Improvement of Rice Cropping Technique in the Mekong Delta Farming Systems

Tadao Kon[a], Pham Sy Tan[b], Tran Ngoc Huan[b], Trinh Quang Khuong[b] and Hoang Dinh Dinh[b]

[a] *Crop Production and Postharvest Technology Division, Japan International Research Institute for Agricultural Sciences (Ohwashi 1-2, Tsukuba, Ibaraki, 305-8686 Japan)*

[b] *Cuu Long Delta Rice Research Institute (Omon, Cantho, Vietnam)*

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Abstract

Rice production in the Mekong Delta has increased rapidly in recent years under Doi Moi policy. Farming Systems which combine agriculture, animal husbandry and fisheries have also been promoted. Through the cooperative research project with Cuu Long Delta Rice Research Institute (CLRRI), Cantho University (CTU) and Japan International Research Center for Agricultural Sciences (JIRCAS), research work is being carried out. Some approaches such as development of a method of diagnosis by leaf color measurement for the control of rice growth and yield components of rice, fertilizer application methods including nitrogen top dressing at the booting stage aiming at improving the nitrogen recovery rate and stabilizing yield, phosphate fertilizer application in the wet season, or water management in fields for the prevention of lodging in direct-seeded rice, should contribute to the development of low input sustainable rice production within the Mekong Delta Farming Systems.

Additional key words: diagnosis, fertilizer application, leaf color, seeding rate, water management, yield component

[a] Present address : Tohoku National Agricultural Experiment Station (Yotsuya, Omagari, Akita, 014-0102 Japan)

Introduction

The Mekong Delta covers an area of 5.9 million hectares (ha), of which 3.9 million ha are located in Vietnam. The Mekong Delta has favorable climatic conditions as shown in Fig. 1 which was drawn using data from Cantho Meteorological Station. Annual mean temperature is 26.6°C, precipitation is 1,632mm and there are 2,592 hours of sunshine per average year. Although the Mekong Delta benefits from such favorable conditions, the productivity had markedly stagnated due to the uninterrupted wars which afflicted the country.

Since 1986, under Doi Moi policy, the Farming Systems Approach which included activities such as improvement of rural infrastructure by canal excavation and dike construction for water control, introduction of high-yielding varieties with high resistance to diseases and insects from the International Rice Research Institute (IRRI), breeding of new varieties at CLRRI and CTU,

