company provides seeds and nursery and settles up after harvest. The Cooperative purchases the fertilizer and chemical in a lump and collect bills after harvest. The Cooperative also makes a chemical spray service collecting bills by spray acreage.
3. Production technique direction; the processing company and district extension committee dispatch the technician and open the training course, and then the students of the course teach farmers of the production team. Nam Cuong Cooperative creates their own criteria for the variety of crop produced and cultivation technique.
4. Shipment and inspection; the farmers assemble their produce at four assembling spot by each production team on designated hours. The Cooperative staffs and processing company staffs together inspect and weigh the farmer’s products every day in the harvesting season. Farmers only bring their products from farm gate to the assembling spot alleviating their sales effort. And the products are carried by heavy vehicle from assembling spots to the processing factory that reduces the shipping cost.
5. Clearance; the Cooperative receives proceeds after deducting seed cost at the

end of harvesting season. And then, the Cooperative checks the shipment volume of each farmer and clears the expense of fertilizers and chemicals. After collecting the commission charge of 50VND per kg, the expenses are paid to the farmers.

The success factors in the formation of contract can be summarized as follows;

1) Nam Cuong Agricultural Cooperative, the old type of cooperative, developed basic condition of cultivation concentrating crop area by each production team.
2) The administrative office, processing company and the agricultural cooperative in Nam Dinh province are strongly collaborated in the promotion of agriculture.
3) The location of processing company is so close to the producing place that the transportation cost is relatively low.
4) Farmers in Nam Cuong Cooperative have an experience to produce not only rice but also commercial products like ground nuts and potato.

2) Collector channel for migratory vegetable

The area of vegetable production in Hai Duong province is largest among Red River Delta. Expanding ratio of migratory vegetable production is highest in Gia Loc district. We investigate migratory vegetable area in Doan Thuong village, Gia Loc district to clarify the role of migratory collector and the formation of vegetable production area.

Table2 Planted area of vegetable in Hai Duong ha

	2000	2002	2003	2004	2005	2006
Whole Province	21,292	26,048	28,783	29,979	30,920	29,261
Hai Duong	298	347	252	216	227	192
Chi Linh	1,767	1,836	1,846	1,784	1,369	1,217
Nam Sach	2,868	2,336	2,360	2,424	2,864	2,492
Kinh Mon	2,128	2,437	2,617	2,827	3,138	3,120
Kinh Thanh	2,048	2,629	3,011	3,689	3,773	3,870
Thanh Ha	2,481	2,760	2,841	2,779	2,770	2,460
Cam Giang	1,245	1,737	2,091	2,327	2,094	1,902
Binh Giang	549	1,370	1,230	1,058	1,176	1,217
Gia Loc	4,179	5,105	6,116	6,368	6,795	6,335
Tu Ky	2,082	2,865	3,464	3,375	3,701	3,559
Ninh Giang	880	1,375	1,635	1,654	1,458	1,189
Thanh Mien	767	1,251	1,320	1,478	1,555	1,708

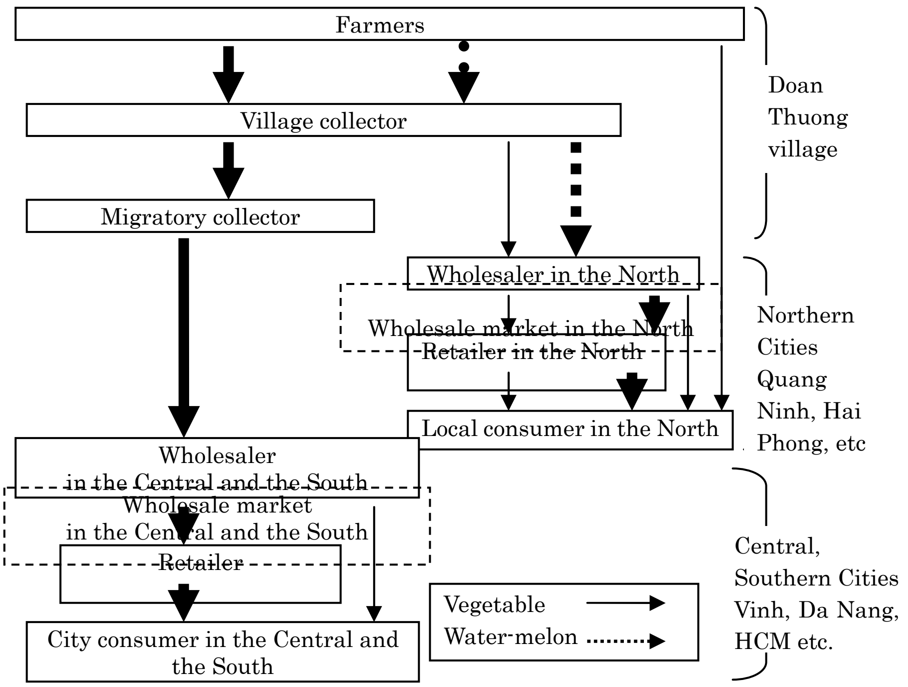
Source: Haidoung Satistical Yearbook, 2006

Along with the expansion of vegetable area, the number of vegetable collectors increased in the village. There were around 40 collectors in 1996; it increased to around 100, among them 10 collectors became specialized merchants. Agricultural cooperative do not engage sale business anymore but only support the commercial activities.

In the marketing channels of agricultural products in Doan Thuong village (figure 2) vegetables are shipped to central or south consumption sites by migratory collectors in the village. Most of vegetables are sent to the central cities for consumption because the price of vegetables is a little bit higher in the off-crop season in that area.

On the other hand, most of watermelon is sent to the north cities because production of watermelon is relatively scarce and there is little watermelon produce area in the north and also specialized watermelon wholesale market is located in Gia Loc district and become a distributing center.

Figure 2 Marketing Channels of Agricultural Products in Doan Thuong village



Note: Weight of arrow stands for volume of distribution of produce
Source: Takanashi Fumie; Role of the shipping wholesaler in development of vegetable producing area in Red River Delta, Vietnam, Agricultural Marketing Journal of Japan (in print) From interview to farmer and collector in 2006.12

The collector in the village purchase vegetables directly from farmer. There are two ways how to purchase vegetables, one is so called spot purchase that is to purchase soon after receiving the order from wholesaler in the harvesting season, another is so called green harvest to purchase from farmer before harvesting.

Migratory collectors who transport assembled vegetables to remote consumer's site in large quantity concentrate their activities on vegetables trade. They gather vegetables from village collectors according to the order received from customer and purchase vegetables from many collectors in the district. Most of the trade between migratory and village collectors is continuous and their connection is fixed. And then, they emigrate all the collected vegetable to the fixed customer, that is, consumer's wholesale merchant in the terminal market of several central provinces. It is characterized these transactions both between village collectors and migratory collectors and migratory collectors and wholesalers are done by open account basis.

With the development of migratory marketing, the collectors differentiate into small village collectors and large migratory collectors, then large scale vegetable area has created by making marketing process efficient.

3) Export oriented company channel

Export oriented vegetable producing area is located in Da Lat, the southern highland, Lam Dong province. We introduce a case of frozen export vegetable processing company for Japan.

Since Da Lat Foods Co.ltd has first entered into the business in 1999, five frozen vegetable processing companies had developed until 2005 in Da Lat area. Taiwanese investor, Green Home Co.ltd has established in 2002, expanded their business along with the increase of frozen vegetable export to Japan after the chemical residue issue occurred in China. The company exported 1900t of frozen spinach and 60t of green soybean to Japan in 2004.

Table3 Planted area of vegetable in Lam Dong ha

	2000	2002	2003	2004	2005	2006
Whole Province	18,879	23,783	25,388	26,788	29,378	35,197
Da Lat	6,232	6,764	7,028	7,176	7,466	9,271
Bao Loc	37	35	44	33	42	42
Lac Duong	321	807	824	986	863	2,103
Don Duong	7,676	10,121	10,215	10,423	11,490	12,550
Duc Trong	3,666	4,839	5,872	6,711	7,865	9,403
Dam Rong					104	110
Lam Ha	506	602	622	607	651	741
Bao Lam	54	95	95	129	151	148
Di Linh	60	113	131	130	130	135
Da Huoai	76	94	66	37	49	114
Da Toh	129	150	279	296	302	304
Cat Tien	122	163	212	230	265	276

Source: Statistical Yearbook, 2006

The company's procurement system of material vegetable has two ways; one is vegetable from direct operation farms and the other is from contract farms. In the direct operation farm green soybeans are grown mostly under fifty years lease land from provincial government hiring 500 to 600 laborers in the on-season or 200 to 300 laborers in the off-season. Another one is the procurement by a contract with 100 individual farmers producing 53 ha of soybean and 50ha of spinach. Contract farmers cultivate average one ha on a contract. The contract detail is to designate a contract field and buy all the produce from that field at fixed price set before seeding. The price of material vegetable shows a tendency to increase recently.

The procedure of contract starts from selecting a field. The Green Home company selects an isolated field with no field around firstly, but in case the field is surrounded by adjacent field, five meter space should be set inside the field. The contract include some conditions as Green Home company also provide chemicals and chemicals should not apply two weeks before harvest. Other than this, minimum plot square of field is fixed and timing of seeding should be dispersed among the seeding season. The company staffs check them at regular intervals. Pesticide testing has conducted three days before harvest and inspected again when the material vegetable carried into the factory.

To compare quality control level with the case of Qingdao, China, the contracted plot of field is smaller and the frequency of check is less. Adding to this, the company staff has to thin the stock solution of chemical for use instead of farmer in Qingdao but farmers thinned them by themselves in Da Lat, so the standard of quality control is lax than China. When Chinese companies restore confidence to Japanese consumer and compete with Vietnamese companies, it seems that Vietnamese companies would become probably inferior to Chinese companies in terms of quality control.

Conclusion

In this report, we take three cases of an agricultural cooperative in Nam Dinh province, migratory collector's in Hai Duong province, and frozen vegetable export companies in Lam Dong province as successful distributive trades in the vegetable marketing channels. The role of these intermediaries in the vegetable marketing channel in Vietnam is quite important hereafter, thus to promote the function of intermediaries and justify the trade transaction should be of great significance.

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A Study on Farming System in Southeast Asia: Slash-and-Burn Agriculture in the Mountainous Area of the Northern Lao PDR

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Abstract

Slash-and-burn Agricultural system is a traditional farming system in the mountainous northern Laos. The system is still a typical in the area and is one of the most applicable farming methods for low income people living in the mountainous region where is not favorable for farming. On the other hand, a growth in slash-and-burn agriculture is causing environmental problems. The Lao government is discouraging the system and promoting the shift to lowland agriculture; however, the system is still exercised.

The objective of this study is to reveal quantitatively the factors of continuing existence of the slash-and-burn agricultural system in the northern Laos. The following three factors were assumed as affecting factors in this study:

1) demographic: ethnicity, number of family members, and education level
2) agricultural: land, labor and capital
3) economic: farming income, off-farm income

In this study, structured interview surveys to 88 farm households were implemented in Pha Oudom district, Bokeo Province in the northern Laos. The data was analyzed first by using a cluster analysis method to classify the farms in order to characterize farmers who implementing slash-and-burn agricultural system. Then, a regression analysis method is applied to identify the affecting factors to the implementation of the system.

The results shows that introduction of the system depends rather on the numbers of family members, rice deficit situation, lowland rice production than ethnicity, mechanization and income. The result implies that improvement in food deficit situation and increase in rice productivity in lowland are important to reduce slash-and-burn agricultural system in the northern Laos.

KEY WORDS

Rice, Slash-and-burn Agriculture, Lao PDR, Farming System

1. Introduction

Slash-and-burn Agriculture is a traditional farming system in mountainous Northern Laos. The system is still common in the area and is one of the most applicable farming methods for the low income people living in the mountainous region where is not favorable for modern farming.

On the other hand, widespread slash-and-burn agriculture is causing environmental problems including deforestation and air pollution. The Lao government is discouraging the system and promoting the farmers to shift to lowland agriculture, however, the slash-and-burn farming is still widely exercised.

Slash-and-burn farming system is often understood as an "extensive" farming system, however; it often requires farmers to commute a long distance to the farming sites. Also, the yield is usually lower than the rice production in the lowland.

Possible reasons of the existence of slash-and-burn farming system are, for example, a culture of ethnic minorities, low productivity in lowland, lack of machinery and inputs, and food deficit. However, actual reasons are not yet identified quantitatively.

Therefore, the objective of this study is quantitatively to reveal the factors that affect an existence of the slash-and-burn farming system in the Northern Lao PDR.

2. Analysis

1) Methodology

In order to pursue the above objective, a Cluster Analysis is used based on the household data collected by a field survey[1)]. By the analysis, targeted farm households are categorized into several groups in order to characterize farm households. In this study the following three factors, i.e. demographic, agricultural, and economic, were assumed as affecting factors. The variables were used in the analysis are as follows:

- Demographic: ethnicity, number of family members, and education level
- Agricultural: land, labor and capital
- Economic: farming income, off-farm income.

Implementing a cluster analysis, Word Method and Euclidean distance technique were applied.

Also, a regression analysis was implemented to determine the factors that increase/decrease the share of rice production by Slash-and-burn farming in the total rice production.

2) Data

A filed survey was implemented in Pha Oudom District, Bokeo Province in Northern Laos in 2007. The district is recognized as one of the poorest districts in Laos. Data collection was done based on the structured questionnaires by random sampling technique, and 88 Farm households were interviewed.

3) Results of the cluster analysis

According to the cluster analysis, the farm households were classified into four clusters i.e. clusters 1-4 in Table 1-3.

Table 1 shows the relationships between demographic factors of households and the clusters. Cluster 1 involves a large share of Khmou ethnic group (93.5%), however, significant differences were not found in terms of age, education, and household size.

Table 2 shows the characteristics of agricultural input and production of the clusters.

Cluster 1 shows the fewer number of labor and tractor possession (no=90.3%), smaller lowland paddy, and higher rate of exercising slash-and-burn farming (48.4%).

Table 1 Characteristics of Households by the Cluster Analysis

Unit:%

		Cluster				
		1	2	3	4	Average
Ethnicity	Khmou	**93.5**	**62.9**	**66.7**	**50.0**	**72.7**
	Lao Loum	6.5	37.1	33.3	**50.0**	27.3
Age	0-19	6.5	8.6	8.3	0.0	6.8
	20-39	29.0	**45.7**	25.0	**70.0**	39.8
	40-60	**51.6**	**45.7**	**58.3**	30.0	**47.7**
	60以上	12.9	0.0	8.3	0.0	5.7
Education	1= Primary	**51.6**	**54.3**	**58.3**	**50.0**	**53.4**
	2= Junior	16.1	17.1	0.0	20.0	14.8
	3= High	0.0	0.0	25.0	0.0	3.4
	4= ilitirate	19.4	14.3	16.7	0.0	14.8
Household Size	2-5	38.7	37.1	16.7	30.0	34.1
	6-9	**45.2**	**51.4**	**66.7**	**40.0**	**50.0**
	10-13	12.9	11.4	16.7	30.0	14.8
	14人以上	3.2	0.0	0.0	0.0	1.1

Notes)
1. Data source:Farm hausehold survey
2. Boldfaces in the table means that rates of answer is the highest in each questions.

Table 2 Charcteristics of Agricultural Input and Production by the Cluster Analysis

Unit:%

		Cluster				
		1	2	3	4	Average
Total Labor	1-2	32.3	28.6	25.0	30.0	29.5
	3-4	**58.1**	**57.1**	**50.0**	**40.0**	**54.5**
	5-7	9.7	14.3	25.0	30.0	15.9
Tractor	0=no	**90.3**	**60.0**	25.0	10.0	**60.2**
	1=yes	9.7	40.0	**75.0**	**90.0**	39.8
Slash-and-burn farming	0=no	**51.6**	**57.1**	**66.7**	**90.0**	**60.2**
	1=yes	48.4	42.9	33.3	10.0	39.8
Paddy Area (rainy+dry)	0-0.5ha	32.3	0.0	0.0	0.0	11.4
	0.5-1ha	**45.2**	31.4	0.0	0.0	**28.4**
	1-1.5ha	19.4	**40.0**	8.3	0.0	23.9
	1.5-2ha	3.2	28.6	**66.7**	0.0	21.6
	2ha以上	0.0	0.0	25.0	**100.0**	14.8

Notes)
1. Data source: Farm Household Survey
2. Boldfaces in the table means that rates of answer is the highest in each questions.

Table 3. Charcterisitcs of Agricultural Output and Income by the Cluster Analysis

Unit:%

		Custer				
		1	2	3	4	Average
Lowland rice production (rainfed+irrigated)	0-2500kg	**100.0**	22.9	0.0	0.0	**44.3**
	2500-5000kg	0.0	**77.1**	0.0	0.0	30.7
	5000-7500kg	0.0	0.0	**100.0**	0.0	13.6
	7500-10000kg	0.0	0.0	0.0	**60.0**	6.8
	10000kg以上	0.0	0.0	0.0	40.0	4.5
Food sufficiency	0=not enough	**71.0**	28.6	0.0	0.0	36.4
	1=enough	29.0	**71.4**	**100.0**	**100.0**	**63.6**
Total cash income (kp)	0-5,000,000	**90.3**	**65.7**	8.3	20.0	**61.4**
	5,000,000-10,000,000	9.7	31.4	**75.0**	**40.0**	30.7
	10,000,000-15,000,000	0.0	2.9	8.3	10.0	3.4
	15,000,000以上	0.0	0.0	8.3	30.0	4.5
Rate of upland rice in total rice production(%)	0	**48.4**	**57.1**	**58.3**	**90.0**	**58.0**
	1～10	0.0	8.6	16.7	10.0	6.8
	11～20	12.9	11.4	25.0	0.0	12.5
	21～30	3.2	11.4	0.0	0.0	5.7
	30以上	35.5	11.4	0.0	0.0	17.0

Notes)

1. Data source: Farm Household Survey
2. Boldfaces in the table means that rates of answer is the highest in each questions.

