Development of Rice Production Technology in Southeast Asia

Nobuyuki Kabaki*

Abstract

Rice cultivation technology in Southeast Asia is undergoing a transition from the traditional method of manual transplanting to direct seeding due to the shortage of labor and increased wages associated with industrialization. In the irrigated areas, "pregerminated direct seeding", in which germinated seeds are sown on well-drained paddy fields after puddling, is being rapidly disseminated throughout Southeast Asia. In the rainfed areas, "dry seeding", in which dry seeds are sown under upland conditions at the onset of the rainy season, is conducted in some countries. Development of new technologies derived from the "Green revolution" such as land preparation, use of high-yielding varieties, application of pesticides and fertilizer has contributed to the adoption of these peculiar types of direct seeding cultivation in Southeast Asia.

Improvement of rice production technology should be directed to the increase of productivity while maintaining a sound environment. Themes to be covered consist of water control at field level, effective production under low inputs, labor-saving large-scale production, improvement of postharvest technology and crop rotation systems including upland crops. The last item is especially important in the context of raising crop production as a whole, since paddy fields have an inherent advantage due to the presence of water compared with upland cropping which is subjected to erosion and environmental stresses. Thus, rice production technology plays a key role in the development of sustainable agriculture in Southeast Asia.

Introduction

Southeast Asia represented by ASEAN countries has been recording a high rate of economic growth recently. The trend of agriculture in this region is a cause for concern since the region is both heavily populated and produces food crops such as rice, cassava, sugarcane and legumes.

Rice production in Southeast Asia amounts to approximately 22% of that in the world out of 26% of the total cultivated area. On the other hand, exports from Southeast Asia accounted for about 45% of the world rice trade in 1993 and the amounts are increasing even more presently, which indicates the importance of this region in terms of world food production (FAO, 1995). Against this background, some questions can be raised such as "Can Southeast Asia increase rice production to meet the demand of population increase?", "Is there any strategy to combine the enhancement of productivity with the protection of the environ-

* Japan International Research Center for Agricultural Sciences (JIRCAS), Japan

ment?" or "Which strategy should be adopted for promoting sustainable agriculture in the monsoon tropics?". To answer these questions, the present situation and prospects of rice production in Southeast Asia are analyzed from the standpoint of technological assessment in this paper.

Trends of production

Asian countries produce more than 90% of world rice, among which China, India and the Southeast Asian countries are the main producers (IRRI, 1997). Production by these countries in the past 30 years has increased remarkably, presumably due to the "Green revolution" (Fig.

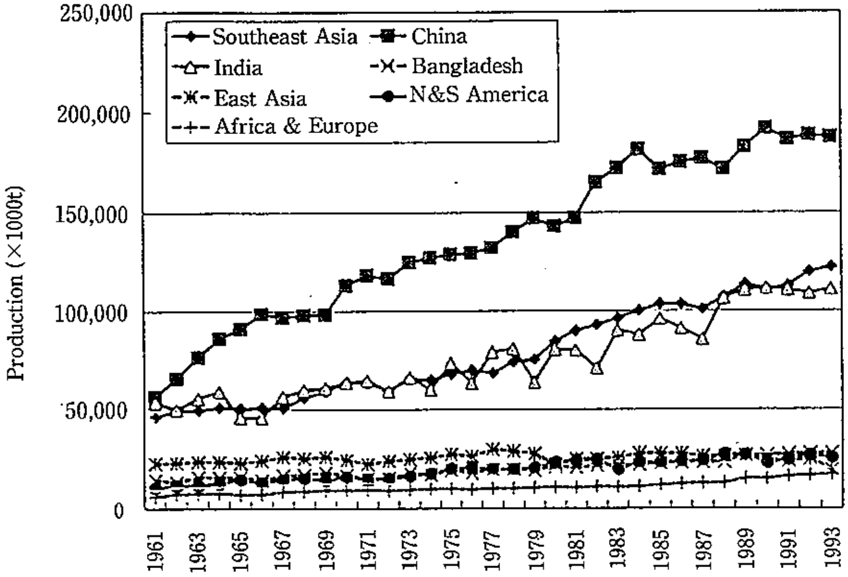

Fig. 1 Trend of rice production in the world
Source: World Rice Statistics 1993-94, IRRI.

1). However, in the past 10 years, production in China and India has reached a plateau whereas that in Southeast Asia shows a gradual increase. Fig. 2 depicts the production in individual countries in Southeast Asia. Indonesia, Vietnam and Myanmar have contributed to the increase of production in Southeast Asia in these years. Based on the changes of harvested area and yield, the increase of yield has been more conspicuous than that of cultivated area. Expansion of the cultivated area has reached a plateau in most of the countries. On the contrary, there are large differences in yield between countries, which suggests that there is room for improvement.