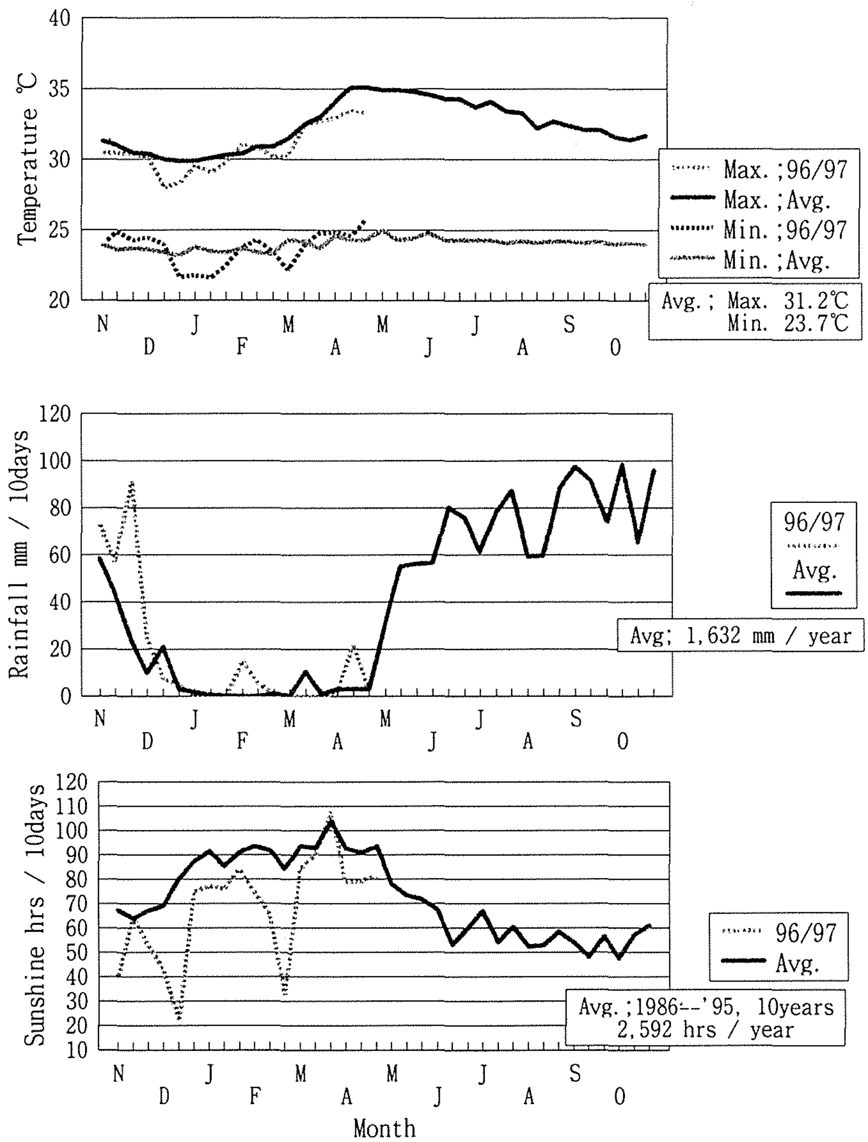

Fig.1. Climatic conditions in Cantho City
*This figure was drawn using data of Cantho Meteorological Station by JIRCAS in CLRRI

improvement and extension of direct seeding techniques of rice, was promoted. Due to the farmers' eagerness to increase productivity that was stimulated by the market-oriented economy, the cropping area increased through field reclamation and introduction of double or triple cropping of rice, and together with the higher yield of newly bred varieties, a rapid increase in rice production has been achieved in recent years.

Through feasibility studies undertaken by JIRCAS, many problems such as instability of emergence and establishment of seedlings in direct seeding culture, insufficient dry matter production and frequent lodging in the rainy season , and instability of rice production in inland acid soil area and coastal salinity soil area were pointed out. Therefore CLLRI, CTU and JIRCAS initiated on the Integrated Research Project titled; "Evaluation and Improvement of Farming Systems Combining Agriculture, Animal Husbandry and Fisheries in the Mekong Delta" from 1994 to 1999. Several programs were implemented in order to stabilize and increase rice cropping, and to improve the techniques of the farming systems, which include animal husbandry and fisheries, in harmony with the ecosystems.

This paper reports the activities in the Mekong Delta carried out two years from June 1995 to the end of May 1997 during which the first author was dispatched by JIRCAS in collaboration with CLLRI and CTU.

Materials and Methods

1) 1995/96 dry season and 96 wet season crop

In order to improve the cultivation methods, the authors developed a test for the diagnosis of rice growth in the 1995/96 dry season crop in CLRRI's paddy fields with the collaboration of the Agronomy Division.

The preparation of the field for the dry season crop began in mid November after water flooding had subsided. At the end of November, many aquatic weeds were removed by hand and the soil surface was puddled by pair of water buffalo using a wooden harrow or hand tractor equipped with puddling wheels. Then rice seeds were broadcast by hand on the drained soil surface, practice referred as "wet seeding" in early December. Rice plants were kept under good condition until harvest in March.

In the wet season, the field was plowed by a large tractor in April and puddled by a tractor with a rotary machine at the start of the rainy season. Wet seeding was practiced in early May and harvest took place in August.

For water control, pumps were employed for the drainage of the water at the start of the dry season and supply of puddling water at the start of wet season. Usually, water management for irrigation throughout the growth period is implemented by utilizing natural conditions when the water level of the canal fluctuates every day due to the tidal conditions.

Field soil composition was as follows; 57% clay, 42.5% silt, and 0.5% sand, for a depth of one meter or more. The pH of the topsoil was 5.2 (Tan, P. S. at al. 1995).

Experimental design is shown in Table 1. Nitrogen application rates ranged from 0 to 150kg/ha (6 levels with 30kg increment) in the dry season and 0 to 120 (5 levels) in the wet season. The rates

Table 1. Design of 1995/'96 dry season and '96 wet season experimrnts

	1995/'96 dry season	1996 wet season
Planting	Direct seeding	Direct seeding
Varieties	IR64, IR50404	IR64, Chiyonishiki
Nitrogen	0, 30, 60, 90, 120, 150kg/ha	0, 30, 60, 90, 120kg/ha
Phosphoric acid	0, 40kg/ha	0, 60kg/ha
Potassium	40kg/ha	80kg/ha
Replication	3	3

of phosphates were 0, 40kg/ha in the dry season and 0, 60kg/ha in the wet season. Potassium was applied at the rate of 40kg or 80kg/ha, respectively in the dry season or wet season. Three rice varieties as follows were tested; 100 day variety IR64 with a high yielding ability and good quality, high-yielding new variety IR50404, and Chiyonishiki (called Ishigaki at CLRRI) introduced from Japan by CLRRI.