Table 3 shows the characteristics of agricultural output and income of the clusters. Cluster 1 has small lowland rice production less than 2500kg, low level of food sufficiency and cash income. However, higher rate of rice production from upland.

Based on the results of the cluster analysis (Table 1-3), the characteristics of the Cluster 1 are summarized as follows:

- large share of Khmou ethnic group
- smaller number of labors
- lower rate of tractor possession
- lower lowland rice production, and
- small cash income. As a result,
- higher rate of slash-and-burn farming
- Higher dependency of rice to Slash-and-burn farming

Cluster 4 showed opposite characteristics to Cluster 1, however, Clusters 3 and 4 included only 25% of all respondents. The majority of farm households have the similar characteristics to Cluster 1, which implies that farming households are still very poor.

4) Results of the regression Analysis

A regression analysis was implemented to determine the factors that increase/decrease the share of rice production by Slash-and-burn farming in the total rice production. The dependent variables were a share of rice production volume in the total rice production volume, and the explanatory variables were demographic, agricultural and economic factors. Ten variables were initially introduced as in Table 4, however; less significant variables were eliminated during the analysis.

Table 4 The List of Variables

	Independent Variables
1	ethnicity 1=Khmou 0=Lao Loum
2	age(years)
3	household members
4	total labor
5	operated paddy (rainy and dry seasons) (ha)
6	tractor 1=have 0=not have
7	lowland rice production (rainfed and irrgated) (kg)
8	total cash income (kp)
9	household food sufficiency 1=enough 0=not enough
10	rice shortage days (day)
	Dependent Variable
1	rate of slash-and-burn farming rice in total rice production(%)

Table 5 The Results of Regrresion Analysis by Variable Diminishing Mehod

Independent Variables	coefficiets	t-value
constant variable	26.11	2.96
ethnicity 1=khmou 0=lao loum	-4.75	-1.13
household menbers(persons)	1.88	2.47
tractor 1=have 0=none	-6.53	-1.32
lowland rice production(rainfed and irrgated)(kg)	-2.45E-03	-2.59
total cash income(kp)	6.97E-07	1.32
household food sufficiency 1=enough 0=none	-14.93	-2.59
rice shortage days(day)	-0.14	-2.91
R^2 0.349		

The results (Table 5) showed that number of household members (persons), lowland rice production, food sufficiency, and the days of food deficit showed impacts with expected signs, and those were statistically significant.

Ethnicity showed significant impact on the rate of slash-and burn farming. Cash income also showed an impact with expected sign. However, those were not statistically significant.

3. Conclusions

The results showed that the factors affecting the existence of slash-and burn farming in the mountainous Northern Laos were affected by family size, lowland rice production, food sufficiency level, and the number of the days of rice deficit. On the contrary, ethnicity, machinery possession and cash income were less significant.

The results also implied that improving food subsistence and increasing lowland rice production were effective to stop family based farm households to exercise slash-and-burn farming. Improving food deficit situation by, for example, improving productivity in lowland, the importance of slush-and-burn agriculture will be decreased.

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"Hybrid Rice in the Integrated Farming System"

Current Situation of Integrated Farming Systems in Red River Delta, Vietnam

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Abstract

In Northern Vietnam, limited natural resources and high population pressure force farmers to seek the ways to wisely use these resources. A highly intensive method of small-scale farming called VAC has thus become popular for a long time, especially in Red River Delta (RRD). Technically, the VAC system consists of three components in which fruit gardening (V), fish rearing (A) and animal husbandry (C) are integrated. In the accordance with the characteristics of agricultural system, the transformation has been found such as VAC, VA, VC, and AC farm. Due to the development of the economy, the VAC system has been changing in the relation with the economic transition. In order to analyze the current situation of the VAC system, field surveys were carried out by interviewing 199 households in 6 districts of 3 provinces in RRD. The results indicated that the VAC system has kept an important role and been adopted in 51% of total farms interviewed. The VAC systems are now in process of transitioning from the traditional VAC (T_{VAC}) to the modified VAC (M_{VAC}) with larger size, higher input and investment, and intensive cultivation. These targets to increase gross return (GR) and return above variable cost (RAVC) comparing to the traditional model. Among the variety of VAC systems, VAC and AC farm appear mostly as the primary forms of the farming system which is applied in 51.4% and 13.0% of the total number of interviewed households, respectively.

Economic efficiency of VAC systems is different among districts which is the highest benefit in terms of RAVC was found to be 99.14 million VND/farm/year (equal 5,831.76 USD/farm/year), and the lowest was 30.52 million VND/farm/year (equal 1,795.29 USD/farm/year). This benefit was twice higher than the averaged income per capita of RRD region. The AC farm achieved high level of RAVC which resulted in the highest of 93.54 million VND/farm/year and the lowest of 109.36 million VND/farm/year (equal to 5502.35 USD/farm/year and 6432.94 USD/farm/year).

In the VAC system, a closed biological flow transfers resources from one component to others, in which the products or wastes can be efficiently used. These can reduce input costs and increase benefits of the whole system. The biological cycle of VAC systems would ensure the sustainable farming system in RRD region of Vietnam.

Key Words: Farming systems**,** garden, Aquaculture, livestock, paddy rice, biology flow

Introduction

The VAC farming systems is a traditional method of small-scale farming in Vietnam, especially in the North of Vietnam. Integrated Farming has been a traditional approach to household food production in the rural areas of Viet Nam. The integration of the fruit gardening, animal husbandry and fish rearing is called the VAC system[12)]. Under the self-supplied economic period, the VAC farming system was a source that supplied important nutrients to people. Lately, it has not only been nutrient source, but also has brought high income for farmers, especially farmers in Red River Delta (RRD). According to the characters of geography, culture and custom of Vietnam agriculture, the household farmers live in villages and communes, and each household has two production areas, one is homestead are a and other is paddy field. The homestead area includes garden (fruit gardening), enclosure for animals (animal husbandry), and pond (fish rearing). The combination of three production activities which is fruit gardening in the garden (V), fish rearing in the pond (A) and breeding in the animal enclosure (C), with paddy-field production (R) has been called VACR farming systems, or VACRR with the addition of forestry (R).

In the history of developing VAC farming system in Viet Nam, farmers transformed traditional VAC farming systems (traditional crop varieties and animal breeds without relations among cropping, livestock, aquaculture and farm household's income) into modified VAC farming systems (larger farm size, higher input and more technologies) to get higher benefit. Main characteristics of the modified VAC farming systems are the interdependence of the three production enterprises, closely linked to natural resource, new technology applied, and the marketing of products. That made it as the integrated VAC farming systems. In the past, there were a lot of studies concerned with efficiency of VAC integrated farming systems in the different ecological regions and the improvement of their components in order to increase economical efficiency and to enhance the enrichment of biology and environment condition. According to Cao Anh Long and Pham Chi Thanh[13)], the VAC farming systems have been developed popularly in the North of Viet Nam, especially in RRD with traditional fruit varieties grown in the garden, combined livestock including cross-bred pig, duck and chicken, and intensified aquaculture. That increased farmer's income compared with previous agricultural activities from 150% to 200% in Ninh Binh province.

Vietnam has been integrated into world's market economy and become member of WTO, so the agricultural production as well as VAC farming system particularly was impacted by market factors and was changed on the structure, components, size and applied technologies. Moreover, the farming system was also influenced by other socio-economic and physical factors as reducing of farmer's land because of growing population, expanding of infrastructures and industrial areas, changing climate, polluting environment etc. In order find out recent problems of VAC farming systems in RRD region, pilot researcher of Hanoi University of Agriculture, Vietnam, in cooperation with Institute of Tropical Agriculture, Kyushu University, Japan, implemented a study to identify the strengths, problems, and opportunities of VAC farming system in RRD and solution in respond with changing factors of global market economy and climate.

Methods

The survey was implemented from June to July, 2008 in three provinces which located in Red River Delta (RRD). They are representing the typical characteristics of sub-region of RRD, which are Hai Duong, Ha Tay, and Ninh Binh province. Samples were chosen in two surveyed districts in each province, and the totals were 26 communes and 199 households.

The survey was carried out by PRA methods (Marsland et al.[14]; Normal and Douglas[4] and Chambers[17]) which was applied for all research periods. That included collecting the secondary data as annual reports, statistical data from district and commune level. Semi-structured interview was applied on leaders and technicians at district and commune level. Farm owners and households (HHs) were selected randomly in each commune[5].

The farming system economic efficiency were analyzed in such of GR (gross return), TVC (total variable cost), and RAVC (return above variable cost) by methods of Norman et al.[5]; Zandstra et al[8]; Normal and Malcolm[4].

Results and Discussion

3.1 The integrated VAC farming system established on the availability of natural and socio-economic resources

Agricultural land area in Red River Delta region is very small and averaged area per person is only from 0.04 to 0.13 ha. The Tam Diep and Nho Quan districts in Ninh Binh province have larger area, because half of these districts are mountainous. These districts in the Hai Duong and Ha Tay province (located in RRD) have agricultural land area smaller than those in Ninh Binh. Total of arable area is accounting for only from 0.04 – 0.07 ha/person (400 – 700 m^2). Since Doi Moi reform, the new agriculture land allocations to households which were changed by the policy creating a new perspective on the agricultural yield and productivity. The reason was farmers could apply new technologies and improvements in the better farming systems. Based on the availability of resources such as: land, biophysical and socioeconomic environment, farmer households seek for the best farming systems in order to optimize production and increase income for their family (Normal and Douglas[4])

Table 1: Land area and distribution of land resource in six districts

No.	District	Total land area (km^2)	Agro. land (ha)	Fruit tree land (ha)	Water area (ha)	Population (person)	Total labour (man)	Income per capita (VND/Per./year)
1	Tam Diep	106,8	7012,0	3,618	364	53,649	36,985	5.0
2	Nho Quan	458,6	16268,9	1530,6	826	148,481	85,213	4.8
3	Thanh Mien	122,3	8732,0	641,0	750	132,461	74,304	6.7
4	Binh Giang	100,0	6400,0	2920,0	780	109,000	24,000	4.7
5	Phuc Tho	117,1	6425,0	3,432	182	163,496	114,447	5.1
6	Dan Phuong	76,57	3851,1	333,8	199	2,251,552	1,080,744	6.0

Integrated farming systems refer to the production, integrated management and comprehensive combination of fish rearing, fruit gardening, and animal husbandry[6]. The VAC farming system is integrated system. Not strictly could farmer design difference systems that depend on their availability of natural resources, economics and market conditions. Availability of natural resources guarantees the number of components in the process of integrating farming technology. Existed markets are considered in such cultural and economic constraints on local consumption (Yang et al.[9]).

The households which have garden, pond, and paddy field will often design full-component VAC farming systems. Farmer households who don’t have water surface areas, and only have garden and paddy field, use VC farming system. Nowadays, there’s no more home garden and water surface area in many villages in RRD region because of population pressure that replaced most of home garden into buildings, industrial areas, or other purposes. Therefore it should be a perception to take type of difference farms based on the variety of combining three components, and those are VAC, VC, VA, AC or V, A, C farm (Table 3). As any formations as it would be, VAC farming systems are still popularly being used with high ratio over 51.4 % of total farms interviewed.

Table 2: Total farm and difference farm types in six districts surveyed in RRD region

No.	District	Total farm	VAC farm	C farm	V farm	A farm	VA farm	AC farm	VC farm
1	Tam Diep	643	100	179	206	0	72	86	0
2	Nho Quan	121	24	44	1	12	0	40	0
3	Thanh Mien	780	519	66	45	45	30	75	0
4	Binh Giang	899	715	1	0	1	0	182	0
5	Phuc Tho	155	119	0	5	3	2	26	
6	Dan Phuong	541	138	21	197	7	0	0	178
	Total	3139	1615	311	454	68	104	409	178

The farm that contained one or two components are C, V, and CA farm occupied over 10%, A, VA or VC farm occupied less than 10%. This proves that the systems combined of fruit tree gardening, animal husbandry and fish rearing is appropriate to farmer’s needs and sustainable to farming systems. The same results was found also in Mekong Delta in research program by K.Yasunobu (NARC,Japan), Nguyen.Q.Tuyen (Cantho University, Vietnam), and R.Yamada (JIRCAS, Japan).

3.2 Model of VAC farming system in RRD region

In general, designing VAC farming systems seeks way to wisely use available resources of households as land, water surface area, labor etc… Objective of the VAC farming system designing would not only be more efficient in utilizing physical resource and increasing benefit, but also in enhancing quantity and quality of the resources and environment to sustain integrated farming. Every VAC farming systems has similar characteristics that are its structural complexity and interrelationship between various components as V, A, C and other activities[11)].

Characteristics of the farm environment of farmer living in Red River Delta separated into two areas that are homestead area located in the village and the paddy field area lain outside. The fruit gardening component perhaps includes some sub- enterprises and fruit species. Secondly, the animal husbandry components are those areas for animal raising such as: pig, chicken, and cattle). The third is aquaculture production area where different kinds of fish are reared. The VAC farming systems adopted in homestead areas are often small (about 280 to 1500 m^2). The average land size of 40 VAC farms surveyed in 2008 shown that area for fruit gardening is 329.4 m^2 and for fish rearing is 306.8m^2. According to Le Thanh Luu (Agriculture report in 2001), also stated that garden is usually small, 400-500 m^2 [12)].

In recent years, many farmers have changed from traditional VAC farming system model (T_{VAC}) to modified VAC farming system (M_{VAC}) with larger land size (but smaller in comparison with the standard provided by BC Regulation, 1995 (Farm classification in British Columbia 411/95)[2)], Dixon et al.[11)], new varieties, and highly intensive investment . The VAC farming systems model positioned outside village are designed by some types of aquaculture components holding main roles in combination with sub-components which is smaller area and less economic efficiency than aquaculture (ex…orchard and livestock). Another is type of bed-ditch system, that is, fruit trees are planted on the bed combining with animal raising (ex…pig, chicken, and duck) or even apiculture, and aquaculture is taken place in the ditch. Moreover, the farming system can be the combination of industrial breeding (pig or chicken farm) with fruit gardening and aquaculture.

3.3 The economic effect of VAC farming systems

Implemented economic analysis consists of the average value of the product in each local area and component in VAC farming systems. The cost and return analysis were used to compare average returns above variable costs (RAVC). We computed average value of GR, TVC, and RAVC of households who have VAC farming systems. The results are shown in Table 3.

Table 3: Average GR and RAVC of a VAC farm in Red River Delta
(Average data of 60 HHs surveyed 2008)

District	GR (mill. VND/framily/year)	TVC (mill. VND/framily/year)	RAVC (mill. VND/framily/year)
Thanh Mien	253.54	156.37	97.16
Binh Giang	74.64	44.16	30.52
Phuc Tho	237.30	177.64	65.33
Dan Phuong	371.51	280.20	99.14
Ninh Binh	140.67	46.58	95.75

Gross return (GR), total variable cost (TVC), and return above variable costs (RAVC) are different between locals. GR is the highest in Thanh Mien with 253.54 million VND/farm/year and the lowest in Binh Giang with 74.64 million VND/farm/year. TVC shows the highest investment in Dan Phuong accounting for 280.20million

VND/farm/year. RACV also appears to be the highest in Dan Phuong with 99.14 million VND/farm/year (equal 5831.16 USD/farm/year), and the lowest RAVC in Binh Giang accounting for 44.16 million VND/farm/year (equal 2597.65 USD/farm/year).

Data analysis shows that GR and RAVC depend on (1) farming size: a large farm has achieved higher GR and RAVC than a small one, (2) higher investment on inputs brings higher RAVC, (3) aquaculture and animal husbandry are main components that raise higher GR and RAVC than the farms with these components in small size. It proves that aquaculture and livestock mainly contributed higher income and benefit of VAC farming systems. Livestock and aquaculture have faced risks of epidemic (some households gained losses due to animal and fish death). For example, Mr. Tran Xuan Lan in Trung Trau commune, Dan Phuong district, Ha Tay province raised 450 pig heads and lost 91.5 mil.VND during 2007. Mr. Le Van Quan in Dong Thap commune, Dan Phuong district, Ha Tay province raised 12,000 chicken heads and lost 62.5 mil.VND. Such a VAC farming system needs diversity even an internal diversity, a component of the homegarden, aquaculture and livestock could be less vulnerable than monoculture (Terry Cacek and Linda L. Langner, 1986 also identified seminar situation)[20].

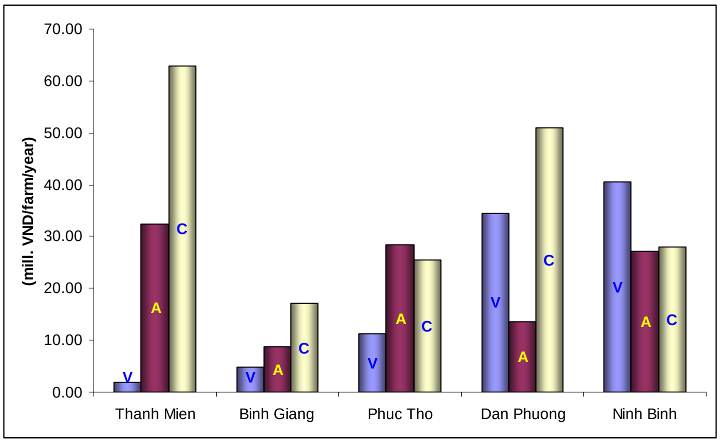

Fig. 3: RAVC of the V, A and C component in VAC farming system (Average data of surveyed farms 2008)

Besides the farms with VAC farming systems, there are farms uncompleted with three components V, A and C such as the A-C farm without V component or V-C farms without A component.

