JARQ 37(1), 37 – 44 (2003) http://www.jircas.affrc.go.jp

Development of a Comprehensive Series of Technologies for Lowland Cropping Systems in Northeast Thailand

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Abstract

A comprehensive series of technologies was developed for the enhancement of rice production, labor-saving crop management, land improvement and water-saving production of vegetables and fruits for the improvement of cropping systems in rainfed lowland areas of Northeast Thailand as follows: (1) No-tillage dry direct seeding cultivation of rice was developed by the combined use of a no-tillage row seeder of the riding type and appropriate crop management, (2) Productivity of KDML105 was enhanced by the use of slow-release nitrogen fertilizers and soil conditioners, (3) A mechanized crop management system was developed for rice and introduced crops along with the development of rational weed control in rainfed paddy fields, (4) Land improvement technologies such as prevention of water leakage and deep tillage enhanced the water retention capacity and productivity of rice, (5) Effective use of agri-byproducts such as rice straw and husks was developed for soil and crop improvement, (6) Hood tunnel, vinyl-mulching and underground drip irrigation were effective for the cultivation of vegetables and fruits with increased water use efficiency.

Discipline: Agronomy
Additional key words: direct seeding, KDML105, weed control, land improvement

Introduction

Thailand is the leading exporter of rice with a production area of 10 million ha and is deemed to be one of the countries which contribute to food supply in the world. Paddy fields in Northeast Thailand account for half of those in the whole country and are expected to play a major role in national rice production. However, agricultural production over this large area has been restricted due to several constraints related to the tropical monsoon climate.

The main problem is the unreliable water supply under rainfed conditions with erratic rainfall. As a result, it is difficult to fix the transplanting date of rice and transplanted rice experiences drought when rainfall is insufficient for cultivation. Shortage and rising cost of labor for transplanting and harvest are other constraints due to the concentration of the population in urban areas[6]. The low fertility of the sandy soils in Northeast Thailand, frequent drought and salinity have led to a decrease of yields, which are already low compared with those in other regions of Thailand[7]. Fluctuations in the yields and quality of Khao Dawk Mali (KDML105) exert an adverse effect on the reputation of this Thai rice variety. The cultivation of upland crops and vegetables for diversified

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Received 1 November 2002; accepted 20 December 2002.

cropping is limited by excessive or insufficient water supply. Due to labor shortage, it is difficult to adopt intensive crop management. Unstable income associated with fluctuations in production and price discourage farmers from the cultivation of cash crops.

The development of sustainable farming systems to overcome these complex constraints is essential not only to increase farmers' incomes, but also to promote national land planning. A comprehensive series of technologies was therefore developed with the objective of simultaneously addressing the multiple constraints of labor shortage, unstable production, poor soil conditions and over-dependence on rice. Such technologies may offer new components for the development of more sustainable cropping systems in Northeast Thailand[5].

Materials and methods

Research sites were selected from the viewpoint of efficient development of new technologies. Basic research for technology development was carried out at Khao Suan Kwang Demonstration Farm, International Training Center for Agricultural Development (ITCAD) in Khon Kaen province. The evaluation of the new technologies was conducted through field trials in farmers' fields in Roiet and Khon Kaen provinces.

1. Development of dry direct seeding cultivation of rice

On-farm trials of dry direct seeding cultivation of rice were conducted during the period 1998–2001 on the fields of Tung Kula Ronghai Land Development Research Center and the fields of 12 farmers in the neighboring Roiet province. Five methods of cultivation, namely tillage (broadcasting, row seeding), no-tillage (broadcasting, row seeding) and transplanting, were evaluated to develop appropriate methods of cultivation. A no-tillage seeder was manufactured in 2000 and large-scale no-tillage direct seeding cultivation (5 locations, 16 ha) was conducted in 2001.

2. Enhancement of productivity and quality of rice variety "KDML105"

Effects of the use of slow-release nitrogen fertilizers and soil conditioners on the growth and yield of Khao Dawk Mali (KDML105) were evaluated in field trials conducted during the period 1999–2001. Growth characteristics at the panicle initiation stage (PI) and harvest were investigated during the period 2000–2001 to develop a growth diagnosis system.

3. Development of labor-saving crop and weed management

Rational and mechanized crop management technologies for rice and introduced crops were developed during the period 1999–2001 for the improvement of crop rotation systems for lowland cropping.

Weed control in rainfed paddy fields was extensively studied for the development of dry direct seeding cultivation of rice during the period 1999–2001.

4. Land improvement for rainfed paddy fields

Two types of fields with dikes surrounded by thick plastic sheets or solidified using a soil conditioner (Mg compound) were constructed at Khao Suan Kwang Demonstration Farm in the early rainy season in 2000.

To improve the properties of sandy soil, deep tillage with a bottom plough was conducted in 2001 prior to the transplanting of rice and its effects were investigated compared with conventional disk plough tillage.