Diagnosis of growth involves the determination of plant height, number of tillers, leaf color using a chlorophyll meter (SPAD502), dry matter production and nitrogen uptake at each growth stage. Relationships between these variables and the yield were analyzed. Yield components were analyzed based on the Japanese standard as listed in Fig. 2. This method is based on Matsushima's theory which determines when and how the grain yield of rice is controlled and enables to predict and to increase the yield (Matsushima, 1966). Specific gravity to select fully ripened grains was changed from 1.06 for Japonica paddy rice in Japan to 1.00 for Indica paddy rice according to Kon et al. (1982).

2) 96/97 dry season crop

In the 96/97 dry season, fertilizer application test was carried out to investigate the optimum time and rate of nitrogen top-dressing (Table 2). Direct seeding was performed in early December using OMCS 94, a 85 day variety and IR64 as standard variety. The total application rates of nitrogen in this experiment were 80 and 120kg/ha, divided into 2 or 3 top dressings of 40kg/ha. First top dressing applied at one week after sowing (as basal dressing) to all the plots, and continuously applied at the establishment stage, tillering stage or booting stage.

3) Experiment for seeding rate

Usually, most of the farmers practice direct seeding of rice at a very high seeding rate 200 to 250kg/ha or even more. This rate of seeding enables to secure a certain number of seedlings and to prevent rice plants from becoming infested with weed. However, sometimes a high density results in weak culm and consequently severe lodging.

Therefore, to determine the optimum seeding

Analysis of Yield Components of Rice

C1; Panicle number,
Counting panicle number per unit area.

C2; Whole grain number per panicle,
Counting whole grain number including fill and unfill grains
Cg = C1 x C2
Cg; Whole grain number per unit area.
Cg indicates yield capacity "sink" .

C3; Percentage of ripened grain.
Ripened grains are selected by specific gravity.
Paddy grains are selected with water; specific gravity 1.0.

C4; 1000 ripened paddy grain weight.
Measured using 1000 ripened paddy grains.
Cr = C3 x C4
Cr; Whole 1000 paddy grains yield.
Cr indicates the ripening ability,
or "source" accumulation in ripening period.
Yield = Cr x Cg

Graph for Yield Components.
Graph is drawn with Cg (X-axis) and Cr (Y-axis) as in Fig. 3.
Yield is shown by hyperbolic curve in the graph.

Fig.2. Method of analysis of yield components in this experiment

Table 2. Design of 1996/'97 dry season experiments

Planting Direct seeding
Varieties IR64, OMCS94
Nitrogen application (N kg/ha)

Plot No.	1 week after sowing	Establishment stage	Tillering stage	Booting stage	Total
1	40	40	0	0	80
2	40	0	40	0	80
3	40	0	0	40	80
4	40	40	0	40	120
5	40	0	40	40	120
6	40	40	40	0	120

Phoshoric acid 40kg/ha
Potassium 30kg/ha
Replication 3

rate in the Mekong Delta, the experiment was conducted in a concrete frame of CLRRI's net house in 1996 wet season and '96/97 dry season. Three seeding rates 5, 10, 15g/m^2 (equivalent to 50, 100, 150kg/ha) were tested with the early variety OMCS 94.

4) Song Hau State Farm

Rice production in the Song Hau State Farm was investigated to obtain further information about rice cropping in the Mekong Delta. This State Farm was founded in 1976. It develops through land reclamation, construction of canals and roads, reallocation of the fields to farmers, etc., and the number of settlers has increased. Today it covers an area of 6,981 ha, 80% of which consisting paddy fields, with 2,800 farmer households and 212 management staffs. Average cultivated area per household is about 2 ha. Farming systems which incorporate rice cropping, animal husbandry, fisheries, and vegetable cultivation have been implemented and good results were obtained.

Farmers grow two rice crops per year, in the dry season and wet season in the same way as at CLLRI . Furthermore, they drain out the water with large pumps (12 - 15 HP) to advance the seeding time at the start of the dry season crop.

The investigation was conducted in the 95/96 dry season, 96 wet season and 96/97 dry season, in collaboration with selected five farmers who adopted rice and fisheries farming systems. In the fields, the plant height, number of tillers, leaf color, depth of submerged water were observed every two weeks after establishment stage of rice. After harvest, yield components were analyzed and each farmer was interviewed in relation to the practices adopted.

Results and Discussion

1) Introduction of growth diagnosis and regulation techniques

(1) Analysis of yield components

Figure 3 shows the yield components in the 95/96 dry season and 96 wet season. The growth and yield of paddy rice in the 95/96 dry season crop were estimated to be satisfactory. Whole paddy grain number changed with the rate of fertilizer application ranging from fifteen thousand to fifty thousand per square meter. Ripening ability (whole 1000 paddy grain yield) decreased according to the increase of the whole grain number. The yield, estimated by multiplying the average whole grain number of 25,000/m^2 by a ripening ability of 20g, reached 5 tons/ha.