The A-C farms occupy 41.8% of total surveyed households, the land owners who have water surface area design ponds for keeping fish combining with livestock. Other farm owners tender or rent public land to build up their farms, so that the type of these farms is larger in size than T_{VAC} from 1500 m^2 to 3000 m^2. They are also good farm managers and capable of investing input with high levels, thus the benefits from these farms are also higher than those from the small farms. The investment of input (TVC value) is from 50.43 to 460.95 mil.VND/farm/y (not including land renting). Relationship between input and output in a farming system is also an indicator to identify sustainability of systems[3] therefore the farm types fast expanded and remained the stable development during last decade. RAVC of M_{VAC} farm get from 93.54 mil.VND/farm/y in Tam Diep and Nho Quan to 109.36 mil.VND/farm/y in Binh Giang district, Hai Duong province (equal \$5502.35 to \$6432.94/farm/y). the report by

MacDonald et al.[10] in United State also indicated that production of traditional program commodity crops shifted to very large farms, commodity payment also shifted sharply. Such farm types are unsuitable with poor farmers with low capital, lacking experiment and farm management skills.

Table 4: Average GR and RAVC of AC farm in Red River Delta
(Average data of surveyed farms 2008)

District	GR (Mill. VND/y)	TVC (Mill. VND/y)	RAVC (Mill. VND/y)
Tam Diep	143.97	50.43	93.54
Nho Quan	143.97	50.43	93.54
Phuc Tho	370.85	266.69	104.16
Dan Phuong	558.41	460.95	97.47
Thanh Mien	316.05	215.83	100.21
Binh Giang	308.31	198.95	109.36

There are 24 farms of V-C farming systems occupying 12.06 % that is a low ratio, these households are trying to make a living from their land with some livestock and crops, this identification suits with the studies from Norman et al.[5]. The GR, TVC and RAVC get lower than VAC and A-C farming systems. The V-A farming system is a common type of farm in some countries like in India[21], but in RRD, in Vietnam the V-A farm is rarely used, surveying 199 HHs, there are only five farmers who apply this model. Because these farm types get low benefit (RAVC only get from 12.02 mil. VND/farm/y to 33.50 mil.VND/farm/y).

Table 5: Average GR and RAVC of one VC and VA farm in Red River Delta
(Average data of surveyed farms 2008)

District	GR (Mill. VND/y)	TVC (Mill. VND/y)	RAVC (Mill. VND/y)
VC farm			
Tam Diep	196.59	109.70	86.89
Nho Quan	20.83	8.82	12.02
Phuc Tho	120.73	69.14	51.59
Dan Phuong	361.00	301.41	59.59
VA farm			
Dan Phuong	91.15	28.65	62.50
Tam Diep	102.00	68.50	33.50

3.3.1 Garden (V) component in VAC farming system

Garden production has played a role as a central part of biology, economics and environment in VAC farming system and it may affect other parts of the system. In RRD region the farmers have used different crops to grow in their homegarden depending on the dominant condition. Le Thanh Luu[12] .We also recorded the gardens with small size, 400-500 m^2 in lowland which were planted with some kinds of fruit crops such as banana, orange, papaya, peach, litchi, longan and apple. In many suburban family gardens, ornamental trees and flowers are planted to gain high income. Vegetable crops are grown in the gardens such as intercrops including green onion, sweet potato, cress, tomato, and cabbage and water spinach. The survey data identifies that garden crops can be classified into two groups which are perennial and annual crop groups planted in the gardens. The perennial crops commonly planted in three provinces are different and also brought different benefit Some crops have brought low benefit thus price- cutting like litchi(*Litchi chinensis* Sonn.), shaddock (*Citrus maxima* Merr.) and longan (*Dimocarpus longan* Lour.). The crops that require high input, techniques, and high demands from the local market bring higher benefit for farm owners such as peach flower, ornamental plant, Huong chi (HC) longan (new variety), Canh orange (*Citrus sinensis* L.), papaya (*Carica papaya* L.) etc. The same kind of crops can bring different benefits. If a place supplies the demand of local market unresponsively the garden products there will get higher benefits. For example, shaddock in Ha Tay gets RAVC from 12.3 -12.8 mil. VND/ha/y (724. – 753.0 USD/ha/year), whereas in Ninh Binh the farmers receive 91.7 million VND/ha/year (5,394 USD/ha/year) because they can sell at higher prices than those in Ha Tay. The special fruit trees with harvested time earlier or later compared with common harvested time could bring farmers higher benefits. For example, Tran Quang Binh in Ha Tay province has 0.97 ha of later maturing longan and gains RAVC of 16 mil.VND/farm/y (equal 941.2 USD/ha/year), Nguyen Van Thich grows 1.44 ha and gets RAVC of 20 mil.VND/farm/year (equal 1176.5 USD/ha/year). Garden planted with mono-crop shows a higher benefit than mixed-crop planting as in Ha Tay province shaddock planted mono-crop in the garden can provide RAVC of 50.83 mil.VND/ha/year (2990 USD/ha/year), whereas mixed-crop planting in both of these provinces has RAVC of 7.53 mil.VND/ha/year (442.94 USD/ha/year). Some intercrops in the garden bring high benefit as chili has the highest RAVC which are 67.37 mil.VND/ha/year. (Equal 3962 USD/ha/year), some intercrops in the garden are input for other components (feed for fish or animal as elephant grass). Other intercrops are self-sufficient in family. The area which can be used for intercrops includes about 10% of fruit tree garden area in young fruit tree period.

The comparison between the orchard and rice production in the paddy field shows that the rice production has a high yield from 5.4 to 7.2 t/ha in spring season and 4.8 to 5.5 t/ha in summer season. The average GR of 199 households surveyed is 32.40 mil.VND/ha/ha and RAVC is 24.17 mil.VND/ha/ha (equal 1422 USD/ha) in spring season and RAVC is 18.72 mil.VND/ha/ha (1010 USD/ha/year) in summer season. If a fruit tree garden is planted with mono-crop and intensive cultivation, it will provide higher benefit than rice production.

3.3.2 Aquaculture (A) component in VAC farming system

Aquaculture has been practiced in many Asian countries (Alex Bocek)[1), furthermore fishery products supply half of the protein requirement for the population and rank the third as a foreign currency earner in Vietnam[22)] Aquaculture component in VAC farming systems is divided into two size levels which are: (1) Ponds lie in homestead boundary, this model has a close link among house – garden – pond and animal stable. Fish pond area is often smaller than 1000 m^2. (2) Other fish ponds or Small Lakes are located outside homestead because farm owners tender the ponds or small lakes which belong to community property, in some cases, farm owners expand farming land by exchanging or hiring land from other farmers in the commune to build AC or VAC farm. This type of farm has a larger size and needs high input, other investment, and farm owners must have good experience and management skills. In surveyed locals, aquaculture by mixing many fish species, main species are grass-carp (*Ctenopharyngodon idella*), Common carp (*Cyprinus carpio*), Bighead carp (*Hypophthalmichthys nobilis*), Black carp (*Mylopharyngodon piceus*), Mud carp or major carp (*Cirrhinus molitorella*) and African carp (*Labeo coubie*). The combination of some fish species make the best volume area of a fishpond which consists of water layers of surface, middle and bottom. Alex Bocek recorded that culturing several different fish species together with complimentary feeding habits in the same pond (multi-culture) is more complicated, but utilizes more available natural food organisms. Higher yields are thus obtainable with Multi-culture rather than by culturing a single fish species. Multi-culture also permits several different species that may command different market prices to be grown. A range of consumer tastes and demands may thus be served from one pond[1]). The benefit of aquaculture component in VAC farming systems with high level, fish farming contributes to GR from 19.7 to 25.0% of total gross return of VAC farming system as illustrated in Fig 4.

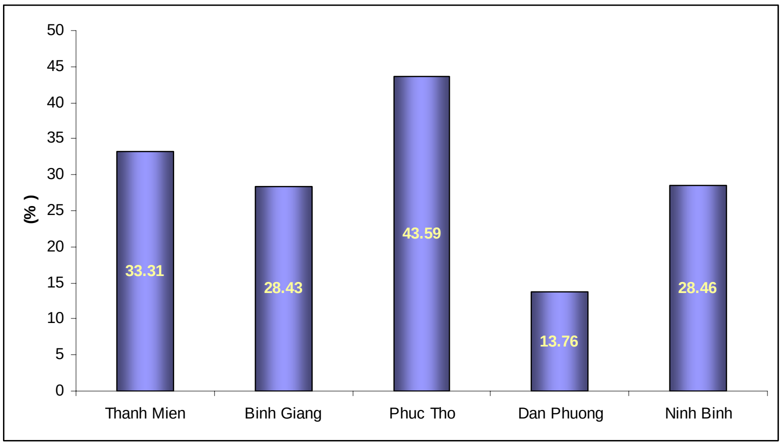

Fig. 4: RAVC ratio of aquaculture component contributed to RAVC of VAC farming systems (Average data of surveyed farms 2008)

3.3.3 Livestock (C) component in VAC farming system

The livestock is an integral production, nowadays there are two manners which are household husbandry hereafter called traditional animal husbandry (TAH) and animal farm hereafter called industry animal husbandry (IAH). In the VAC farming system there are also two manners mentioned above. TAH applied in small farms and in all VAC farming systems are located in homestead boundary and IAH has a larger size. Livestock farming (C) component contributes high benefit to VAC farming system from 14.37 to 40.36 % RAVC of VAC farming systems. Three locals which get the highest RAVC from C component are Ninh Binh (60.11%), Thanh Mien (40.26%) and Binh Giang (38.64%). This indicates that in Red River Delta region with high population, a small arable area from 400 to 700 m^2/person, the husbandry keeps a very important role in farmer's livelihood. This results is a seminar situation in other developing countries like Nepal, the contribution of livestock component to the Nepalese economy has been estimated as 21% of total agricultural output[19]).

There are some kinds of animals which are raised in the C component as pig, chicken, cow, swan, duck etc. but pig is the most common animal. The number of households raising pig occupies 66.83%, raising chicken is 39.19% and keeping duck is 19.09% of the 199 households surveyed. Husbandry bring high income for households; Raising pig widely spreads and gets the highest RAVC but quite different among survey districts, pig farming, either by the backyard system or by the Vuon – Ao – Chuong (VAC) systems[18)].

Thanh Mien district has an average 71of pig heads/HH and RAVC are 47 mil.VND/HH/yr (equal 2764.8 USD/HH/yr). Binh Giang district with the average number of pig heads is 81 heads/HH/yr gets 66.3 mil.VND/HH/yr (equal 3899.9 USD/HH/yr), Tam Diep achieves 55.33 mil.VND/HH/yr (equal 3254.9 USD/HH/yr), Nho Quan get 113.70 mil.VND/HH/yr (equal 6688.4 USD/HH/yr), Phuc Tho gains 28.52 47 million VND/HH/yr (equal 1677.5 USD/HH/yr), Dan Phuong gets the lowest RAVC which is 16.0647 mil.VND/HH/yr (equal 944.7 USD/HH/yr). Ha Tay has lower RAVC from pig raising because of epidemic diseases, especially, Porcine Reproductive Respiratory Syndrome disease (PRRS) has occurred recent years in Vietnam. Farms raising chicken also face risk seminar that is disease of H5N1 virus. For example, in Nho Quan the average amount of fund which each chicken farm loses is up to -23.17 mil.VND/farm/yr (equal 1352.94 USD/farm/yr).

3.4 The biological effectiveness of VAC farming system

The strong point of VAC farming system is that it makes a closed biological flow cycle from garden to animal stable and to pond, the products or waste of this component are inputs of other components.

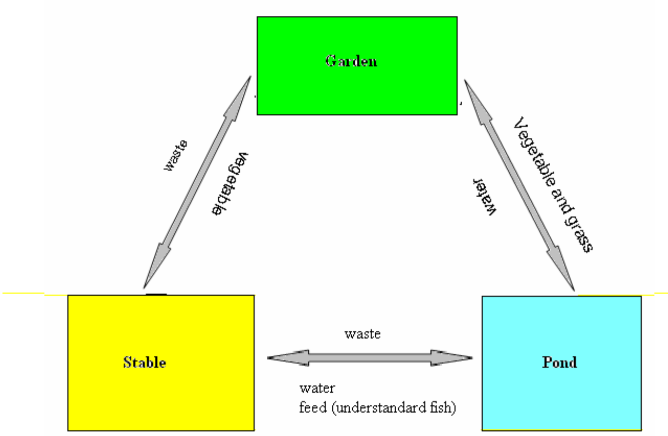

Fig. 5: Biological flow of VAC farming systems

The waste from livestock component is input for garden and fish, our studies indicate that a household raising 2 pigs can collect an average 1 - 1.5 kg of waste per day from the first to the third month and from the third to the fifth month can collect 2.5 to 3 kg of waste per day. Total quantity of waste from pig raising supplies garden and pond with 1,542.2 kg/farrow without additive material as grass or water hyacinth (*Eichnoria* Kunth*)* and can get 1,836 kg/farrow if additive material is supplied, the study of S.D.Tripathi and B.K. Sharma, 2001 also received similar results[21)]. The garden products could supply input to other components as elephant grass (*Pennisetum purpureum*) supplied feed for cattle and fish so that it has expanded during recent years. An Average yield of elephant grass in the garden can get 7.5 to 9 t/ha/yr depending on species of fruit tree with their planting distance (Huazhu Yang et all indicated grass species, which can easily be produced on the farm, can serve as low-cost supplemental feed for fish[9]). The potential advantages of establishing mixtures of fodder tree species on farms when developing new feeding systems have been described by Rosales and Gill[15)]

Wastes from livestock component and elephant grass supplies input to other components and through the recycling of otherwise unused wastes as renewable resources as garden soil and pond water[7]. According to the study by Trach[16] the animal farms with large size will make the environment polluted if there are not any gardens and ponds to reuse their waste. Pig-grass-fish integration is widely practiced and has good economic returns depending on labor costs.

Conclusion

Integrated VAC farming systems prove an approach towards sustainable agricultural development, there is an excellent farming system which is suitable to agro-ecosystem throughout the North of Viet Nam, this system generates not only more goods for the society, but also more income and employment for farmer families. Recently years, VAC farming systems have been moved from traditional model to VAC model towards market with lager size, high input investment and intensive cultivation so that they have brought higher GR and RAVC in comparison with the traditional model.

There are some forms of VAC farms such as VAC , VA, VC, AC farms, but VAC farming systems are still the main ones keeping high ratio of over 51 % of farm in total of 6 surveyed districts. The AC farms occupy 41.8% of surveyed household in total. Benefit of VAC farming system is different among locals depending on physical, Scio-economic conditions and farmer capacities, the highest benefit which the farmers can get is RAVC of 99.14 mil.VND/farm/year (equal 5,831.76 USD/farm/year) and the lowest benefit is 30.52 mil.VND/farm/year (equal 1,795.29 USD/farm/year). This benefit is 2 times as high as the income per capita of RRD region. AC farms also get RAVC of high level from 93.54 to 109. 36 mil.VND/farm/year (equal 5502.35 to 6432.94 USD/farm/year).

Garden component has an important role in the VAC farming systems on the biological, economical and environment area. Different crops grown in garden depend on the local dominant condition but include perennial fruit trees with annual crop. The garden planted mono-crop shows more economic efficiency than mixed-crop. The Fruit garden enterprise develops a noticeable step in VAC farming system.

Aquaculture component in VAC farming systems is divided into two size levels which are small pond in the homestead boundary, this model has closing link among house – garden – pond and animal stable. The second one is ponds or Small Lakes located outside homestead because farm owners tender ponds or small lakes belonging to community property, this form has larger farm size and needs high input and investment. There are some kinds of fish species which are kept in the pond. The aquaculture component contributes to GR from 19.68 to 25% of total gross return of VAC farming system and from 13.76 % to 43.59% of RAVC in total of VAC farming systems.

The livestock is an integral production system, in which nowadays there are two manners of traditional animal husbandry (TAH) and animal farm (IAH). In the VAC farming system, there also exist two mentioned manners. TAH can be applied in small farms and all VAC farming systems located in homestead boundary and IAH has a larger size. Livestock farming (C component) contributes high benefit to VAC farming system from 14.37 to 40.36 % RAVC of VAC farming systems. There are many kinds

of animal husbandry in the C component of VAC farming systems such as pig, chicken, cow, swan, duck etc. But the most common animals are pig, chicken and duck.
The strong point of VAC farming system is that it makes a closed biological flow cycle from garden to livestock, pond component and return. The combination of V, A and C also reduces input cost and increases economic efficiency

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Population Structure of Rice Sheath Blight Pathogen, *Rhizoctonia solani* AG1-IA, by Rep-PCR and ITS Sequence in Red River Delta, Vietnam

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Abstract

Representative isolates of 25 *Rhizoctonia solani* AG1-IA associated with rice sheath blight were examined for rep-PCR fingerprinting variations and sequence variations in the ITS-5.8S rDNA region. The isolates were collected in rice-growing irrigated paddy fields in Red River Delta, Vietnam. Isolates were maintained in the growth chamber at 25ºC for 2 weeks until use. Assay of rep-PCR was subjected to the two primers evaluations, ERIC2 and BOXA1R, respectively. Moreover, sequences of these isolates were aligned with other known *R. solani* sequences from the NCBI and GenBank and distance and parsimony analysis were used to obtain population structures. Clonal population of *R. solani* AG-1 IA, causal agent of rice sheath blight, were presented at the two distinct groups (Rep-Vet1 and Rep-Vet2) based on the fingerprinting dendrograms with the similarity coefficient score at 75% differentiations. Geographical relationships of the clonal population such as the two distinct groups were not presented. However, these two subgroups including clonal populations of Rep-Vet1 and Rep-Vet2 were divided into different clade separated from known AG1-IA subgroups based on sequencing analysis. Vietnam AG1-IA Isolates collected from Red River Delta presented not correlation of geographical distribution but dispersals in the collection area by analyzing of their clonal population structures.