5. Efficient use of agri-byproducts

Labor-saving handling of rice products, simple method of producing charcoal rice husks, effective use of

Table 1. Yield of rice depending on the methods of cultivation

Cultivation method		Yield (kg/ha)			
		1998	1999	2000	2001
Direct seeding					
No-tillage	Row seeding	1,373 (122)	2,700 (104)	2,269 (89)	2,513 (107)
	Broadcasting	1,313 (117)	2,606 (101)	2,550 (100)	2,500 (106)
Tillage	Row seeding	1,463 (130)	2,544 (98)	2,400 (94)	2,550 (109)
	Broadcasting	1,250 (111)	2,644 (102)	2,556 (100)	2,581 (110)
Transplanting		1,125 (100)	2,588 (100)	2,544 (100)	2,350 (100)

Notes: 1) Yield is the average recorded in farmers' fields (12 locations during the period 1998-2000, 10 locations in 2001). 2) 1998: Drought, 1999–2001: Flooding. 3) The numbers in the parentheses represent the percentage to the values obtained in the case of transplanting.

agri-byproducts for vegetable cultivation were investigated during the period 2000–2001.

6. Water-saving cultivation of crops

Cultivation of upland crops, vegetables and fruits after the harvest of rice was extensively studied to develop efficient water use technologies during the period 1999–2001. Effects of hood tunnel, vinyl-mulching and underground drip irrigation were investigated under various conditions.

Results and discussion

1. Development of dry direct seeding cultivation of rice

Unfavorable weather conditions characterized by drought in 1998 and flooding in 1999, 2000 and 2001 occurred during the field trials conducted for a period of 4 years and adversely affected the growth and yield of rice (Table 1). Although the yield of rice was lower in 1998 due to drought, the yield of direct-seeded rice was higher than that of transplanted rice as a result of delayed transplanting due to insufficient rainfall. During the 1999–2001 period when flooding occurred, the yield of rice under direct seeding cultivation and transplanting was not appreciably different and showed small variations. No significant differences in the yield were observed between tillage and no-tillage seeding, which indicated the advantage of no-tillage in omitting the procedure of tillage. No-tillage was superior to tillage when the subsequent rainfall after seeding was scarce in 1998, promoting the growth of rice due to the higher soil moisture associated with the undisturbed soil conditions.

The manufactured no-tillage seeder was composed of a rotary disk and drill seeder, which operated satisfactorily on sandy soil. Rotary disk grooved the ground with wilted weeds or remaining rice stubbles effectively and rice seedling establishment was uniform. Large-scale direct seeding cultivation with the manufactured no-tillage row seeder was successfully achieved in 2001 (Figs. 1&2), resulting in an identical or higher yield of rice in the case of no-tillage compared with transplanted rice in the neighboring area.

Dry direct seeding is currently practiced by the farmers in Northeast Thailand whereby rice seeds are broadcasted on dry soil after tillage of the field. Seeds are incorporated into soil with subsequent harrowing and germinate with the increase of the soil moisture associated with rainfall[3]. Although this method is suitable when rainfall is erratic, the yield remains low due to problems such as unstable growth and proliferation of weeds. Broadcasted seeds on the soil surface are damaged by drought or birds, resulting in poor growth. Weed control is most difficult due to the high density of broadcast seeding. Labor-saving no-tillage row seeding technology which was currently developed may contribute to the dissemination of direct seeding hereafter.

2. Enhancement of productivity and quality of rice variety "KDML105"

The application of slow-release nitrogen fertilizers (LP) enhanced the growth and yield of KDML105 due to the increase of dry matter production and of the number of spikelets through the prolonged effect of fertilizers which enabled to avoid leaching in sandy soil (Table 2). However, it also caused lodging and a decrease of the ripening percentage when the effect was too strong at the later stages of growth. Selection of the type of fertilizer with appropriate time of application is important to derive the advantage of slow-release fertilizers. On the other hand, soil conditioners also affected the growth and yield of KDML105, in which magnesium oxide exhibited the largest effect. Combination of slow-release fertilizers and soil conditioners could become a promising technol-

Fig. 1. Rice seeding using a no-tillage seeder

Fig. 2. Germinated rice in no-tillage field

Table 2. Effects of the application of slow-release fertilizers on yield components of KDML105

	Application of urea		Slow-release nitrogen (coated urea)
	Basal only	Basal + PI	
Total dry weight (g/m^2)	507 (100)	527 (104)	607 (120)
No. of panicles ($No./m^2$)	87 (100)	106 (121)	120 (138)
No. of spikelets ($No./m^2$)	9,178 (100)	12,947 (141)	13,696 (149)
Ripening percentage (%)	83.1 (100)	62.3 (75)	71.8 (86)
1,000 grain weight (g)	26.9 (100)	25.6 (95)	27.5 (102)
Paddy yield (g/m^2)	193 (100)	204 (106)	257 (133)

Notes: 1) Basal application: 60 kgN/ha. Top dressing at panicle initiation (PI) stage: 30 kgN/ha. 2) The numbers in the parentheses represent the percentage to the values obtained in the case of basal application only.