On the other hand, the 1996 wet season crop was not satisfactory. Even the largest whole grain number was around 22,000/m^2 , less than half of that of the dry season crop. The ripening ability was also low. As a result the yield was less than half of that of the dry season. The low yield was attributed to the fewer sunshine hours in the wet

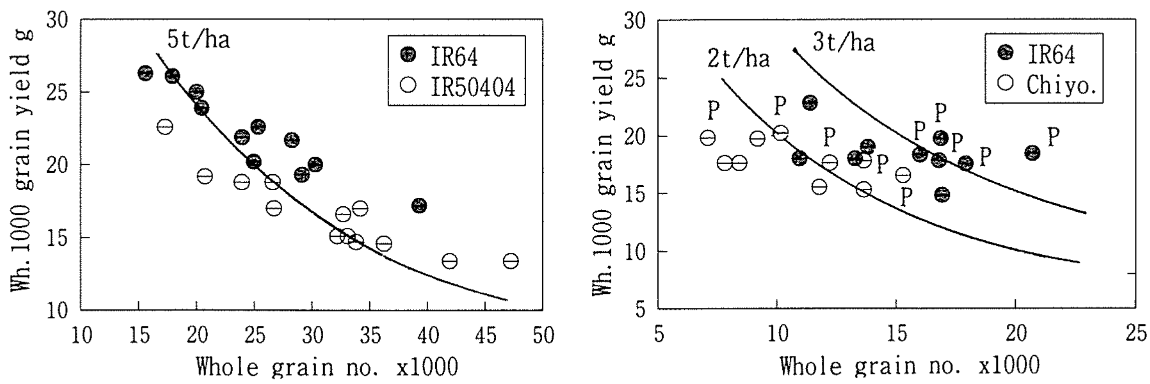

Fig.3. Yield components of direct seeded rice in 1995/'96 dry seasson and 1996 wet season
*Hyperbolic curves in graph show the yield of paddy rice (t/ha)
*Symbol "P" refers to the plots where phosphate fertilizer was applied

season as shown in Figure 1. Since cloudy weather had continued from the tillering stage to the ripening stage from early July to August, the growth capacity and whole grain number were reduced and the ripening ability decreased due to low photosynthesis activity. In addition, severe lodging occurred in the 1996 wet season due to the strong wind of a typhoon which attacked central part of Vietnam.

The yield of IR64 was about 3t while that of Chiyonishiki was very low, 1.5 to 2.5t/ha. IR50404 experienced lodging due to of its thin culm and yield was lower. Chiyonishiki's growth and yield were insufficient. It is not recommended to introduce Japanese varieties directly into this area as in this experiment. Selection of the varieties is very important to attain a stable and high yield.

Figure 3 shows the importance of phosphate fertilizer application in the wet season crop as pointed out by Tan, P. S. (1995) already. It was also observed in this experiment that of the growth of rice in the plots without phosphate application led to a lower number of grains and yield.

(2) Growth diagnosis by leaf color

At each growth stage, there was a high correlation between the SPAD value and nitrogen content in the leaf blade. Figure 4 shows the correlation at the panicle formation stage as representative of all stages. The two varieties, in both dry and wet seasons showed a high correlation (r=0.841 and 0.857, respectively) indicating the validity of the leaf color test for the diagnosis of the condition of nutrient nitrogen.

Regression lines of dry and wet season were estimated as Y= -0.368 + 0.0958X and Y= -0.159 + 0.0755X, respectively. Nitrogen content of the leaf blade for the same SPAD value in the wet season was lower than that in the dry season. According to Kitagawa et al.(1987), the regression line was estimated as Y= -0.511 + 0.097X in Koshihikari which is the most popular cultivar with good quality in Toyama Prefecture in the central part of Japan. The regression coefficient of 0.097X in their report is similar to the coefficient obtained in the dry season experiment but different from that of the wet season. Therefore, the growth of rice in the wet season was considered to be different or abnormal compared with the growth in the dry season.

Although a significant correlation between the leaf color or SPAD value and yield was obtained in the dry season, in some plots which showed a high SPAD value at the panicle formation stage, the yield was reduced because of lodging. In the wet season, the yield was highest, 30 to 35 SPAD value, at the panicle formation stage without a significant correlation. With deeper leaf color, rice plants become too soft to prevent them from experiencing frequent lodging, and therefore the yield did not increase.