Introduction

Rhizoctonia sheath disease of rice, comprising sheath blight, cause significant yield losses in many rice-growing regions of the world (Johanson et. al., 1998; Kobayashi et. al., 1997). The emergence of Rhizoctonia sheath disease is recent and has been attributed to the intensification of rice-cropping systems with the development of new short-stature, high-tillerilng, high-yielding varieties; high plant densities; and an increase in nitrogen fertilization. These factors promote disease spread by providing a favorable microcrimate for *Rhizoctonia* species due to a dense leaf canopy with an increased leaf-to-leaf and leaf-to-sheath contact (Banniza et. al., 1999; Savary et. al., 1995).

Rice sheath blight (SB), one of the most serious fungal diseases of rice, is caused by multinucleate *R. solani* Kuhn that are soilborne Basidiomycete fungus *Thanatephorus cucumeri*s, a ubiquitous pathogen and cause economically important disease on rice crops throughout the world (Jones and Belmar, 1989). Isolates of R. solani AG1-IA have been associated with the development of rice SB (Banniza et. al., 1999; Gangopadhay and Chakrabarti, 1982). This pathogen produce lesion on the leaf sheath and is known to occur in California, Argentina, and East Asia including Vietnam (Gunnell and Webster, 1984; Johanson et. al., 1998). In addition to the disease occurrence, distinguishing the various *Rhizoctonia* species in culture is difficult due to the lack of stable morphological characters on which to base a definitive classification of the *Rhizoctonia* species. Also, identification of *R. solani* AG1-IA based on anastomosis grouping on a slide is not accurate because isolates of AG1-IA fuse with other AG1 isolates (Ogoshi, 1987).

Isolates of *R. solani* AG1-IA associated SB have been the subject of different diversity and population studies, in which variation has been measured using pathogenicity tests (Neeraja et.al., 2002), morphological characteristics (Vijayan and Nair, 1985), enzymes and proteins (Mohammadi et. al., 2003), cellular fatty acids (Stevens Johnk and Jones, 1994), RFLPs (Rosewich et. al., 1999) and simple-sequence repeat PCR (Banniza and Rutherford, 2001). The species concept for *R. solani* AG1-IA has been poorly defined in the past and it has been unclear whether different molecular subgroups represent different species or populations (Cubeta et.al, 1996).

Previous investigations support the hypothesis that isolates of AG1-IA causing SB display high genetic diversity (Banniza and Rutherford, 2001; Rosewich et. al., 1999). In a recent population genetic study of *R. solani* AG1-IA from India that was based on RFLP and Rep-PCR, results were consistent with small genetic distances among populations and high levels of gene flow (Linde et. al., 2005). Moreover, in a previous population genetic study from Texas and Brazil based on RFLP markers, results were consistent with a high degree of gene blow between populations and regular outcrossing within field populations (Rosewich et. al., 1999; Zala et. al., 2007). Prior to these finding, the perception was that *R. solani* AG1-IA is a mostly asxual fungus, with dissemination over relatively short distances by natural movement of asexual propagules (sclerotia), and over longer distances via movement of contaminated machinery, seed, or irrigation water.. However, the methods that have already been used to study rice sheath disease often lack adequate discriminatory power and the reproducibility of some genetic population study such as RFLP markers is poor (Lynchi and Milligan, 1994). Consequently, it is necessary to establish high sensitive and reliable genomic typing methods for Rhizoctonia isolates.

The repetitive element PCR (Rep-PCR) method is based on random amplification of amplification fragments generated from total genomic DNA. This Rep-PCR fingerprint technique is more effective at distinguishing clones than the RFLP fingerprint probe used by Resewich et. al. (1999). Therefore, we investigated whether Rep-PCR could be adapted for fingerprinting and genetic structure analysis of *Rhizoctonia* species isolates obtained from rice in Vietnam. The objectives of this study were to determine which clonal populations are associated with pathogenicity to rice sheath in Vietnam, and to determine population genetic structure of *R. solani* AG1-IA from Vietnam, with subsequent comparisons to other clone populations. Information on dispersal (gene and genotype flow) and mode of reproduction could influence the current control and management strategies for rice SB in Vietnam.

Materials and Methods

Isolates

Infected leaves were collected from rice plants showing characteristics symptoms of sheath blight. Leaf and sheath samples were plated on 2% Water agar plates and hyphal tips from subsequent *Rhizoctonia* growth was transferred to Potato dextrose agar (PDA) after 24 h to isolate *R. solani* AG1-IA. Sclerotium production was documented after 12 days of growth on PDA. Samples from three rice fields in North Vietnam, Red River Delta, were collected using transecting sampling. Samples were collected at locations distributed approximately every 50 m along a transect in each rice field. A simple usually consisted of a single rice tiller which either had sheath blight lesions on the sheath/pseudostem, or the leaves, or both. The sampled tillers had green leaves and were in later tillering or flowering stage of the crop. One of the rice fields was collected from Ha Tay, Ha Nam and Bao Ninh, where those places placed in the center of Hanoi, along with Red River Delta in Vietnam (Fig. 1). The rice fields from Ha Tay, Ha Nam and Bao Ninh were geographically distant to each other, separated by ~ 10km in a rice-growing area planted to thousands of hectors.

DNA extraction and Rep-PCR

For each isolate, scraped mycelium from 5-week-old cultures grown on PDA amended with 50 µg l^{-1} kanamycin was added to 40 ml of PDB (also amended with 50 µg l^{-1} kanamycin) and incubated in an Erlenmyer flask on a rotary shaker at 20ºC. Mycelium was harvested after 5 days and freeze dried. DNA was extracted from the lyophilized tissue with the DNeasy Plant Mini DNA extraction kit (Qiagen, Hilden, Germany) according to the specifications of the manufacturer. Clonal populations were differentiated using Rep-PCR fingerprinting with primers ERIC2F and BOXA1R (Linde et.al., 2003), which provided clear, easily scored banding patterns, instead of the RFLP fingerprint probe, R18, used in the Rosewich et. al. (1999) study, which had a high background hybridization signal and was difficult to interpret. Allele designations in this experiment followed the previous RFLP study on *R. solani* (Rosewich et.al., 1999). Isolates having the same multilocus RFLP and Rep-PCR patterns were considered members of the same clonal lineage.

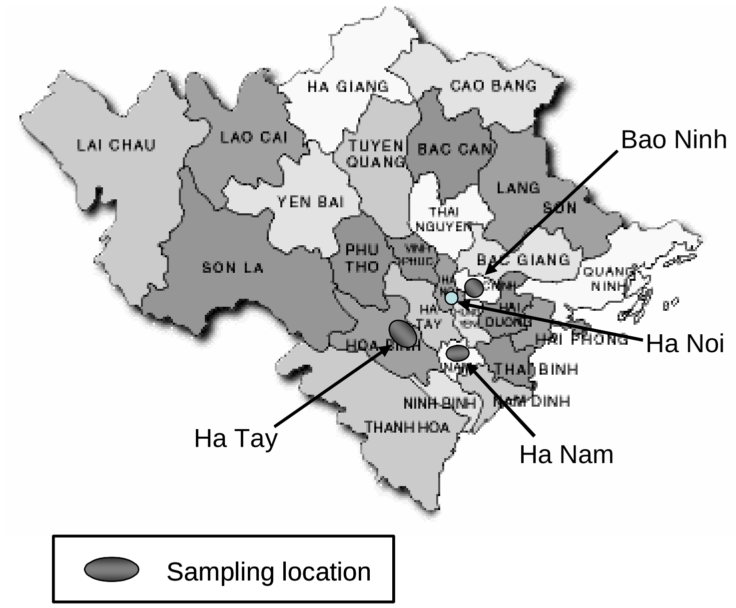

Fig. 1. Geographic locations of the three Rhizoctonia solani AG-1 IA fields (provinces) populations sampled in North Vietnam

Rep-PCR fingerprint analysis

For visual comparison of rep-PCR fingerprints generated from *R. solan*i AG 1 IA clonal populations, similarity dendrograms were constructed using the unpaired group method of analysis (Sokal and Sneath, 1963). Differences of dendrograms with respect to the proportion of isolates having all replicate fingerprints clustered together, without interposition of fingerprints from other isolates, were evaluated using McNemar's test. A isolate's similarity index under a particular set of conditions was calculated as the mean of the similarity coefficients for all pairwise combinations between different replicates of that isolate as tested under standard conditions (high values = better same-strain reproducibility). Means for these indices was calculated across the obtained isolates for each set of conditions, and a paired t test was used to compare these indices between conditions, with individual isolates serving as the unit of analysis. The threshold for statistical significance was a P value of < 0.05.

Sequence analysis for molecular identification

The rDNA internal transcribed spacer (ITS including 5.8S rDNA) sequences were determined for the isolates where subgroups identification was in conduction because of the confirmation of rep-PCR fingerprintings. In total, 2 isolates were sequenced using primers ITS1 and ITS4 (White et. al., 1990). Sequencing was performed on an ABI 3100 Sequencer using Taq-Cycle automated sequencing with DyeDeoxy Terminators (BigDyeTM Terminator v3.0 Cycle Sequencing Ready Reaction; Applied Biosystems) with both primers to ensure reliability of the sequence data. Sequences were assembled and aligned using SequencherTM 4.1 (Gene Codes Corporation, Ann Arbor,k MI). BLAST serchers (Altschul et. al., 1997) were done against the NCBI/GenBank databases.

Results and Discussion

In the present study, total 46 strains of *R. solani* AG1-IA were isolated from the different three sample collection sites, Ha Tay, Ha Nam, and Bao Nihn province, respectively and listed in Table 1. Sampling was conducted at July – August in 2007 and weather condition is humidity and hot season. Among 46 strains of R. solani AG1-IA from Red River Delta in Vietnam, 17 strains from Ha Tay, 15 strains from Ha Nam, and 14 strains from Bao Ninh province, were obtained and stocked. These strains were occupied by Dr. Cuong belonged to Hanoi University of Agriculture in Vietnam and Dr. Matsumoto belonged to Institute of Tropical Agriculture, Kyushu University in Japan, respectively. These strains were stored and maintained at room temperature in Hanoi University and Kyushu University until use. In this experiment, 24 strains of *R. solani* AG1-IA were used for rep-PCR assay and 5.8S-rDNA sequencing.

Rep-PCR assay was conducted for differentiation and characterization of clonal populations of R. solani AG1-IA strains in Red River Delta, Vietnam. Different sizes of ladder bands were obtained by using the two primers which were generated at 11 bands with BOX1AR and 10 bands with ERIC2R, respectively. Comparison of rep-PCR fingerprinting generated from Vietnam strains revealed that two distinct subgroups were observed by the values of similarity index at 75% (Fig. 2.) and named as rep-Vet1 and rep-Vet2 (Fig. 2.). The occurrence of diversion of the two subgroups would be responsible for the existence of differential clonal populations in Vietnam strains. Moreover, clonal population structures of *R. solani* AG1-IA strains in Red River Delta, Vietnam formed low level correlation with geographic distributions but deep relations with their dispersal existences in this experiment.

Differentiation of rep-PCR fingerprintigs for rep-Vet1 and rep-Vet2 was also correlated with their differences of morphological characteristics that are showed by culturing strains mycelia (data not shown). Morphological characteristic of rep-Vet1 is formed large sizes of sclerotia that are shown

Table 1. Lists of *Rhizoctonia solani* AG1-IA isolates from Red River Delta, Vietnam

Accession Num.	Isolate Name	Sample Location	Occupation
RSNVT07001	HT-07001	Ha Tay	H.V. Cuoung
RSNVT07002	HT-07002	Ha Tay	H.V. Cuoung
RSNVT07003	HT-07003	Ha Tay	H.V. Cuoung
RSNVT07004	HT-07004	Ha Tay	H.V. Cuoung
RSNVT07005	HT-07005	Ha Tay	H.V. Cuoung
RSNVT07006	HT-07006	Ha Tay	H.V. Cuoung
RSNVT07007	HT-07007	Ha Tay	H.V. Cuoung
RSNVT07008	HT-07008	Ha Tay	M. Matsumoto
RSNVT07009	HT-07009	Ha Tay	M. Matsumoto
RSNVT07010	HT-07010	Ha Tay	M. Matsumoto
RSNVT07011	HT-07011	Ha Tay	M. Matsumoto
RSNVT07012	HT-07012	Ha Tay	M. Matsumoto
RSNVT07013	HT-07013	Ha Tay	H.V. Cuoung
RSNVT07014	HT-07014	Ha Tay	H.V. Cuoung
RSNVT07015	HT-07015	Ha Tay	H.V. Cuoung
RSNVT07016	HT-07016	Ha Tay	M. Matsumoto
RSNVT07017	HT-07017	Ha Tay	M. Matsumoto
RSNVT07018	HN-07001	Ha Nam	H.V. Cuoung
RSNVT07019	HN-07002	Ha Nam	H.V. Cuoung
RSNVT07020	HN-07003	Ha Nam	H.V. Cuoung
RSNVT07021	HN-07004	Ha Nam	H.V. Cuoung
RSNVT07022	HN-07005	Ha Nam	H.V. Cuoung
RSNVT07023	HN-07006	Ha Nam	H.V. Cuoung
RSNVT07024	HN-07007	Ha Nam	M. Matsumoto
RSNVT07025	HN-07008	Ha Nam	M. Matsumoto
RSNVT07026	HN-07009	Ha Nam	M. Matsumoto
RSNVT07027	HN-07010	Ha Nam	M. Matsumoto
RSNVT07028	HN-07011	Ha Nam	H.V. Cuoung
RSNVT07029	HN-07012	Ha Nam	H.V. Cuoung
RSNVT07030	HN-07013	Ha Nam	H.V. Cuoung
RSNVT07031	HN-07014	Ha Nam	H.V. Cuoung
RSNVT07032	HN-07015	Ha Nam	H.V. Cuoung
RSNVT07033	BN-07001	Bao Ninh	H.V. Cuoung
RSNVT07034	BN-07002	Bao Ninh	M. Matsumoto
RSNVT07035	BN-07003	Bao Ninh	M. Matsumoto
RSNVT07036	BN-07004	Bao Ninh	M. Matsumoto
RSNVT07037	BN-07005	Bao Ninh	M. Matsumoto
RSNVT07038	BN-07006	Bao Ninh	M. Matsumoto
RSNVT07039	BN-07007	Bao Ninh	M. Matsumoto
RSNVT07040	BN-07008	Bao Ninh	H.V. Cuoung
RSNVT07041	BN-07009	Bao Ninh	H.V. Cuoung
RSNVT07042	BN-07010	Bao Ninh	H.V. Cuoung
RSNVT07043	BN-07011	Bao Ninh	H.V. Cuoung
RSNVT07044	BN-07012	Bao Ninh	M. Matsumoto
RSNVT07045	BN-07013	Bao Ninh	M. Matsumoto
RSNVT07046	BN-07014	Bao Ninh	M. Matsumoto

the black and dark brown colored, on the other hand, rep-Vet2 showed no formation of sclerotia in this experiment. Moreover, mycelial characterization of the two clonal populations were formed the white colored mycelia of rep-Vet1 and the light brown color mycela of rep-Vet2, respectively (data not shown). Hyphal growth speed is also investigated with the two clonal populations of rep-Vet1 and rep-Vet2 that are differed and faster the rep-Vet1 strains compared to the rep-Vet2 strains in this experiment (data not shown).