Southeast Asian countries can be classified into four groups from the standpoint of rice production. The first is composed of the countries which consider rice as one of the export commodities. Thailand and Vietnam are such countries and they contribute to world trade by exporting almost half of the global circulation. The second group consists of Malaysia,

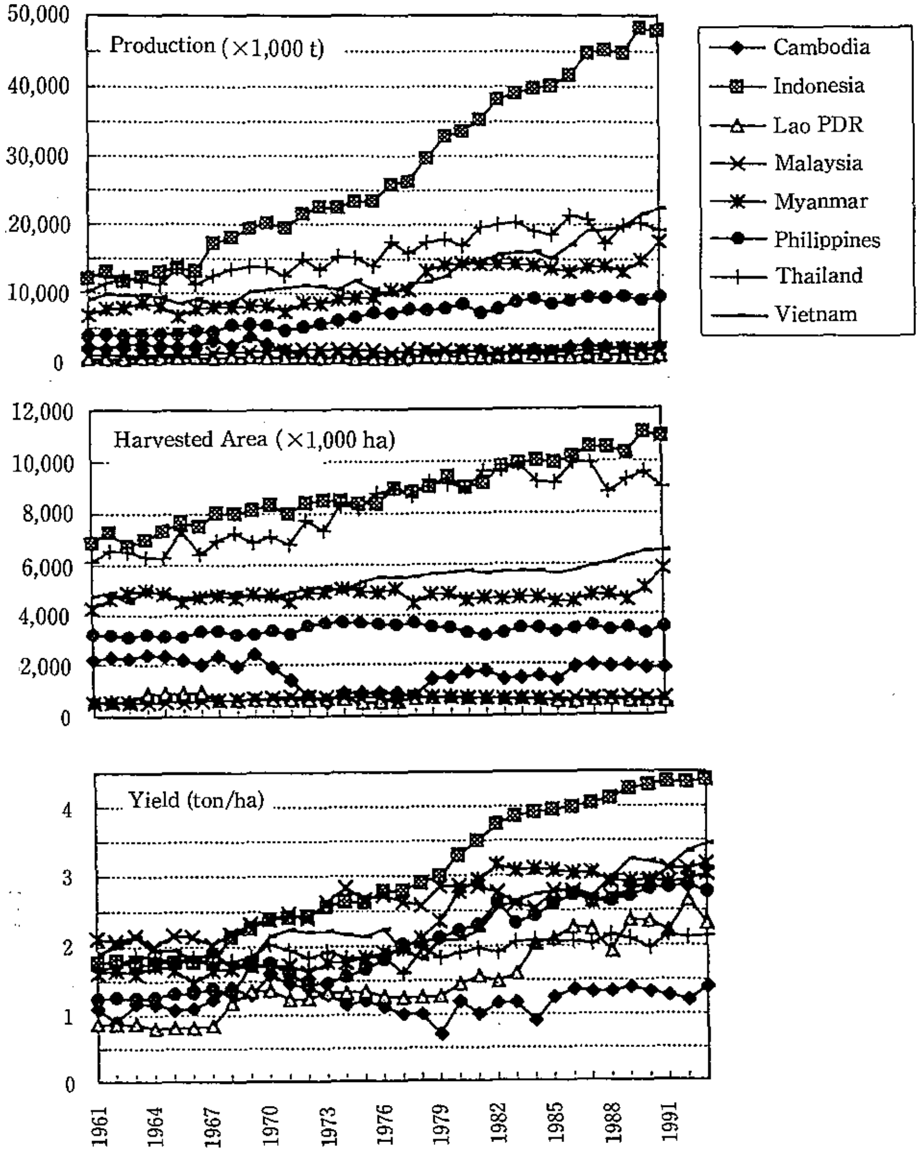

Fig. 2 Trend of rice production in Southeast Asian countries
Source: World Rice Statistics 1993-94, IRRI.

Singapore and Laos which import rice constantly. Although Malaysia has a capacity to produce rice, it limits the rate of self-supply to a certain level. Indonesia and Philippines form the third group which has promoted a policy of self-sufficiency. They have attained self-sufficiency in recent years but occasionally export or import rice depending on the fluctuations of production. The fourth group is composed of Cambodia and Myanmar which are self-sufficient in rice while having a large potential to increase production.