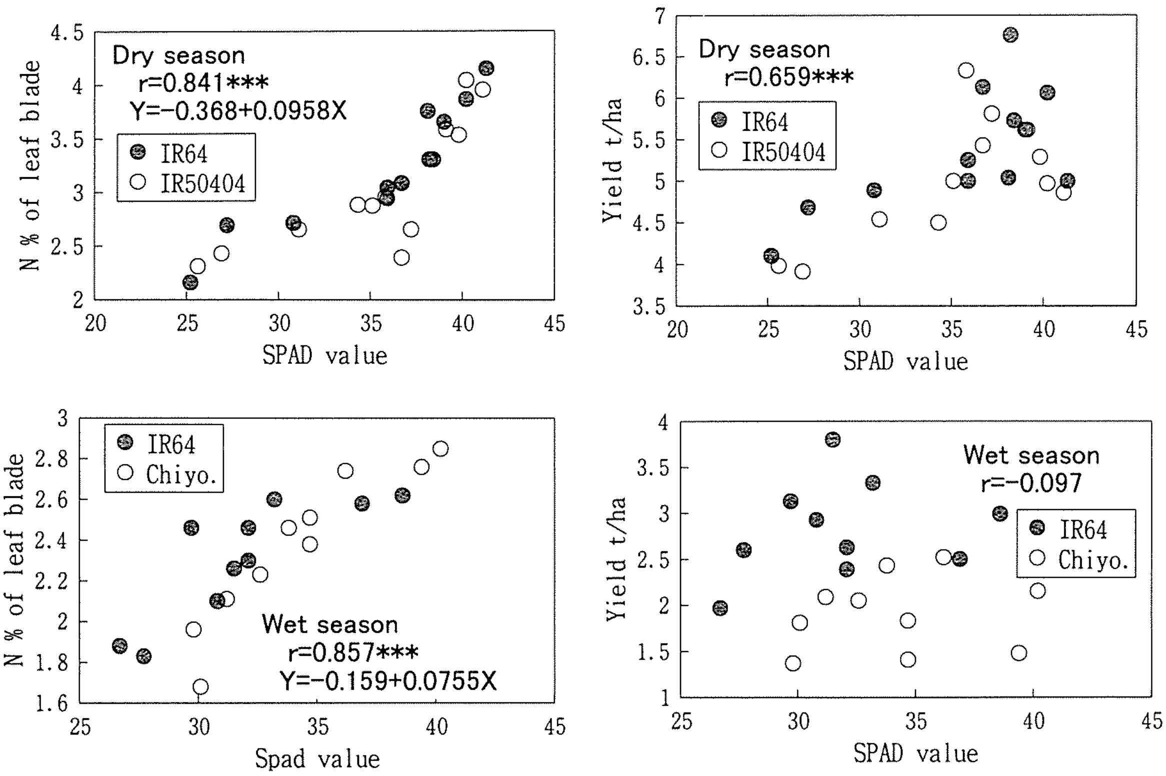

Fig.4. Correlation between SPAD value and nitrogen content and yield
*SPAD value was measured using "Chlorophyll Meter SPAD-502"
*Mark "***" indicates significance at 0.1% level

Through the questionnaires, it was revealed that many farmers tended to apply additional nitrogen top dressing because of the slow growth of rice plants in the wet season. To avoid lodging which might be caused by heavy manuring, top dressing should be performed based on the leaf color diagnosis.

As mentioned above, the growth diagnosis which employs the leaf colour as an indicator can be considered to be a valuable method in tropical rice cropping.

2) Improvement of fertilizer application for stable yield

In the 1996/97 dry season, due to unfavorable weather conditions (Fig. 1.) with fewer sunshine hours and low maximum temperature, plant growth had declined at the early stage. However with the recovery of the weather conditions from February, ripening was adequate and high yield was obtained.

The effects of nitrogen application on the yield components are shown in Fig. 5. In both varieties, plots No.3 which had received 40kg nitrogen in the first week after sowing and at the booting stage (OMCS94: 8th week, IR64: 9th week) gave the highest yield. This figure revealed that number of grains increased and ripening ability remained relatively high by the application of nitrogen at the booting stage. Obviously nitrogen recovery was improved by this application method.

In contrast, in the plots which received 40kg nitrogen before the booting stage, the nutrient appeared to have been spent for excess growth of stem and leaf and did not affect the increase of grains. In some plots with heavy manuring like No.5 (both varieties) and No. 6 (OMCS94) rice plants experienced early lodging, and gave low yields. These results suggest the need to reconsider the use of top dressing early stages in fields with fertile clay soil in the Mekong Delta.

Figure 6 shows the influence of nitrogen application on the changes of leaf color (SPAD value). The value of the leaf color of the plants in plot No.3, the highest yielding plot, was lower than that of the plants in other plots at the panicle formation stage. These data suggest that early growth of the plants in plot No. 3 which received less nitrogen at the early stage of development was regulated to avoid excess growth by restriction of nitrogen uptake.