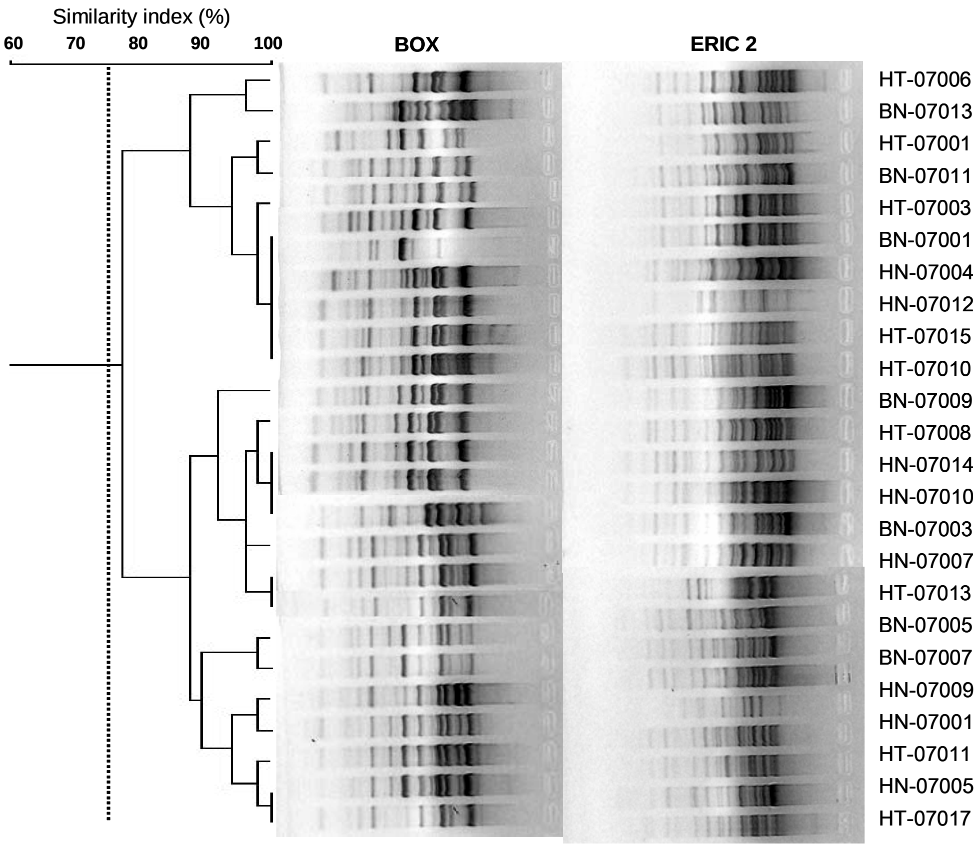

Fig. 2. Clonal genetic phyenotypes of two distinct groups of *R. solani* AG-1 IA strains in North Vietnam based on the similarity of bands patterns generated from rep-PCR fingerprints and clustered using UPGMA methods.

rDNA-ITS sequencing analysis of the rep-Vet1 and rep-Vet2 strains in Vietnam revealed that these showed at 96.7% similarity of homological index, while *R. solani* AG1-IA isolates from Japan showed at a 95.5% similarity of homological index, respectively (Fig. 3.). Phylogenetic analysis based on their sequence similarity of rDNA-ITS regions from *R. solani* AG1-IA in Japan and Vietnam results the geographically districted between Japan and Vietnam strains and two clonal populations of rep-Vet1 and rep-Vet2 were divergent and formed the specific clades in this experiment. Length of nucleotide sequence of *R. solani* AG1-IA strains displayed the 637-638bp and their comparison based on the maximum marching tests resulted high component (more than 90%) and geographically specific existence and dispersals in Red River Delta, Vietnam.

In the Texas study, clones were identified in populations separated by up to 280 km (Rosewich et al., 1999). In our study, clones were no shared among populations after clone identification using rep-PCR fingerprintings (Fig. 3). If only the RFLP multilocus haplotypes were considered, then some clones were found to b3 shared among populations. These findings could indicate that the rep-PCR fingerprint technique utilized in this study is more effective at distinguishing clones than the RFLP fingerprint probe used by Rosewich et al. (1999). Another possibility is that man-aid dispersal of sclerotia is more common in Texas than in Vietnam. Many similarities were found between the *R. solani* AG-1 IA populations from Texas, India and Vietnam. Those indicate evidence for short-distance asexual propagule dispersal, possible long-distance dispersal of basidiospores (leading to high levels of gene flow regionally), sexual reproduction, and persistence of successful clones in sub-populations (as seen by excess heterozygosity and occurrence of clones). *R. solani* from rice also appeared to be a genetically homogeneous group, although two distinct groups of rep-Vet1 and rep-Vet2 were found to be involved in the disease in North Vietnam. The main difference between the two distinct groups was that clones were shared geographically in the Red River Delta, North Vietnam, while some shared clones were found dispersedly among Vietnam populations.

```
AT0711~1      1 AATTTTATTA ATGAGGAGTT GAGTTGTTGC TGGCCTTTTC TACCTTAATT    50
RSNVT0~1      1 AATTTTATTA ATGAGGAGTT GAGTTGTTGC TGGCCTTTTC TACCTTAATT    50
RSNVT0~2      1 AATTTTATTA ATGAGGAGTT GAGTTGTTGC TGGCCTTTTC TACCTTAATT    50

AT0711~1     51 TGGCAGGAGG GGGCAGGTGC CCCCCTTCTC TTTCATCCAT CACACCCCCT   100
RSNVT0~1     51 TGGCAGGAGG GG-CATGGGC ACCCCTTCTC TTTCATCCAT CACACCCCCT   100
RSNVT0~2     51 TGGCAGGAGG GGC-ATGTGC ACACCTTCTC TTTCATCCAT CACACCCCCT   100

AT0711~1    101 GTGCACTTGG GAGACAGCAA TAGTTGGGGG ATTTAATTCC ATC--CCATT   150
RSNVT0~1    101 GGGCACTTGG GAGACAGCCA TAGTTGGTGG AATTAATTCC ATCATCCATT   150
RSNVT0~2    101 GTGCACTTGT GAGACAGCAA TAGTTGGTGG ATTTAATTCC ATCATCCATT   150

AT0711~1    151 TGCTGTCTAC TTAATTTACA CACACTCTAC TTAATTTAAA CTGAATGTAA   200
RSNVT0~1    151 TGCTGTCTAC CTAATTTACC CACACTCTAC TTAATTTAAA CTGAATGTAA   200
RSNVT0~2    151 TGCTGTCTAC TTAATTTACA CACACTCTAC TTAATTTAAA CTGAATGTAA   200

AT0711~1    201 TTGATGTAAC GCATCTAATA CTAAGTTTCA ACAACGGATC TCTTGGCTCT   250
RSNVT0~1    201 TTGATGGAAC GCATCTAATA CTAAGTTTCA ACAACGGATC TCTTGGCTCT   250
RSNVT0~2    201 TTGATGTAAC GCATCTAATA CTAAGTTTCA ACAACGGATC TCTTGGCTCT   250

AT0711~1    251 CGCATCGATG AAGAACGCAG CGAAATGCGA TAAGTAATGT GAATTGCAGA   300
RSNVT0~1    251 CGCATCGATG AAGAACGCAG CGAAATGCGA TAAGTAATGT GAATTGCAGA   300
RSNVT0~2    251 CGCATCGATG AAGAACGCAG CGAAATGCGA TAAGTAATGG GAATTGCAGA   300

AT0711~1    301 ATTCAGTGAA TCATCGAATC TTTGAACGCA CCTTGCGCTC CTTGGTATTC   350
RSNVT0~1    301 ATTCAGTGAA TCATCGAATC TTTGAACGCA CCCTGCGCTC CTTGGTATTC   350
RSNVT0~2    301 ATTCAGTGAA TCATCGAATC TTTGAACGCA CCTTGCGCTC CTTGGTATTC   350

AT0711~1    351 CTTGGAGCAT GCCTGTTTGA GTATCATGAA ATCTTCAAAG TAAACCTTTT   400
RSNVT0~1    351 CCTGGAGCAT GCCTGTTTGA GTATCATGAA ATCTTCAAAG TAAACCTTTT   400
RSNVT0~2    351 CTTGGAGCAT GCCTGGTTGA GTATCATGAA ATCTTCAAAG TAAACCTTTT   400

AT0711~1    401 GTTAATTCAA TTGGTC-TTT TTTACTTTGG TTTTGGAGGA TCTTATTGCA   450
RSNVT0~1    401 GGTAATTCAA TTGGT-CTTT TTTACTTTGG TTTTGGAGGA TCTTATTGCA   450
RSNVT0~2    401 GGTAATTCAA TTGGTCTTTT TTTACTTTGG TTTTGGAGGA TCTTATTGCA   450

AT0711~1    451 GCTTCACACC TGCTCCTCTT TGTGCATTAG CTGGATCTCA GTGTTATGCT   500
RSNVT0~1    451 GCTTCACACC TGCTCCTCTT TGTGCATTAG CTGGATCTCA GTGTTATGCT   500
RSNVT0~2    451 GCTTCACACC TGCTCCTCTT TGTGCATTAG CTGGATCTCA GTGTTATGCT   500

AT0711~1    501 TGGTTCCACT CGGCGTGATA AGTTATCTAT CGCTGAGGAC ACCCGTAAAA   550
RSNVT0~1    501 TGGTTCCACT CGGCGTGATA AGTTATCTAT CGCTGAGGAC ACCCGTAAAA   550
RSNVT0~2    501 TGGTTCCACT CGGCGTGATA AGTTATCTAT CGCTGAGGAC ACCCGTAAAA   550

AT0711~1    551 AAGGTGGCCA AGGTAAATGC AGATGAACCG CTTCTAATAG TCCATTGACT   600
RSNVT0~1    551 AAGGTGGCCA AGGTAAATGC AGATGAACCG CTTCTAATAG TCCATTGACT   600
RSNVT0~2    551 AAGGTGGCCA AGGTAAATGC AGATGAACCG CTTCTAATAG TCCATTGACT   600

AT0711~1    601 TGGACAATAT TCTATTTTAT GATCTGATCT CAAATCAGG- ..........   650
RSNVT0~1    601 TGGACAATAT TCTATTTTAT GATCTGATCT CAAATCAGG- ..........   650
RSNVT0~2    601 TGGACAATAT TCTATTTTAT GATCTGATCT CAAATCAGGT ..........   650
```

Fig. 3. Sequence data of rDNA-ITS regions of *R. solani* AG-1 IA in North Vietnam two distinct groups and Japan 1 strains

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Effects of Rice Cultivation on Water Quality and Diatom Species Composition in a Paddy Field at Hanoi University of Agriculture

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Abstract: Recently, eutrophication of water has become a serious environmental problem in low-lying agricultural area of Vietnam. The present study aims to investigate the relationship between water quality and attached diatom species composition in and around an experimental paddy field at Hanoi University of Agriculture. Water quality items of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, redox potential (Eh), NH_4-N, NO_3-N, PO_4-P and temperature were monitored once a week from the end of July to beginning of October in 2007 in five sites of the experimental paddy fields. At the same sampling sites, attached diatom species composition was investigated once a fortnight. Water quality based on diatom species composition was evaluated using Diatom Assemblage Index to organic water pollution (DAIpo). As a result of water quality analysis, average of water quality items of five sampling sites were 12.5-25.4 mg/L of BOD, 71.4-85.0 mg/L of COD, 2.7-3.6 mg/L of DO, pH7.2-7.3, 178.8-200.2 mV of Eh, 2.0-8.9 mg/L of NH_4-N, 0.4-0.9 mg/L of NO_3-N, 1.2-3.4 mg/L of PO_4-P, 25.1-26.1 ^{o}C, respectively. From these results, high level of organic pollution was confirmed in the sampling sites during this period. In addition, the concentration of PO_4-P and NH_4-N were observed at high levels. On the other hands, about 94 species of attached diatoms were observed in the five sampling sites. They were classified into three groups of 9 species of saproxenous taxa, 16 species of saprophilous taxa and 44 species of indifferent taxa. Seventeen species could not be identified as known species by light microscopy. Average of DAIpo in the five sites was 18.8-24.7 indicating high organic pollution levels. Especially, statistically significant correlations were observed between DAIpo and three items (COD, Eh and NO_3-N). As a conclusion, the present study showed that attached diatom species composition was a useful indicator of water quality in agricultural fields of Vietnam.
Keywords: Attached diatom, Rice cultivation, Water quality, DAIpo

INTRODUCTION

Recently, eutrophication of water has become a serious environmental problem in low-lying agricultural area of Vietnam. One of the reasons of this problem is thought to be excess application of fertilizers in agricultural activities including rice cultivation with increasing demands of food production. Thus, it's increasingly important to monitor and comprehend water quality dynamics in a paddy environment regularly. However, analysis of water quality is often time consuming and expensive due to much labor, and so many reagents and apparatus. Therefore, numerous studies have been performed to evaluate water quality using aquatic organisms through laboratory experiments and field studies since early times all over the world. Attached diatom species composition is known to be a good indicator of water quality in freshwater area. However, there are not so many studies on diatom assemblage as the indicator of water quality in Vietnam (Duong, 2006, 2007). The present study, therefore, aims to investigate the relationship between water quality and attached diatom species composition in and around an experimental paddy field at Hanoi University of Agriculture.

MATERIALS & METHODS

During August to October, attached diatom species composition was investigated once a fortnight in five sites of the experimental paddy fields. For sampling of attached diatoms, special plastic sampling plates (figure 1) were used. After immersing the plates in water for about two weeks, attached diatoms were collected in 11, 25 of August, 8, 12 of September, and 6 of October 2007. Diatom sample was fixed in and fixed in 4% formalin. Cleaning of diatom shell was performed by a simple method described in Nagumo (1995) and prepared slide was made according to a method described in Patrick and Reimer (1966), and species were identified based on the morphology of cleaned siliceous shell of diatom by light microscopic observation at 400 to 1000-fold magnification. Water quality based on diatom species composition was evaluated using Diatom Assemblage Index to organic water pollution (DAIpo; Watanabe, 1986). This index is calculated by the following formula.

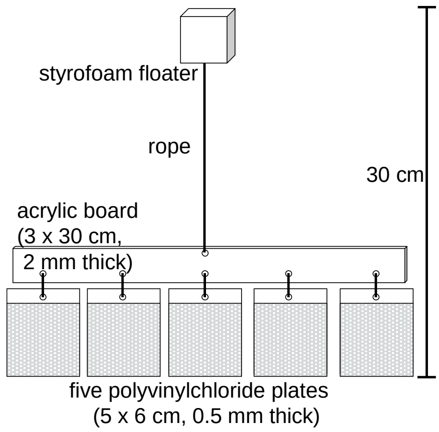

Figure1. The illustration of sampling equipment used in this study. Attached diatoms were collected from gray colored areas (5 x 5 cm) on both sides of five polyvinylchloride plates.

DAIpo = 50+(A –B)/2

A: relative frequency (%) of total saproxenous taxa cells.

B: relative frequency (%) of total saprophilous taxa cells.

Water quality items of biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), pH, redox potential (Eh), NH_4-N, NO_3-N, PO_4-P and temperature and temperature were monitored once a week from 28 July to 5 October in the same sites of diatom sampling.

RESULTS

The diatom species observed in this study were shown in Table 1. More than 85 species of attached diatoms were observed in the five sampling sites. They were classified into four groups of 9 species of saproxenous taxa, 16 species of saprophilous taxa and 44 species of indifferent taxa. The other 17 taxa could not be identified as known species by light microscopy and included in ecologically unclear group. Temporal change of DAIpo was shown in figure 2. DAIpo of all sampling sites increased gradually from early August and maximum value were observed in 22 September.

As a result of water quality analysis (figure 3), average of water quality items of five sampling sites were 12.5-25.4 mg/L of BOD, 71.4-85.0 mg/L of COD, 2.7-3.6 mg/L of DO, pH7.2-7.3, 178.8-200.2 mV of Eh, 2.0-8.9 mg/L of NH_4-N, 0.4-0.9 mg/L of NO_3-N, 1.2-3.4 mg/L of PO_4-P, 25.1-26.1 ^oC, respectively.

Table 1. The diatom species observed in a paddy field at Hanoi University of Agriculture

taxa	Diatom species
Saproxenous taxa (clear water type diatoms; 9 species)	*Achnanthes lanceolata, Achnanthes minutissima, Cocconeis placentula* var.*lineata, Cymbella silesiaca, Cymbella tumida, Navicula cari, Navicula contenta* f.*biceps, Navicula cryptotenella, Synedra ulna* var.*ramesi*
Saprophilous taxa (polluted water type diatoms; 16 species)	*Achnanthes exigua, Cyclotella atomus, Cyclotella meneghiniana, Gomphonema parvulum* var.*lagenula, Gomphonema pseudoaugur, Navicula atomus, Navicula confervacea, Navicula goeppertiana, Navicula pupula, Navicula seminulum, Navicula subminuscula, Navicula tenera, Nitzschia amphibian, Nitzschia gracilis, Nitzschia nana, Nitzschia palea*
Indifferent taxa (wide range type diatom; 44 species)	*Achnanthes hungarica, Amphora libyca, Amphora Montana, Caloneis bacillum, Eunotia bilunaris, Gomphonema gracile, Gomphonema minutum, Gomphonema parvulum, Gomphonema pumilum, Gyrosigma scalproides, Hantzschia amphioxys, Navicula bacillum, Navicula cryptocephala, Navicula elginensis, Navicula gregaria, Navicula minima, Navicula radiosa, Navicula schroeterii, Navicula veneta, Navicula viridula var.rostellata, Nitzschia acicularis, Nitzschia clausii, Nitzschia filiformis var.conferta, Nitzschia fonticola, Nitzschia frustulum, Nitzschia inconspicua, Nitzschia intermedia, Nitzschia linearis, Nitzschia paleacea, Nitzschia perminuta, Nitzschia umbonata, Pinnularia braunii, Pinnularia gibba, Stauroneis phoenicenteron, Synedra ulna*
Ecologically unclear taxa (25 species including 17 of unidentified species)	*Achnanthes* sp., *Amphora* sp., *Diploneis* sp., *Eunotia* sp., *Gomphonema insigne, Gomphonema* sp., *Gomphonema turris, Gyrosigma* sp., *Navicula halophila, Navicula* sp.-1, *Navicula* sp.-2, *Navicula* sp.-3, *Navicula* sp.-4, *Navicula* sp.-5, *Navicula tenelloides, Neidium ampliatum, Nitzschia debilis, Nitzschia reversa, Nitzschia* sp., *Nitzschia* sp.-1, *Nitzschia* sp.-2, *Pinnularia acrosphaeria, Pinnularia* sp., *Plagiotropis* sp., *Stauroneis* sp.

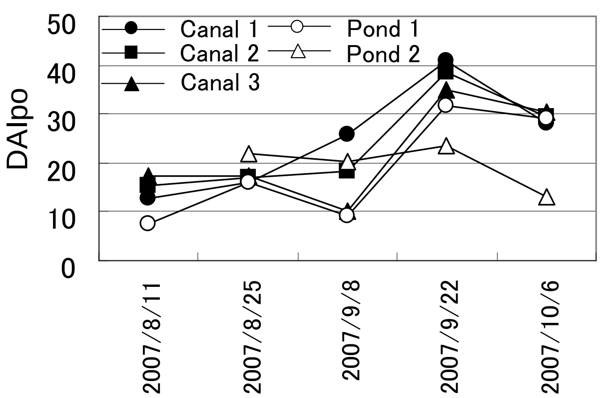

Figure 2. Temporal change of DAIpo in a paddy field at Hanoi University of Agriculture.