To interpret the present situation from the standpoint of supply and demand of food in the world, Southeast Asia plays a role of food supplier through the production of rice. Increase of population is not as steep as during the era of "Green revolution" and per capita consumption of rice has generally tended to decrease due to the diversification of eating habits associated with industrialization. However, expansion of cultivated area has reached a plateau and is decreasing due to industrialization. Thus, long-range consideration points to the necessity of enhanced production from the limited cultivated area to meet the demand of a steadily increasing population. Policy making and technology innovations are indispensable to raise the productivity of rice in Southeast Asia.

Characteristics of rice cultivation in Southeast Asia

Rice is characterized by the ability to grow in water, a tropical origin and simple method of cultivation. Presence of water stabilizes the production by preventing drought or the proliferation of weeds. The tropical origin results in the susceptibility to low temperature damage in the temperate zone. Handling is simple not only during cultivation but also after harvest. Processing to food requires fewer steps than for other crops and paddy itself has a long storage life. Against this background, rice production in Southeast Asia seems to have an advantage compared with that in other areas. Abundant rainfall and high temperature due to the tropical monsoon provide a good environment for rice and the simplicity of cultivation reduces work under a hot climate.

However, several constraints hamper rice production in Southeast Asia including the difficulty of water control (TARC, 1988). Although in Southeast Asia annual precipitation exceeds 1,000 mm which is generally considered to be the threshold for rice cultivation, there are two seasons, wet and dry. Cultivation in the dry season requires irrigation and that in the wet season is prone to flooding due to heavy rain. The presence of irrigation and drainage facilities is important to control water and each country has devoted efforts to develop them. The need for heavy investment or competition for water with the industrial sector is becoming a limiting factor to the installation of irrigation systems in many countries.

Hot and humid climate in Southeast Asia is not necessarily suitable for the productivity of rice (Kon, 1997). High night temperature leads to the depletion of the photosynthates accu-

Table 1 Growth and yield of rice in relation to season and cultivation methods in the Mekong Delta

Season	Cultivation method	Weather condition		Total dry weight (g/ha)	Crop growth rate (CGR)		Number of spikelets (x100/m2)	Ripening percentage (%)	Paddy yield (t/ha)
		Temperature (℃)	Sunshine (hr/day)		Before heading ($g/m^2/day$)	After heading ($g/m^2/day$)			
Dry season	Transplanting	25.7	8.78	1,339	17.88	17.25	308	77.3	5.95
	Direct seeding	〃	〃	1,321	18.66	13.16	349	65.3	6.07
Wet season	Transplanting	27.4	6.23	1,156	15.76	12.86	220	73.5	4.82
	Direct seeding	〃	〃	1,100	14.47	9.85	204	62.4	2.98

Weather conditions were expressed by the mean value in the dry season (December - March) and wet season (May-August) (Kon, 1997).

mulated in the daytime because of elevated respiration. Solar energy in the wet season decreases conspicuously in some countries. These factors inhibit dry matter production of rice and lead to reduced yield (Table 1). Thus, the biological yield potential in the tropics is not as high compared with the temperate zone although rice originated from the tropics.

Lack of agricultural inputs is another factor for the limitation in the production of rice. Low price of rice limits the application of costly fertilizers or pesticides. In addition, the biota (fauna and flora) in Southeast Asia are abundant, periodically causing damage to rice in the form of insects, pathogens, weeds or small animals.

On the other hand, the excess of application of agricultural inputs leads to environmental degradation. Topography of the rice area in the Southeast Asian countries is wide and flat, which leads to water pollution in the form of eutrophication or contamination by agricultural chemicals. Thus, yield increase should be attained in harmony with the environment.

Current technology for production

Rice cultivation in Southeast Asia has been conducted by hand transplanting traditionally. However, shortage of labor due to industrialization has resulted in a change of the production technology. Direct seeding which has been introduced mainly in irrigated areas is referred to as "Pregerminated direct seeding" (Morooka *et al.*, 1996). Rice seeds that germinate to a length of about 5 mm are broadcasted on the paddy field which is drained after puddling. Seeds located on the soil surface are supported by young plumules while roots secure good elongation. As a result, seedling establishment is rapid due to the high temperature in the tropics. Water is introduced at around 1 week after sowing of seeds and herbicides are applied to suppress weeds. Seeding rate is high (more than 100 kg/ha), which enables ample growth to obtain high yield.

Several technological innovations have been associated with the development of direct seeding. Elaborate land preparation and levelling, and water control through minute irrigation and drainage are essential to obtain good seedling establishment. Semi-dwarf high-yielding varieties must be used to avoid lodging after heading. Application of herbicides is indispensable to suppress weeds and agricultural inputs such as fertilizers or pesticides are necessary to achieve a higher yield. Introduction of machine harvester is convenient to harvest broadcasted rice. This production technology is not only in line with the "Green revolution" but also aims at a flexible form of production utilizing the environment of the tropics.