The growth control technique through nitrogen application is recognized in the Mekong Delta to be valid. Improvement of fertilizer application based on growth regulation and higher efficiency of nitrogen utilization would result in higher and stable yield but low input in harmony with the ecosystems.

3) Seeding rate suitable for wet seeding in the Mekong Delta

Number of established seedlings in this experiment was about 200, 350, 500 plants/m^2 with 5, 10, 15g/m^2 seeding rate, respectively. These numbers did not vary appreciably with the cropping season, and establishment rates were calculated to be about 80% of total seeds. Usually established rate is about 60% or more less in field experiments. Therefore 15g/m^2 obtained in this experiment in the net house is almost equivalent to 200kg/ha in farmers' fields. To improve the establishment rate of seedlings in farmers' field, more careful land preparation is required.

Four elements of yield components are shown in Table 3. The distribution of two elements was summed into 2 components and the yield is shown in Fig. 7. In the wet season, high density of seeding, 15g/m^2, led to the production of a large number of panicles only on the main culm while very few grains per panicle were obtained and finally the whole grain number per unit area was low. Though the plot with 10g/m^2 seeds produced a larger whole grain number, whole 1000 paddy grain yield, indicator of ripening ability, decreased more appreciably than in the plot with 15g/m^2. On the contrary, in the plot with 5g/m^2 seeds with a moderate panicle number, the plants maintained a high ripening ability and a relatively high yield was obtained. Most of the panicles were formed on the

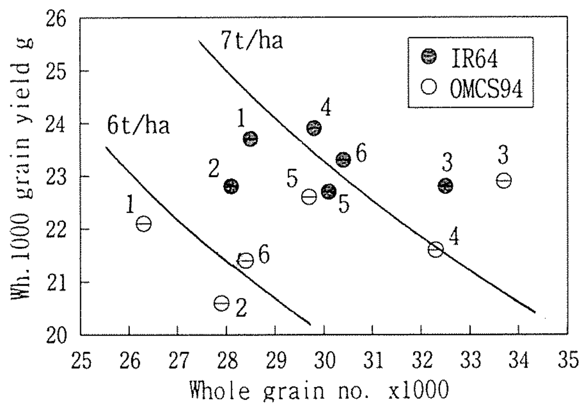

Fig.5. Yield components in fertilizer application experiment, 1996/'97 dry season
*Symbols of "1"---"6" ; plot numbers in Table 2

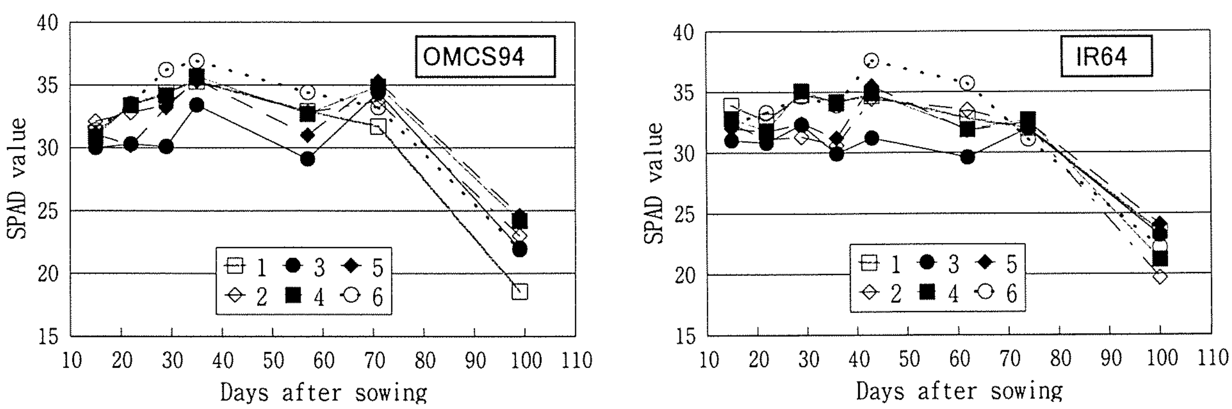

Fig.6. Change of leaf color influenced by nitrogen application method, 1996/'97 dry season crop

Table 3. Yield and components at different seeding rates

Season	Seeding rate g/m^2	No. Panicles /m^2	Whole grain no. /panicle	Whole gtain no. x1000/m^2	Ripened grains %	Ripened grains weight g/1000	Whole grain yield g/1000	Yield g/m^2
1996	5	366	68	24.7	72.2	25.1	18.0	445
Wet season	10	413	63	26.1	50.1	26.2	13.1	342
	15	552	41	22.4	62.1	25.4	15.8	353
1996/67	5	351	63	21.9	80.7	26.5	21.4	469
Dry season	10	414	58	24.0	78.5	26.4	20.8	499
	15	599	48	28.6	77.9	26.5	20.6	589