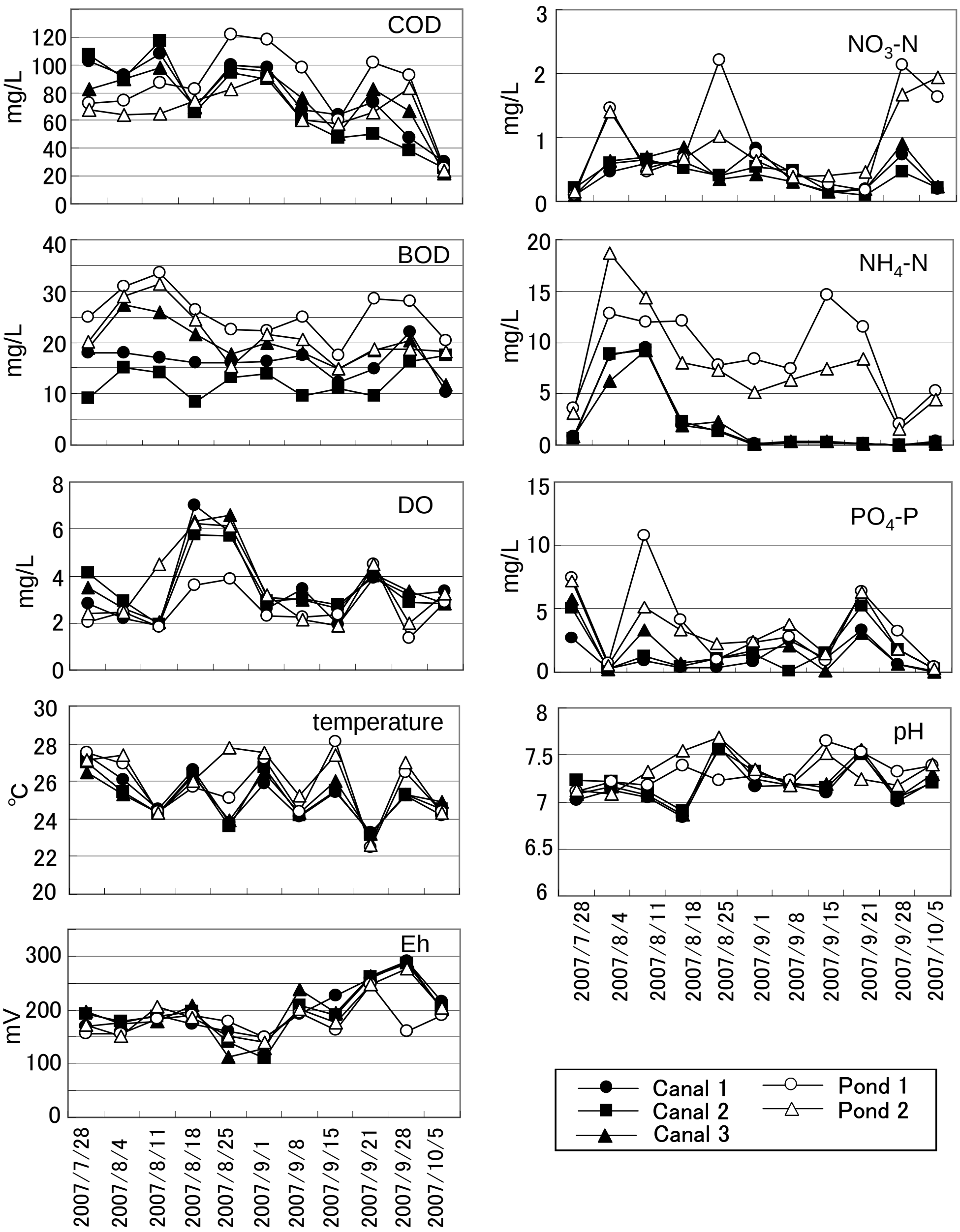

Figure 3. Temporal change of water quality parameters in a paddy field at Hanoi University of Agriculture.

Relation of DAIpo and each water quality parameters was shown in figure 4. Statistically significant relations (analysis of variance) were observed between DAIpo and COD, NO_3-N, NH_4-N, Eh, or temperature (Figure 4).

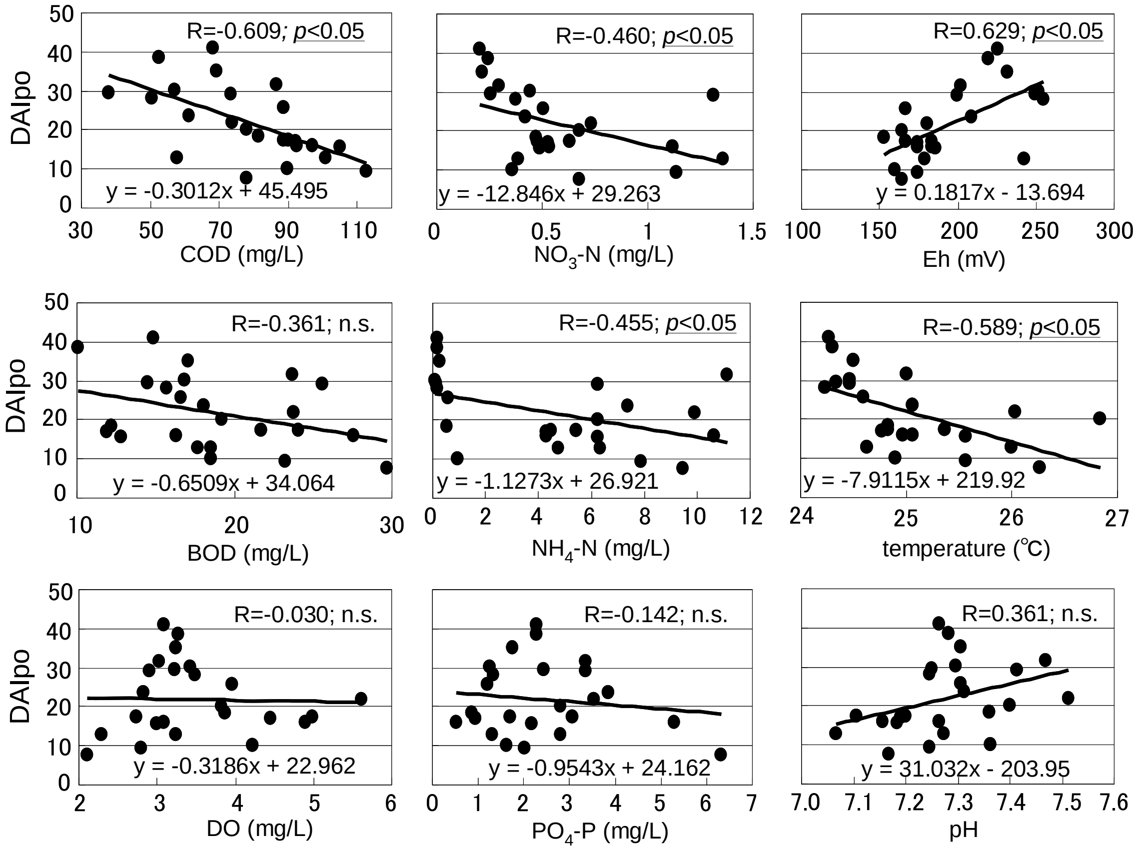

Figure 4. Relation of DAIpo and each water quality parameters. Each value (black spot) in water quality were expressed as an average of 3 times analysis data during about 2 weeks of immersion of diatom sampling plates. Statistically significant relation was evaluated by analysis of variance using SPSS 10.0J. "n.s." means no significant.

DISCUSSION

In this study, statistically significant relation between DAIpo and COD, NO_3-N, NH_4-N, Eh, or temperature. This result indicates that diatom species composition DAIpo reflect water quality.

There was no significant (p=0.083) relation of DAIpo and BOD in this study. Generally, DAIpo have a proportional relationship with geometric increase or decease of water quality such as electric conductivity, COD, BOD, total nitrogen and total phosphorus (Watanabe, 2005) in the 0 to 100 range of DAIpo. One of reason of no significance between DAIpo and BOD may be due to relatively narrow range of DAIpo (7.5 to 40.9) in this study.

About 94 species of attached diatoms wereobserved by light microscopic analysis. However, there were 17 of unidentified species. Completed udentify may be needed using electron microscope.

In future, eutrophication of water will become more serious environmental problem in low-lying agricultural area of Vietnam because growing demand of food production. Thus, it's increasingly important to monitor and comprehend water quality dynamics using aquatic organisms through laboratory experiments and field studies in a paddy environment.

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Effect of Low Input of Chemical Fertilizer on Growth and Grain Yield in F_1 Hybrid and Inbred Rice (*Oryza sativa* L.)

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Abstract
This study was conducted to determine the affection of three levels of chemical fertilizer (kg per ha) application such as : 60N+ $45P_2O_5$ + $45K_2O$ (C1); 90N + $67.5P_2O_5$ + $67.5K_2O$ (C2); 120N + $90P_2O_5$ + $90K_2O$ (C3) and non-chemical fertilizer application (C0) on agronomic characters and grain yield in F_1 hybrid rice variety (TH3-3) and inbred rice variety (P6) in both spring and autumn cropping season. As increasing fertilizer, the maximum number of tillers per hill significantly increased in the hybrid only in spring season (from 7.9 to 11.0), while the increase was observed in the inbred rice in autumn season (9.4 to 13.4). As increasing fertilizer level, leaf N content increased higher in the hybrid than that in the inbred rice at the tillering stage. At heading stage, LAI was higher in the hybrid (4.7-5.6) than in the inbred (2.9- 4.1) in spring season, in contrast, this value was higher in the inbred in autumn season. As increasing fertilizer level from C1 to C2, grain yield increased more strongly in hybrid rice (from 6.32 to 7.65 ton ha^{-1} in autumn season) than in inbred rice (from 5.52 to 6.31 ton ha^{-1} in autumn season). In autumn season, the higher grain yield was mainly due to the larger number of spikelets per panicle. In both cropping seasons, grain yield of two rice varieties was the highest at C2 level. Thus, low fertilizer would be applied for both hybrid and inbred rice cultivation in Vietnam.
Key Words: grain yield, hybrid rice, low input application, nitrogen

Introduction

Nitrogen fertilization is a key input for increasing rice productivity in Vietnam and other Asian countries. Although the introduction of high-yielding cultivars and hybrid rice has significantly contributed to the prospect of increasing yields, this increase was often associated with intensive cultivation, in which a high level of nitrogen was applied. However, negative effects on the environment resulted from so-called high-input agriculture, in part as a consequence of the widespread use of nitrogen fertilizers (National Research Council, 1989; Hirel and Lemaire, 2005). Even in paddy rice cultivation, nitrogen fertilizer affects the quality of water at the land preparation and of air through the growth season (Hasegawa, 2003). Heavy nitrogen application also increases the cost of rice production. We need to develop rice cultivation methods that would increase the absorption of nitrogen at each growth stage of rice plants (Wada et al., 1986), while maintaining high and reliable dry matter production and grain yield.

The average level of nitrogen applied for rice production recorded recently in the Red River Delta, the second largest rice production area in Vietnam, amounted to 120 kg ha^{-1} $crop^{-1}$ (Kurosawa *et al.*, 2004), while in Japan it was approximately 80 kg ha^{-1}

crop^{-1} (FAO, 2002). This high rate of application might negatively affect the agro-environment through nitrate leaching and ground water pollution. Therefore, it is necessary to improve the management of nitrogen fertilization to maintain the growth and productivity of rice and develop a more sustainable production system. It is necessary to better manage fertilization to maintain growth and productivity of rice and achieve a more sustainable production system. From these reasons, we tried to evaluate the effect of low input chemical fertilizer on growth and grain yield in F1 hybrid and inbred rice cultivars

Material and Methods

1. Plant materials and field conditions

Cultivation and experiments in the present study were conducted in autumn cropping season in 2007 and spring cropping season in 2008. F_1 hybrid (TH3-3) and inbred (P6) were used as plant materials. Young seedlings of 4 or 5-leaf stage, approximately 3 weeks after sowing, were transplanted to the experimental field in Hanoi University of Agriculture in July of autumn cropping season and February of spring cropping season. Fertilizer condition was set at 4 levels: One condition applied with chemical fertilizer with the amount of 120 kg of nitrogen, 90 kg of phosphorus (P_2O_5) and 90 kg of potassium (K_2O) to the field (ha) (P_3) as basal dressing. C_2 and C_1 conditions were 75% and 50% of C3 level, respectively. P_0 was non-input condition. The experiment was laid out in a split-plot design with three replications. Each plot area was 20 m^2 with 40 hills m^{-2} of planting density, where each hill was 2 seedlings.

2. Sampling and measurements

At maximum tillering and heading stages, 5 hills per each plot were selected for surveying a tiller number. After counting the number, these plants were sampled and leaf area was measured with the automatic area meter (ANA, GA45, Japan). Thereafter, the leaves were dried at 80^{o}C for a few days in an oven to measure dry matter weight. The fried leaves were powdered, and the nitrogen was determined according to the semi-micro Kjeldahl method. At harvesting stage, 5 hills per each plot were sampled for surveying grain yield and its components.

Results and Discussion

Tiller number of each cultivar, TH3-3 and P6, was a little different between the 2 cropping season of autumn 2007 and spring 2008 at respective fertilizer conditions (Table1). However, this value of each cultivar at 2 cropping seasons showed similar

Table1 Tiller number at maximum tillering stage under different fertilizer conditions of TH3-3 and P6 in autumn cropping season 2007 and spring cropping season 2008.

Fertilizer	Autumn 2007		Spring 2008	
levels	TH3-3	P6	TH3-3	P6
C0	7.9±1.0c	9.4±0.5b	7.9±0.8a	9.9±1.1b
C1	9.5±1.1b	10.7±0.9a	8.0±0.7a	10.1±1.0b
C2	11.0±1.3a	10.9±0.7a	8.8±0.6a	13.4±1.4a
C3	10.6±1.0ab	10.1±0.6ab	8.2±0.8a	10.4±0.8b

Mean values±SD which column followed by same letter are not significantly different at 5% lelvel by Tukey’s test.

Table2　Lear area index (LAI) at maximum tillering stage under different fertilizer conditions of TH3-3 and P6 in autumn cropping season 2007 and spring cropping season 2008.

Fertilizer	Autumn 2007		Spring 2008	
levels	TH3-3	P6	TH3-3	P6
C0	4.7±0.4b	2.9±0.8b	4.9±0.4b	5.9±0.5b
C1	5.0±0.3ab	4.1±0.4a	5.5±0.6b	6.7±0.6ab
C2	5.5±0.5ab	4.5±0.3a	5.6±0.3b	6.9±0.3a
C3	5.6±0.3a	4.1±0.4a	6.4±0.4a	7.2±0.5a

Mean values±SD which column followed by same letter are not significantly different at 5% lelvel by Tukey's test.

tendency. In particular, the value of C2 level of both cultivars exhibited the highest and was significantly higher than that of C0 level.

Leaf area index (LAI) of TH3-3 showed higher value than that of P6 in each fertilizer level in autumn 2007 (Table2). In spring 2008, however, this value was adversely found to be higher in P6. LAI of C3 of both cultivars was significantly higher than that of C0 in 2 cropping seasons. However, LAI among C1, C2 and C3 was non-significantly different except for TH3-3 at spring 2008. Therefore, these results suggest that rice canopy in this cultivated region might adequately maintain the form for light-interception even the decrease in fertilizer application to 50%.

Leaf nitrogen content of TH3-3 was higher than that of P6 in each fertilizer condition at both tillering and heading stages (Table 3). The decrease in the amount of fertilizer application induced the decrease in leaf nitrogen content of both cultivars. In addition, the content of C0 level of each cultivar was significantly lower than that of C3 level at tillering and heading stages. In contrast, the leaf nitrogen content of both cultivars was not found to be significant difference among C1, C2 and C3 levels, except for P6 at tillering stage.

Grain yield of TH3-3 showed significantly higher value than that of P6 in each fertilizer level (Table 4). In yield components, there was not significant difference of number of panicles in TH3-3 and P6 at each fertilizer level. However, in number of

Table3　Leaf nitrogen content of TH3-3 and P6 at tillering and heading stages of autumn cropping season 2007.

Fertilizer	Tillering		Heading	
levels	TH3-3	P6	TH3-3	P6
C0	1.67±0.45c	1.56±0.41c	4.09±0.48b	2.77±0.40b
C1	2.74±0.23bc	2.14±0.48b	4.23±0.59ab	2.98±0.54b
C2	3.02±0.62ab	2.79±0.38a	4.42±0.57a	3.00±0.34b
C3	3.16±0.35a	2.86±0.48a	4.60±0.41a	4.05±0.46a

Mean values±SD which column followed by same letter are not significantly different at 5% lelvel by Tukey's test.