Pregerminated direct seeding is however associated with shortcomings (Kabaki, 1987). Damage from golden snails is severe in some areas. Proliferation of weeds such as barnyard grass is observed since the initial stage of growth occurs under drained conditions. High density seeding itself poses some problems in productivity as shown in Fig. 3. Vigorous growth in the initial stage leads to the depletion of available nutrients resulting in reductive condition of soil especially in the rainy season when the solar energy is scarce.

Rainfed area accounts for 60 % of the total rice field area in Southeast Asia leading to unstable production due to either shortage or excess of water. Production technology in the rainfed area varies depending on the conditions. Direct seeding is practiced in the upland rice or floating rice areas. Hand transplanting has been conducted in the area where water

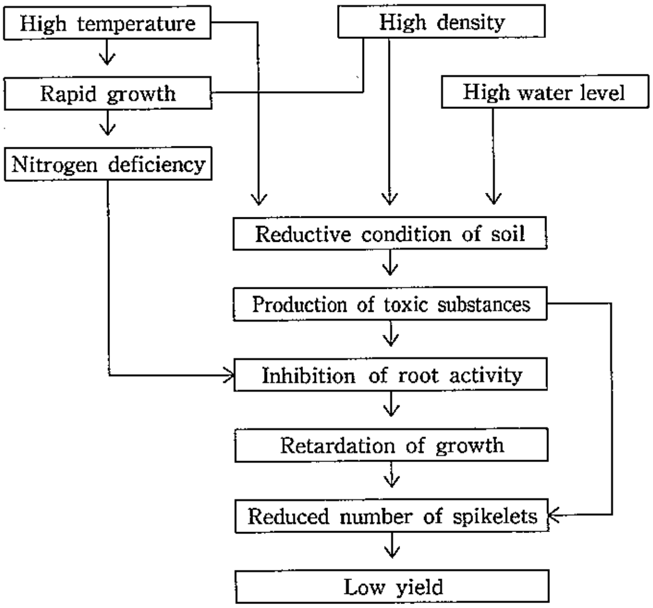

Fig. 3 Physiological mechanism of growth inhibition in pre-germinated direct seeding in the tropics
Source: Kabaki, 1987.

Table 2 Prospects for production technology of paddy crops in Southeast Asia

Item	Objectives	Key technology (examples)
Infrastructure	To improve water control at farm level	On farm irrigation and drainage system Tank irrigation, Ditches and dikes
Productivity	To increase the yield under local conditions	Stress-tolerant high-yielding varieties Growth monitoring system
Protection of environment	To reduce the input of agricultural chemicals	Integrated pest management Varieties tolerant to diseases and insects
Reduction of labor and cost	To promote large scale low cost production	Direct seeding cultivation Efficient crop tending system
Postharvest and quality control	To reduce the loss and improve quality	Storage and processing system High quality varieties
Multiple cropping systems	To raise productivity with sustainable production	Water recycling system Crop rotation system

becomes available in the rainy season. However, transplanting culture in these areas is unstable because of the fluctuation of rainfall in the beginning of the rainy season. Land preparation such as puddling is hindered or damage from drought occurs after transplanting occasionally due to dry spells at the onset of the rainy season. Shortage of labor for transplanting poses problems. Eventually, a type of direct seeding which is referred to as "Dry seeding" is currently spreading (Kono *et al.*, 1997). In this method, ungerminated rice seeds are sown under upland conditions after tillage of the field. Rice seeds germinate with the increase of soil moisture due to rainfall. Water is introduced into the field when it becomes available and rice is cultivated under waterlogged conditions as in the case of transplanting culture. This method of direct seeding is suitable when rainfall is erratic while weed control is essential to protect rice.

Thus, current rice production technology in Southeast Asia is undergoing a transition from hand transplanting to direct seeding. This orientation is peculiar to the region compared with other rice-producing countries. The United States, Australia or European countries have developed fully mechanized large-scale direct seeding technology, whereas Japan and Korea have applied machine transplanting for cultivation on a small scale. Development of production technology in Southeast Asia in this stage is characterized by a reduction of labor with limited application of agricultural inputs (Hamamura, 1991).

Prospects for sustainable production

It is important to maintain a harmonious development of agricultural production along with the progress of industrialization in Southeast Asia. Rice production is expected to be the support and driving force of development. Here, the prospects for production technology are discussed from the standpoint of sustainable agriculture (Table 2).