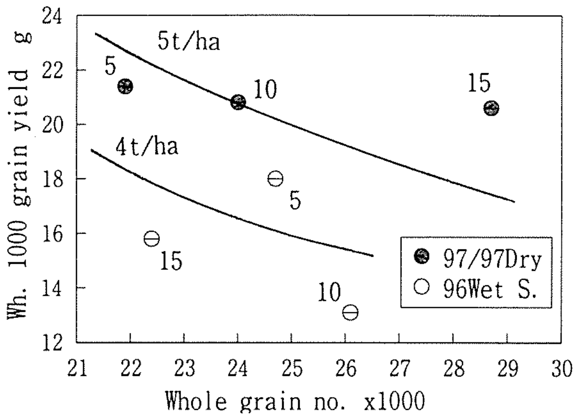

Fig.7. Influence of seeding rate on yield components
*Figures 5, 10, 15 show the seeding rate (g/m^2)

main culm or on the thick culm sprouted from lower node in this plot.

In the dry season, whole grain number per unit area increased with higher seeding rate. As the ripening ability did not vary significantly with the grain number, yield increased according to whole grain number up to about 30,000/m^2 in this experiment.

It was important to obtain an adequate density of about 200 plants/m^2, equivalent to 85kg/ha of seeds for an establishment percentage of 60% in farmers' fields in the wet season. In the dry season, high density of about 500 plants resulted in higher yield but the seeding rate was adequate at 15g/m^2 in this experiment or equivalent to 200kg/ha for on establishment percentage of 60% in farmers' field.

According to Hiraoka's report (1991) in Malaysia the same results were obtained. A plot with a high plant density, 400 plants m^2, gave a higher yield in the 2nd season, being equivalent to that of dry season crop. However no significant difference was recognized among the planting densities in the 1st season crop, the yield being equivalent to that of the wet season.

Further studies on seeding rate and land preparation techniques are required for the improvement of direct seeding rice culture in the Mekong Delta.

4) Field investigations in Song Hau State Farm

(1) Input of fertilizer and chemicals

Table 4 shows the results of interviews with farmers on fertilizer and chemicals applications in farmers' fields. Fertilizer was applied in accordance to the manual of the State Farm. Amounts of applied nitrogen were about 100kg/ha in dry season and 85kg/ha in the wet season and heavy manure application was not practiced. Chemicals applications were also rare due to the low incidence of pests and diseases, as a result of the moderate fertilizer application and the use of resistant varieties.

These results are very important for environmental conservation in water-based society in the Mekong Delta.

(2) Yield and yield components

Paddy yield estimated from yield components in the dry season crop exceeded 6t/ha, with about 30 thousand grains per m^2 and the ripening ability exceeded 20g per 1000 whole paddy grain yield. The wet season crop yielded about 4t/ha level, with 20-25 thousand grains per m^2 and a lower ripening ability about 20 g per 1000 whole grains

Table 4. Fertilizer and chemicals application in farmers' fields

Farmer	Fertilizer kg/ha						Frequency of chemicals application					
	N		P_2O_5		K_2O		Fungic.		Insectic.		Herbic.	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
A	99	76	58	48	19	14	0	0	2	2	1	0
B	83	72	52	54	5	19	1	1	0	0	0	0
C	95	85	44	58	4	17	1	0	0	2	1	1
D	76	87	53	46	8	0	3	0	0	2	0	1
E	98	89	46	47	4	4	2	2	0	1	0	1

*Fungicide; Tilt, Validacin, Anvil, Banistin, etc.
*Insecticide; Monitor, Azodrin, etc.
*Herbicide; 2, 4D, Sirius, Whips, etc.

(Fig. 8).

(3) Water management

In the fields of the five farmers, yield of farmer A's field was lower than that of the others due to heavy lodging caused by deep water submergence (Table 5). Deep water was maintained first, to induce an optimal environment for fish raising in the paddy field and second, to prevent damage of rice by rats. By deep water submergence, not only the plant growth and number of grains were reduced but the ripening ability also decreased due to the occurrence of rolling type lodging caused by the low soil bearing capacity.

On the other hand, farmer E who managed water submergence with close attention, obtained a large number of grains with good ripening ability, resulting in a high yield, more than 7 tons in the dry season and 4.5t/ha in the wet season.