Table 4 Grain yield, number of panicles and number of spikelets under different fertilizer conditions of TH3-3 and P6 in autumn cropping season 2007

Fertilizer levels	Grain yield (ton ha^{-1})		No. of panicles (hill^{-1})		No. of spikelets (panicle^{-1})	
	TH3-3	P6	TH3-3	P6	TH3-3	P6
C0	6.03cd	4.74e	5.10b	5.20b	180.6a	131.6b
C1	6.32bc	5.52d	5.30b	5.70ab	188.8a	140.2b
C2	7.65a	6.31bcd	5.70ab	6.30a	190.1a	142.2b
C3	6.83b	5.72d	5.50ab	5.90ab	190.5a	146.3b

Mean values ± SD which column followed by same letter are not significantly different at 5% lelvel by Tukey's test.

spikelets, the value of TH3-3 showed significantly higher than that of P6. Thus these results suggest that the higher grain yield observed in TH3-3 might be due to much number of spikelets. Furthermore, C2 level of both cultivars lead to the highest grain yield, which implies that low fertilizer would be applied for both hybrid and inbred rice cultivation in Vietnam.

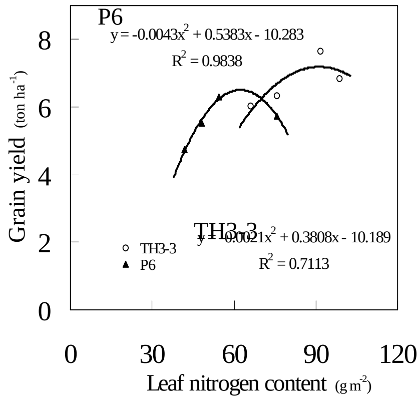

Fig. 1 The relationship between grain yield leaf nitrogen cpntent of TH3-3 and P6 in autumn cropping season 2007.

The relationship between leaf nitrogen content and grain yield of both cultivars could have regression curve with high coefficient (Fig.1). Moreover, this relationship between the parameters showed the optimum point of grain yield in both cultivars. In the present study set the four fertilizer levels, the value of grain yield of C2 level was located on the nearest to the optimum point. Generally, grain yield increases with the increase in nitrogen content of leaves located on the upside of the canopy. In this result, however, leaf nitrogen content was evaluated under the whole plant range. Therefore, this analysis needs to be conducted on the canopy range. We can propose that the way of this analysis is important tool to determine the management of the fertilizer control.

From these results we could suggest that the reduction in fertilizer application was possible for production of hybrid and inbred rice with high-yielding with concerning the reduction in negative impact to agro ecosystem.

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Seasonal Change of Soil Nitrogen Components in Paddy Fields, Vietnam.

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Key Word: nitrogen behavior, paddy field, urea fertilizer, organic matter

Abstract

The objective of this study is to investigate the seasonal change of nitrogen in the paddy field under different fertilization condition in Hanoi, Vietnam. The paddy soil samples were taken once every two weeks from 8 plots fertilized with different amount of urea fertilizer and cropped with two varieties of rice for about a year including two rice cultivation seasons of summer rice and spring rice. The levels of fertilizer treatment are set from no fertilizer application (0 kg N - 0 kg P_2O_5 - 0 kg K_2O) to conventional fertilizer application (120 kg N - 90 kg P_2O_5 - 90 kg (K_2O). The concentrations of NH_4^+ and NO_3^- in soil were measured for each fresh soil and pH (H_2O), organic matter (OM) and total nitrogen (TN) contents were measured for air-dried soil samples. No significant difference was detected for pH(H_2O) and OM content during the cultivate seasons among all plots. In some plots, TN content increased during the cultivation and decreased after harvesting. The concentration of NH_4^+ increased immediately after fertilization because of the decomposition of urea to NH_4^+. The amount of NH_4^+ increased after fertilization was varied with timing of fertilization and season. Although the concentrations of NO_3^- in soil were much lower than the concentration of NH_4^+ during the cultivation in all plots, the concentrations of NO_3^- increased moderately after the harvest of summer rice. This result may indicate that the NO_3^- concentrations increased by decomposition of organic matter in soil under oxidative condition. In order to predict the nitrogen behavior in paddy field, climate, temperature and water management that affect the transport of nitrogen species and the digestion of urea and soil organic matter should be considered.

Introduction

Nitrogen chemical fertilizer is necessary to attain high yield of agricultural products, although its excessive use cause the surface or ground water pollution by NH_4^+ or NO_3^-. The water including high concentration of NH_4^+ and NO_3^- is harmful for human health. In order to prevent the water pollution by NH_4^+ and NO_3^-, the effective use of nitrogen fertilizer and lowering nitrogen leaching is required. Another reason for the requirement of effective use of chemical fertilizer is its rising price.

In Vietnam, urea is usually used as nitrogen chemical fertilizer. Urea is digested to NH_4^+ by urease in soil, and NH_4^+ is oxidized to NO_3^- under oxidative condition. The digestion rates of urea and oxidation of NH_4^+ in soil can be affected by urea concentration, pH, water management, temperature, soil property, redox potential, etc.

(Gould et al., 1973; Keeney and Sahrawat, 1986; Yadav et al., 1987; Cabrera, 1991). The behavior of nitrogen in soil strongly depends on those chemical forms. For example, NH_4^+ is well adsorbed on soil solid surface although NO_3^- is little adsorbed. The nitrogen form also affect to the efficiency of absorption of nitrogen to crops (Cox and Reisenauer, 1973; Youngdahl et al., 1982; Tan, 2000). The effluent of nitrogen from paddy field, which is major use of agricultural field in Vietnam, should have high impact to the environmental pollution.

The objective of this study is to investigate the seasonal change of inorganic nitrogen concentration in the paddy field under different fertilization condition in Hanoi, Vietnam. In order to examine the behavior of nitrogen near the additional fertilizer application, the NH_4^+ and NO_3^- concentration in surface water and soil were also measured.

Materials and Methods

This study was carried out in the paddy experimental field in Hanoi University of Agriculture. Four or five application rates of fertilizers (P1, P2, P3, P4, P5) were used to grow two varieties of rice species (G1: TH-3, G2: P3) (Table 1). Urea was used as nitrogen fertilizer. Each treatment was tested in triplicate. The investigation was performed from July in 2007 to October in 2008. The agricultural activities during the cultivations were summarized in Table 2.

Soil samples were taken once every two weeks during cultivations and NH_4^+ and NO_3^- were immediately measured using fresh soil. In order to extract NH_4^+ and NO_3^- from the soil samples, some amount of fresh soil samples was taken into a vessel and 1 M KCl solution were added, then those were shaken for 1 hours. The suspensions were filtered and the concentrations of NH_4^+ in the extracts were determined by modified indophenol method and the concentrations of NO_3^- were measured by modified calaldo method. Rests of fresh soil samples were air-dried. Fresh samples and air-dried samples were weighed to calculate water content. Air-dried soil samples were measured for pH, organic matter content and total nitrogen content using glass electrode method, Turin's method and Kjeldhal method, respectively.

The concentrations of NH_4^+ and NO_3^- in soil and surface water were measured before and after second additional fertilization about summer rice in 2008 to investigate nitrogen behavior. The surface water was filtered and measured NH_4^+ and NO_3^- using same method with soil samples.

Table 1. The amount of tested fertilization.

	Amount /kg ha^{-1}		
	N	P_2O_5	K_2O
P1	0	0	0
P2	60	45	45
P3	90	67.5	67.5
P4	120	90	90
P5*	150	112	112

* tested only in summer rice in 2008

Table 2. The agricultural events in each cropping season.

Agricultural event	Summer rice in 2007	Spring rice in 2008	Summer rice in 2008
Fertilization1 (50 % total)	7/12	3/8	7/17
Transplanting	7/13	3/9	G1:7/17; G2:7/17
Fertilization2 (30% total)	7/19	3/16	G1:7/24; G2:7/28
Fertilization3 (20% total)	8/21	4/30	G1: 8/25; G2:8/30
Cultivation	G1 10/13, G2 10/25	G1 6/7, G2 6/10	G1:10/26; G2:10/28

G1: TH3-3; G2: P6

Results

pH, organic matter contents, and total nitrogen

There were no significant change in organic matter contents and pH(H_2O) during summer rice in 2007 (Table 3).

Table 3. Changes in pH(H_2O) and organic matter contentsduring summer rice in 2007.

	pH(H_2O)				Organic matter content/ %			
	7/28	8/25	10/6	12/14	7/28	8/25	10/6	12/14
P1G1	6.6	5.9	7.2	6.4	3.5	3.8	3.5	2.9
P2G1	6.5	6.6	7.0	6.5	3.7	3.9	3.6	3.4
P3G1	6.4	6.2	6.5	6.3	3.7	3.3	3.4	3.6
P4G1	6.5	6.9	6.6	6.3	3.8	3.3	3.3	3.5
P1G2	6.7	6.6	6.9	6.6	3.7	4.1	3.0	3.5
P2G2	6.4	6.9	6.5	6.3	3.5	3.9	3.4	3.7
P3G2	6.3	6.6	6.9	6.2	3.7	4.2	3.6	3.5
P4G2	6.2	6.6	6.9	6.3	3.7	4.4	3.9	3.6

The total nitrogen content in soil samples during summer rice in 2007 is shown in Table 4. There was no obvious change of total nitrogen content in a cultivation period. Thus, the chemical fertilizer seemed to little effect on total nitrogen content in soil.

Table 4. Changes in total nitrogen content in soil during summer rice in 2007

	Total nitrogen /%			
	7/28	8/25	10/6	12/14
P1G1	0.18	0.20	0.23	0.23
P2G1	0.29	0.23	0.36	0.23
P3G1	0.20	0.23	0.20	0.17
P4G1	0.29	0.26	0.23	0.17
P1G2	0.19	0.23	0.20	0.17
P2G2	0.20	0.23	0.19	0.17
P3G2	0.23	0.26	0.36	0.14
P4G2	0.20	0.29	0.24	0.17

Variation of NH4 and NO3 concentration during cultivation period

Figure 1 shows changes of NH_4^+ and NO_3^- concentrations in soil for treatments P1G1, P4G1, P1G2 and P4G2 during summer rice in 2007, spring and summer rice in

2008. There were no significant differences in NH_4^+ and NO_3^- concentration between G1 and G2. The main form of inorganic nitrogen in soil was NH_4^+ during cultivation. The NH_4^+ concentration was very high after fertilization and decreases immediately. The NO_3^- concentration was much lower than NH_4^+ concentration during cultivation, although the NO_3^- concentration began to slightly increase in winter after the harvest. This may be because the redox potential of soil increased.

The NH_4^+ concentration in soil tended to increase with the higher application rate of fertilizer. The extent of increment of NH_4^+ concentration in soil after additional fertilization was smaller than after basal fertilization. NO_3^- concentration at the beginning of the spring rice cultivation was smaller than the concentration of NO_3^- in December 2007. This indicates that part of NO_3^- lost in winter between cultivations.

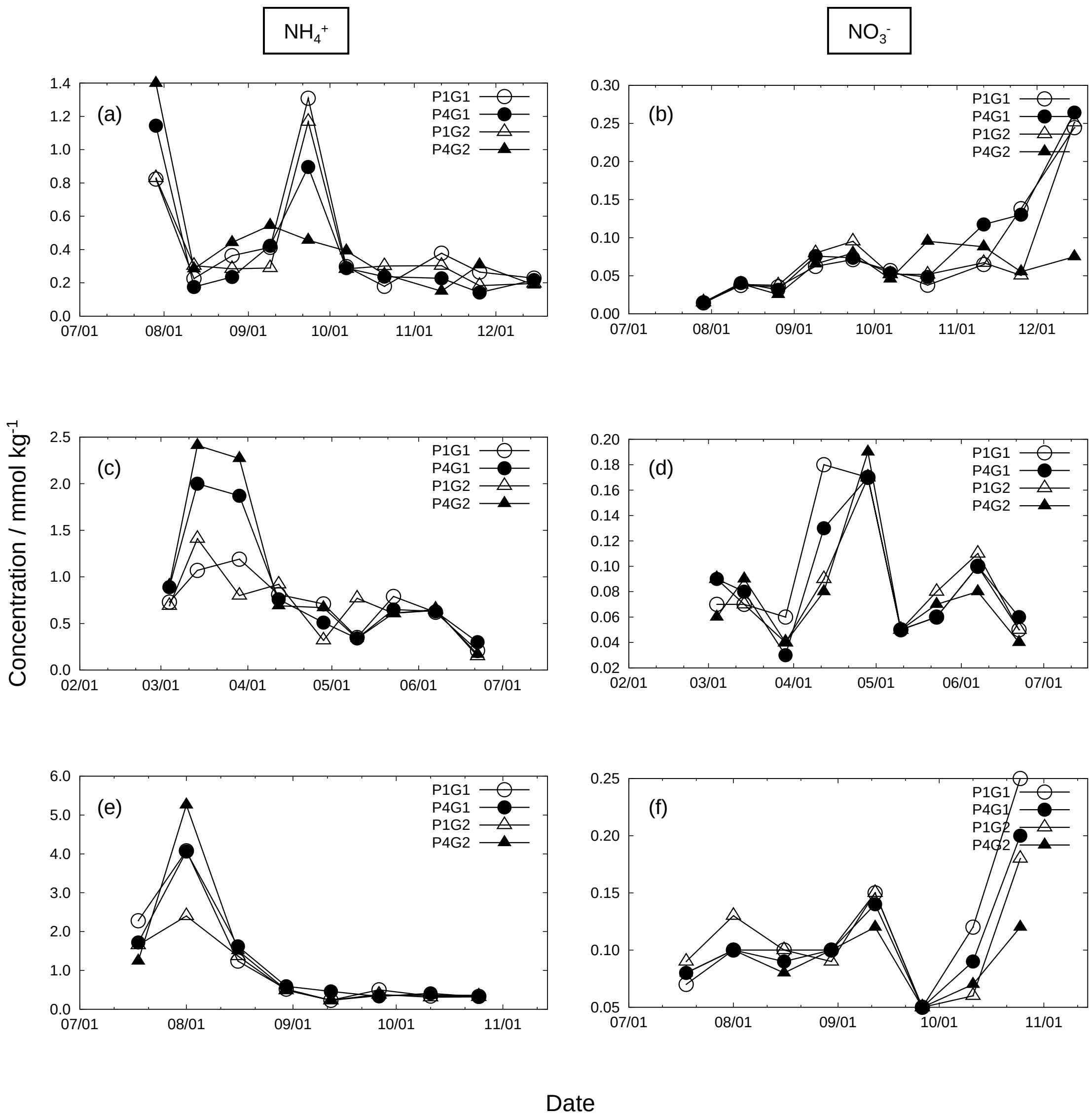

Figure 1. Variation of the NH_4^+ and NO_3^- during cultivation period. (a)(b): Summer rice in 2007, (c) (d): Spring rice in 2008, (e) (f) Summer rice in 2008.

Variation of NH4 and NO3 concentration in surface water and soil after surface application of urea fertilizer

Figure 2 shows the changes of inorganic nitrogen concentration in soil and surface water before and after second additional fertilization during summer rice season in 2008. The concentrations of NH_4^+ in surface water for G1 variety immediately increased one day after the application of fertilizer, then little NH_4^+ could be detected in the surface water 5 days after fertilization. The changes in NH_4^+ concentrations in surface water for G2 were not so clear. The NO_3^- concentrations also increased after fertilization although the NO_3^- concentrations were much lower than NH_4^+.

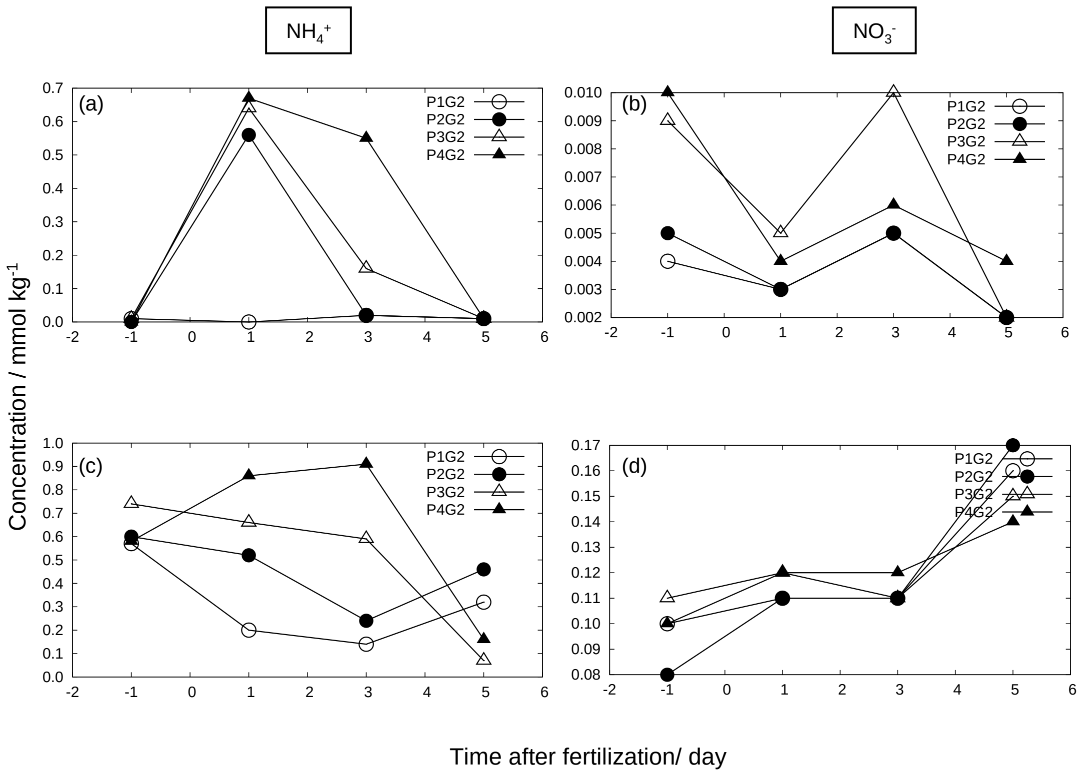

Figure 2. Variation of the NH_4^+ and NO_3^- during cultivation period. (a)(b): in surface water and (c) (d): in soils

Discussions

The amount of NH_4^+ concentration in soil after fertilization was not same in each cropping season (Figure 1). The reason was assumed to be the effect of intervals between fertilizer application and soil sampling. If the applied urea decomposed to NH_4^+ and lost from soil quickly, the peak concentration could not be measured with this sampling interval. It was reported that almost all urea decompose to NH_4^+ within a day or a week (Vlek et al., 1980; Zaman et al., 2008).