1 Infrastructure

Water management is a prerequisite to raise the productivity in rice. Although the irrigation and drainage facilities have been extensively constructed in the Southeast Asian countries, the rate of expansion has reached a plateau in some countries because of the topography or competition for water with the industrial sector (Kono *et al.*, 1997). However, "irrigation" which until now had been mainly limited to arterial and water control in individual paddy fields cannot be continued. The utilization efficiency of water may increase if the irrigation and drainage system of collateral or terminal channels could be connected to a paddy plot . Minute water control is also important to raise the productivity of rice especially in the case of direct seeding which requires special care at the onset of growth.

In the rainfed area which occasionally becomes a flood plain, small-scale facilities which enable to drain or irrigate water when the water level is high and low, respectively are required. Construction of tanks or dikes which enables recycling of water on a small scale will be effective to raise crop production in the rainfed area.

2 Productivity

Rice production in Southeast Asia has traditionally taken the form of low input agriculture and relied on the expansion of the cultivated area when it is necessary to increase production, as observed in Thailand in which the northeastern region increased the rice area during the period of 1950-1970. On the other hand, expansion of area has reached a limit in most of the countries and increase of production per unit area has become the main objective. Breeding of high-yielding varieties with tolerance to environmental stress such as high and low temperatures, drought or submergence is essential to raise productivity under the diverse growth conditions. Development of suitable cultivation methods under the limited adoption of agricultural materials is also important to raise the productivity of rice. Intensive crop tending is essential to adjust the condition of rice to changing local environment.

3 Need to protect the environment

There is a growing tendency to increase the use of agricultural inputs such as fertilizers and pesticides. Widespread adoption of direct seeding which requires the application of herbicides seems to accelerate this trend. In that case, the effect on the environment should be taken into consideration. Topography of lowland areas in Southeast Asia is flat and water stagnates. Water pollution tends to occur more readily than in rice areas where the topography is steep. Excessive application of fertilizers causes eutrophication of rivers or lake water. Growth diagnosis of rice is essential to determine appropriate method of application. Use of agricultural chemicals such as herbicides, insecticides or fungicides should be minimized through the adoption of integrated pest management (IPM). Biotechnology will also play an important role in the incorporation of effective genes which enhance tolerance to insects, diseases or environmental stresses along with the conventional breeding procedures.

4 Reduction of labor and cost

Large scale cultivation with low cost production is another problem to address for the cultivation of rice in Southeast Asia. Rural population is decreasing in many countries due to the rapid industrialization and it is important to raise the income of farmers through concentration of fields with reduced cost of production. Technology innovations should be developed in various aspects of cultivation and directed to fit local conditions. Establishment of direct seeding may be one of the measures which enable to achieve this objective and efforts should be made to develop production techniques suitable for Southeast Asia.

5 Postharvest and quality control

Improvement of postharvest technology is important from the standpoint of food supply and quality control. Extensive loss of rice occurs after harvest due to inappropriate handling such as deterioration under high moisture level or damage by insects or rats during storage (Food Agency, 1995). While the utilization of combine harvester is increasing to save labor for harvest, facilities for processing are not sufficiently developed in many countries.

Quality control is also essential to make rice production profitable. Breeding of varieties with good taste and nutritive value along with careful processing enhances the value and extends the market for rice.

6 Multiple cropping systems

Large-scale monoculture of upland crops in the tropics is facing a crisis due to the degradation of soil fertility or erosion. Paddy fields offer an advantage in view of sustainable production due to the presence of water. Introduction of rice-upland crop rotation systems by converting the field water regime alternatively from flooding to upland conditions has several advantages in terms of total crop production. Growth retardation due to nematodes or fungi by continuous cropping under upland conditions can be avoided by periodic flooding. Proliferation of dominant weeds is suppressed depending on the water regimes. Productivity of rice can be enhanced by the increase of soil nitrogen content through soil drying effect after cultivation of upland crops. Thus, development of infrastructure to enable multiple cropping systems is important to raise productivity in Southeast Asia.

Conclusion

Southeast Asia is a "rice bowl" supplying large amounts of rice to the rest of the world while experiencing rapid industrialization. Therefore, the trends of supply and demand of rice in this region are a cause for concern. There is a potential for increasing the production in many countries provided that appropriate measures are taken, as mentioned above, depending on the agricultural policy implemented or national consensus in each country.

Increase of production and simultaneous protection of the environment may not be compatible except for rice production in paddy fields which allows for sustainability. Environmental pollution could be minimized by the application of comprehensive production technology.

Since the utilization of paddy ecosystems for agricultural production is promising in Southeast Asia because of the favorable conditions in this region, the development of rice-based farming systems should be promoted through agricultural research.

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