The yield of the dry season crop was equivalent to the average yield level of Koshihikari in Niigata prefecture, central part of Japan, where paddy yield is 7t/ha (estimated from brown rice yield divided by 0.8) with 30,000 whole grains/m^2 and 23.3g whole 1000 grain yield (Kon et al. 1992). It was anticipated that a yield of 8.5 to 9 tons could be attained by careful and efficient farming.

Obviously, water management such as mid-season drainage is effective for strengthening rice plant and increasing the soil bearing capacity, prevention of rolling type lodging. Through the extension of this technology, rice production could be stabilized in the Mekong Delta.

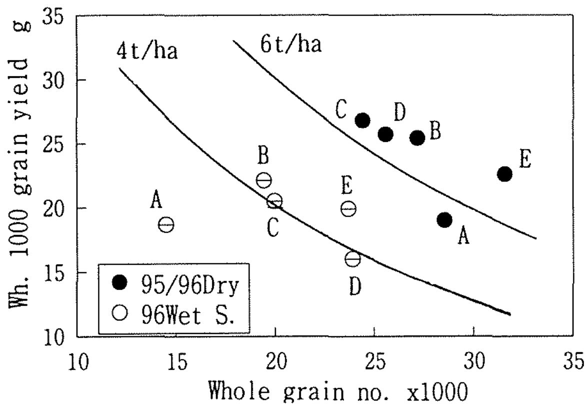

Fig.8. Yield components in fields of 5 farmers' in Song Hau State Farm, 1995/96 dry season and '96 wet season
*Symbols "A"---"E" stand for farmers

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Table 5. Depth of submergence water in farmers' fields (cm, 1996 wet season)

Farmer	28/4	12/5	26/5	9/6	23/6	7/7	21/7
A	8	23	25	29	26	6	Hav
B	Tp	10	13	24	20	20	0
C	8	1	8	18	21	9	0
D	8	13	15	18	21	9	0
E	Tp	0	2	9	3	0.5	0

*Tp; befor trans-planting. Hav; after harvesting.

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メコンデルタのファーミングシステムにおける稲作技術の改善

金　忠男[a)]，ファン　シ　タン[b)]，チャン　ゴック　ファン[b)]，
ティン　カン　クン[b)]，フォン　ディン　ディン[b)]，

[a)]国際農林水産業研究センター生物資源部
（〒305-8686　茨城県つくば市大わし１－２）

[b)]クーロンデルタ稲作研究所
（ベトナム　カントー省　オモン）

摘　要

ベトナムに所属するメコンデルタ(面積は39,000km^2)の中心地，カントー市の気候条件は年間の平均気温26.6℃，降水量1,632mm，日照時間2,592時間と恵まれており，稲の栽培も盛んである。かって，第２次世界大戦後の相次ぐ戦争の影響で生産活動は停滞していたが，1986年以降のドイモイ政策とファーミングシステム・アプローチ（農業研究者，行政担当者等による農業振興運動）による，運河(canal)掘削等の基盤整備，耐病性・耐虫性に優れたIRRIの高収品種の導入，ベトナムの研究機関における新品種の育成，直播栽培技術の改善と普及等が推進された。これと市場経済の促進によって向上した農民の生産意欲とがあいまって，開墾のみならず水稲の２期・３期作の導入等による作付け面積の拡大と単収の増加が実現し，米の生産量は急速に増加している。

こうした情勢の中で，クーロンデルタ稲研究所とカントー大学との共同で，国際農林水産業研究センターの総合プロジェクト研究「メコンデルタにおける農畜水複合技術体系の評価と改善」が1994年度から1998年度にわたって実施されている。研究はなお継続中であるが，本報では筆頭著者が1995年から1997年にかけて，ファーミングシステムの中心となっている稲作の現状と改善方向について検討してきた結果をまとめて報告する。

葉色を中心とした生育診断試験では，葉色と葉身の窒素含有量との間には生育各期に高い正の相関関係があり，メコンデルタにおいても，重要な生育診断指標であることが分かり，また，収量との関係では幼穂形成期の葉色が濃い区での倒伏の発生と収量の低下が認められた。こうした結果の検討を受けて実施した施肥法試験では，初期の窒素追肥を抑え，穂孕期に追肥することによって増収し，生育制御技術の適用の重要性が示唆された。隣接するソンハウステートファームにおける農家圃場の調査では，農場が指導している中庸な施肥水準が遵守され，農薬の使用回数も少なく，水準の高い稲作が実施されていること，ある農家では，圃場の水管理で安定した稲作を行っていること等が分かった。

こうした成果は，メコンデルタにおける低投入，持続型稲作技術の確立の基礎的な知見として役立つものと期待される。

キーワード：生育診断，施肥法，葉色，水管理，収量構成要素

[a)]現在：東北農業試験場　水田利用部（〒014-0102　秋田県大曲市四ツ屋）