The NO_3^- concentration was much lower than the NH_4^+ during every rice cultivation period, although it increased after harvest of summer rice (Figure 1). The reason might be decomposition of soil organic matter under oxidative condition after harvest. The leaching of NO_3^- in winter might not be negligible in considering nitrogen transportation from agricultural field.

At the surface application of urea fertilizer, the concentration of NH_4^+ in soil was not so changed (Figure 2). Vlek et al. (1980) shown that urea in flood water was hydrolyzed at soil-water interface. Eriksen and Nilsen (1982) reported that deep placement of urea increased the yield 20 % larger than surface application. According to this report, when the urea applied to paddy field by surface application, the efficiency of urea by surface application was less deep placement of urea such as basal fertilization. The reason could be the runoff of surface water or evaporation of NH_4^+. To increase the urea availability of additional fertilization, it is necessary to use another form of fertilizer or to change the water management.

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Numerical Modelling on Nitrogen Balance in Integrated Farming Systems in Red River Delta, Vietnam—A Preliminary Model—

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Key Words: VAC system, nitrogen flow, agricultural production, aquaculture, animal husbandry

Abstract:

The agricultural production and farming systems in Vietnam have been intensified and diversified in keeping with the growing economy and food demands. For the efficient use of natural resources, an integrated farming system so called VAC system in Vietnam has become popular throughout the country. The intensification of agricultural system often resulted in such environmental degradations as eutrophication of surface water and groundwater, soil loss and contamination, etc. Because of the direct effect on both human health and agricultural production, it is quite important to assess the impacts on soil and water environments. However, the diversified structure of the farming systems makes it difficult to evaluate the impact from the integrated farming systems. To cope with the diversity, an approach based on mathematical models would be very much helpful in describing the complex processes and interactions. The present report aims to show a basic concept on a preliminary model for simulating nutrient dynamics in the integrated farming system in Red River Delta, Vietnam. Due to the diversity and complexity of the VAC systems in Red River Delta, nitrogen balance around paddy fields was focused as a first step of the modelling. Future direction for modelling water and nutrient dynamics will be presented together with the result of field measurements.

INTRODUCTION

The demand for food is considerably increasing due to the rapidly growing world population. To cope with the food crises, it is essential to expand agricultural area together with increased agricultural productivity in the world. However, water resource available for agriculture is now decreasing as a result of a competition with non-agricultural sectors in both developing and developed countries. In addition, the boom of cash crop production, e.g., for biofuel production, would foster the competition of water resources with food production. This may lead to the rapid changes of landuse and its management policy. Under such unstable conditions and changing world climate, it is important to aim at effective uses of water and natural resources for achieving sustainable development together with increased agricultural productivity. Increasing water productivity is one approach to find a break-through out of this competition as in Bouman et al. (2007) which focused on water-saving techniques in irrigated rice production. Tuong et al. (2005) also discussed on the strategies and technologies for increasing water productivity at different scales in space, and on the possible negative impacts of reducing water input for rice production. Towards sustainable agricultural production, assessment of biophysical environment and agricultural system is essential for the better planning and management which would maintain the balance between agriculture and natural systems.

Since 2007, a collaborative project on research and education have launched between Kyushu University and Hanoi University of Agriculture (HUA) under the framework of Kyushu University Interdisciplinary Programs in Education and Projects in Research Development (so-called, P&P). In this project, integrated farming systems in flat low-lying agricultural area in Red River Delta, Vietnam are focused for clarifying the mechanism of effluent load such as pathogens, agrochemicals and fertilizer from integrated farming system together with the assessment of its impacts on ecophysiology of agricultural crops, and surrounding environment. Towards this goal, field surveys and laboratory experiments have been conducted by considering the five key components: a) Hydrological assessment of water and nutrient cycle in target site; b) Passage of water-carrying loads such as pathogens, fertilizer, etc.; c) Ecophysiological characteristics of agricultural crops on water and soil purification; d) Soil biogeochemical property for soil and water purification in paddy environments; and e) Ecotoxicology of agrochemicals on aquatic ecosystem. Through these activities, human networks for the further collaboration in research and education would be strengthened especially among young researchers in partner universities. This can be the basis of establishment of new research projects in tropics and subtropics.

The present report aims to show a basic concept of a preliminary model to simulate water and nitrogen dynamics in surface water at a paddy field. This is a first step for the development of numerical model on water and nutrient dynamics in the integrated farming system in the target area. Future direction for modelling water and nutrient dynamics will be presented together with the result of field measurements as an example.

CONCEPT & METHODOLOGY

In this section, we firstly give a brief concept of modelling water and nutrient flows in the integrated farming system. Secondly, modelling approaches of surface water at paddy fields will be briefly presented together with the results of field measurement. Finally, the future direction of this project will be discussed for modelling the complex, integrated farming system.

Modelling Integrated Farming System

As presented in Liet et al. (2009), integrated farming systems in Red River Delta are quite complex in terms of structure, size and biological flow. In general, integrated farming system consists of four farming components of garden (V), pond (A), livestock (C), and rice (R). The combination of these components depends on farmers' choice derived from biophysical environment and available resources in the region. The economical conditions would also affect farmers' choice and resource management in the integrated farming systems. As a concept, it is therefore necessary to develop a model focusing not only on water and nutrient dynamics in the integrated farming systems but also on the economic consequence resulted from the farming practice and resource management in the system. This would be the key step towards the sustainable planning and management of natural resources and agricultural production.

In Mekong Delta, comprehensive research project was conducted aiming at the development of technologies for sustainable farming system in that region (Yamada and Yamasaki, 2007). In the same region, Watanabe and Nagumo (2001) evaluated the nitrogen flow by considering the linkage between different components (Fig. 1), in which external components such as market were included in the nitrogen flow. Although this analysis was done at a regional scale, the basic idea and approach can be applied to the analysis at a much smaller scale which the present project focuses on.

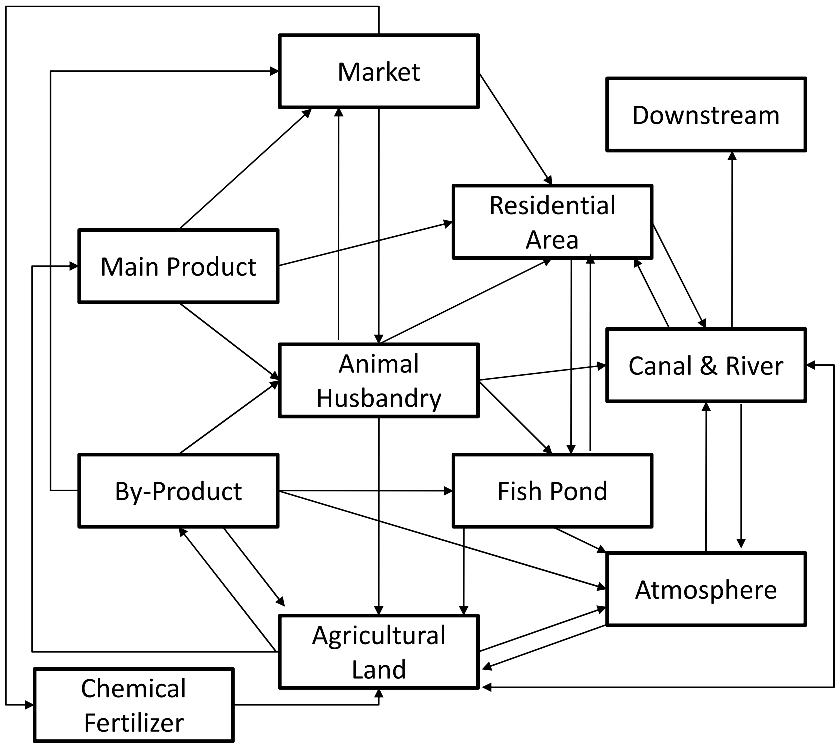

Figure 1 Example of nitrogen flow (modified from Watanabe and Nagumo, 2001)

To cope with the complex structure and interactions between components in the integrated farming system, it would be better to start from a simplified conceptual linkage between key components in the system (Fig. 2). In the following section, approaches for modelling water and nutrient dynamics in a paddy environment will be briefly explained based on the previous researches.

Modelling Water & Nutrient Dynamics in a Paddy Field

Many studies have been conducted to evaluate nutrient flow or balance in paddy environment (Shiratani et al., 2002; Chinh et al., 2008; Maruyama et al., 2008; Antonopoulos, 2008; Yoshinaga, 2008). These studies play a key role in evaluating multifunctionality of paddy environment, in which different models and approaches were taken for the modelling of water and nutrient dynamics. For instance, Shiratani et al., (2002) conducted open channel experiment so as to analyze quantitatively the interaction of nutrients on the sediment in a clayey canal. The other studies evaluated the nutrient flow or balance in paddy environments based on the field measurement and mathematical models (Chinh et al., 2008; Maruyama et al., 2008; Antonopoulos, 2008; Yoshinaga, 2008). The approach taken by Chinh et al. (2008) would be applicable to our target environment which is often described as flat low-lying area. The parameterization of the model and collection of necessary data would be the pre-requisite for the application of their approach.

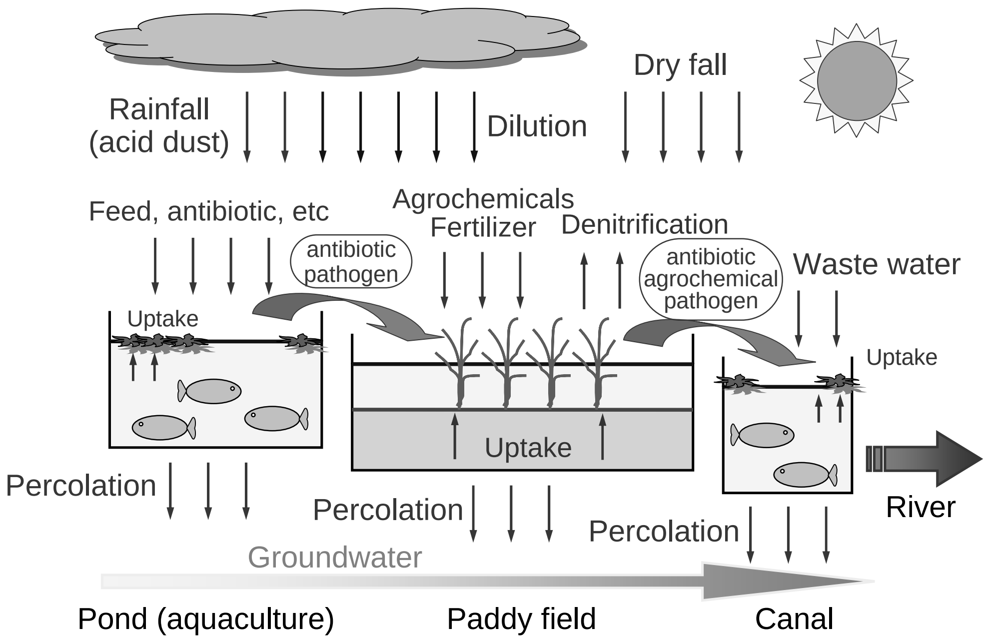

Figure 2 Conceptual linkage of target environment

Water temperature is one of the most important variables in modelling water quality dynamics of surface water in paddy environment. Despite the importance, there is no measurement of water temperature neither in paddy fields nor in agricultural canals. Fortunately, as shown in Fukuda et al. (2007), daily water temperature in paddy fields can be estimated by using a simple numerical model. The approach employed by Fukuda et al. (2007) requires only four variables of air temperature, relative humidity, daily sunshine duration, and leaf area index (LAI) of rice plants grown in the target paddy. For the purpose of modelling, climatic conditions of air temperature, wind speed, precipitation, relative humidity and atmospheric pressure have been measured at Hanoi University of Agriculture (Fig. 3). To cope with the lack of sunshine duration data, a preliminary model which estimates incoming solar radiation has been developed by using the available climatic data measured in 2000 (Fukuda et al., 2008). Based on the model developed and climatic data measured in this project, it would now be possible to simulate water and nitrogen dynamics in a paddy field (Fig. 4). As shown in Fig. 4, we have conducted field experiments under different treatments of fertilizer application and different variety of rice. These results may provide information on the better farming practice not only for rice production but also for the environmental sustainability in the paddy fields.

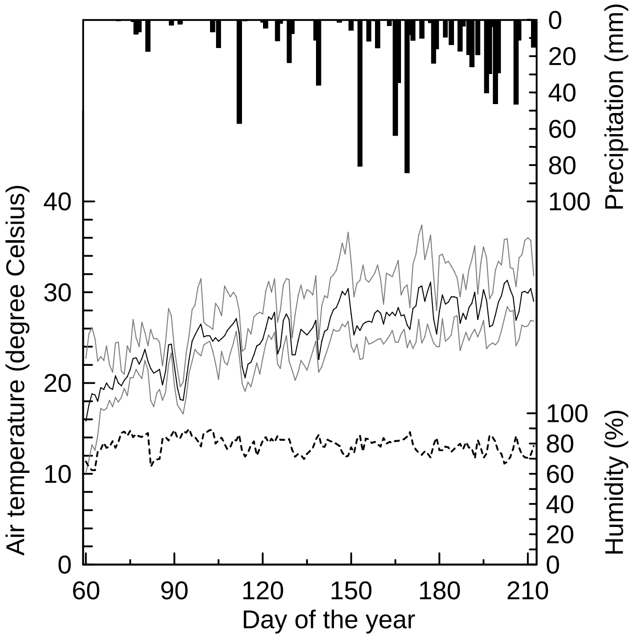

Figure 3 Climatic condition at Hanoi University of Agriculture from 1 March to 31 July 2008

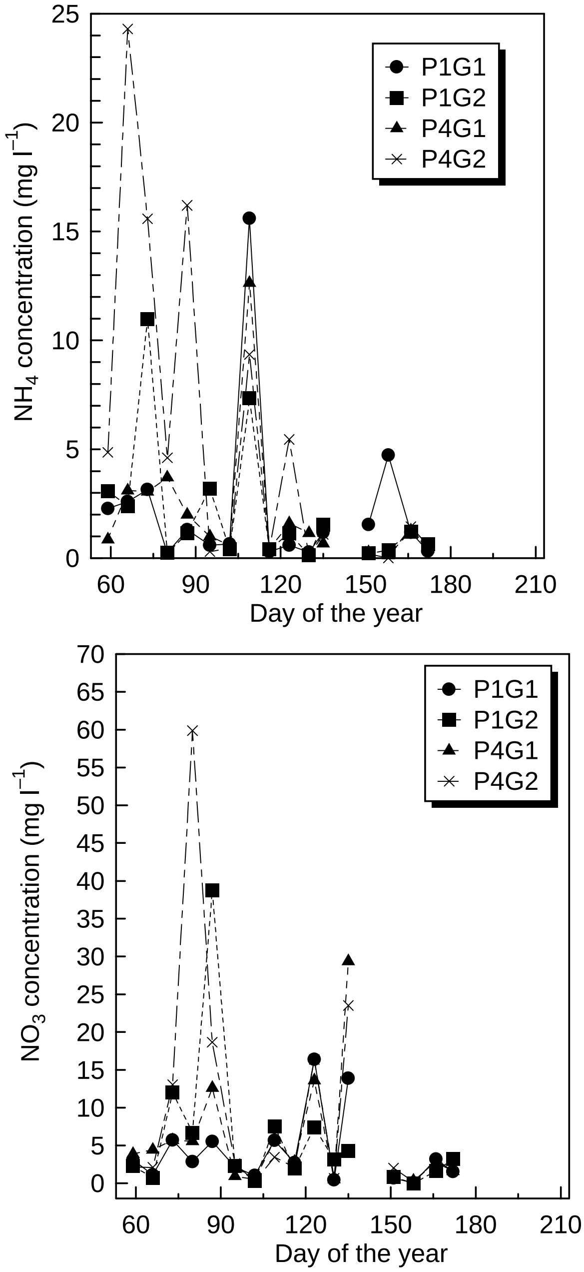

Figure 4 Concentration of NH_4-Nand NO_3-N in the surface water of experimental paddy field (spring rice in 2008), in which P1 and P4 indicates the treatment of fertilizer application, and G1 and G2 indicate the rice variety grown in the target paddy.

Future Direction

For the better understandings of the integrated farming system, an integrated approach across different disciplines would be necessary since all the phenomena are resulted from the complex interactions between water, soil, and plant. For instance, the canopy of rice plant shades the water surface, by which water temperature decreases compared to the case of no rice canopy (Fukuda et al., 2007). In this case, it is essential to work with crop scientists since physiological information on hybrid rice developed in

Vietnam is still scarce despite the importance in modelling water quality and nutrient balance. Some other components such as fertilizer, agrochemical, and pathogens can also affect agricultural production and agro-ecosystem. A series of laboratory experiments in a controlled environment would be necessary to clarify these complex interactions. Based on the result from the experiment, the research may be extended over actual conditions in the field. Further activities can be directed to the last missing components of rural economy. This is an important step especially in the decision making process and evaluation of alternatives available for the farmers and managers in the region.

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