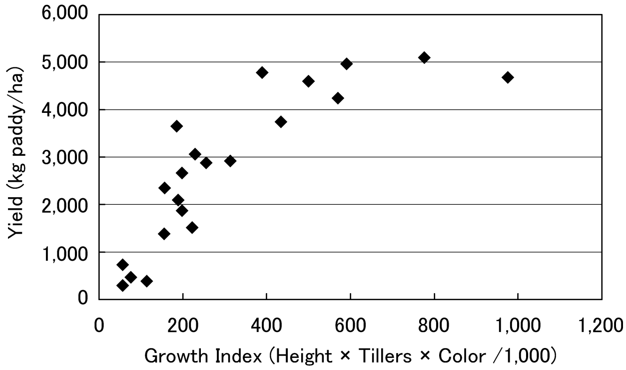

Fig. 3. Estimation of the yield of KDML105 at the panicle initiation (PI) stage

ogy to improve the nutritive conditions of KDML105.

The growth index at the panicle initiation stage (25 days before heading) was directly related to the yield at harvest (Fig. 3), which enabled the development of a growth diagnosis system to stabilize KDML105 yields.

3. Development of labor-saving crop and weed management

A rational and mechanized crop management system was developed for small-scale rainfed paddy fields. Dry direct seeding cultivation was adopted for rice production with land preparation using a rotary tiller, seeding with a drill seeder, weeding with a soil cultivator, pesticide application with a shoulder broadcaster and harvest using a binding harvester (Table 3). No-tillage cultivation of legumes or sweet corn was introduced for the effective use of soil moisture after rice with similar crop management to that for rice.

Emergence of weeds in rainfed paddy fields was investigated to develop weed control methods in dry direct seeding of rice[4]. Cyperaceae were the major weeds that damaged rice at the onset of rainfall, followed by Gramineae and broad-leaf weeds associated with increased rainfall. A soil moisture rate above 25% was necessary for promoting the emergence of Cyperaceae (Fig. 4), while the direct-seeded rice variety “KDML105”

Table 3. Crop management in dry direct seeding cultivation of rice
(Khao Suan Kwang Demonstration Farm, 1999)

Crop management	Machinery	Characteristics	Operation time (h/ha)
Land preparation	Rotary tiller	Tillage depth: 15–20 cm Fine pulverization Leveling of soil	3.2
Seeding	Drill seeder	Sequential operations of tillage, seeding, fertilizer application and soil coverage	3.9
Weed control	Cultivator	Tillage between rows of crops Two times (2 and 4 weeks after seeding)	7.7 × 2
Pest management	Shoulder broadcaster	Application of herbicides, insecticides and fungicides (both liquid and granule type)	1.5 × 2
Harvest	Binding harvester	Application to row seeding Cutting and binding in sequential operations	6.0

Note: Operation time was measured in a 1 ha (100 ×100 m) field.

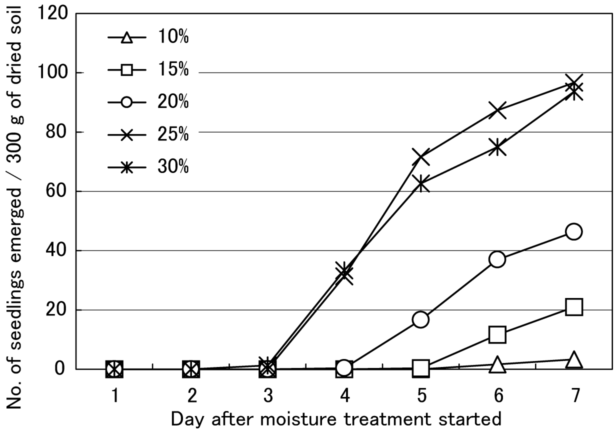

Fig. 4. Emergence of Cyperaceae weeds at different soil moisture rates

Fig. 5. Surface fermentation (bubbling) due to wilted weeds in a no-tillage field

emerged vigorously at a soil moisture rate of 20%. These results strongly suggest that the optimum sowing time may coincide with a soil moisture level of 20%, in order to facilitate adequate germination of rice while suppressing the emergence of weeds.

Weeds in the no-tillage field wilted due to the application of non-selective herbicides before seeding, resulting in surface fermentation (bubbling) after inundation, which in turn suppressed the emergence of new weeds (Fig. 5). Foliar treatment with selective herbicides at 3–4 weeks after seeding was effective to control the weeds that emerged subsequently.

4. Land improvement for rainfed paddy fields

An appropriate method of constructing dikes with plastic sheets was developed through various trials[2]. Height of the dike from the soil surface became uniform, followed by the excavation of a vertical section, insertion of plastic sheets, filling up of soil and shaping up. For the construction of consolidated dikes, the surface soil of the dike was scraped and mixed with the soil conditioner (Mg compound). The mixture was placed on top of the dike and solidified using a trowel with the adjustment of the soil moisture (Fig. 6). Changes in the depth of standing water were monitored with a water depth meter before and after the construction of the dikes. While the initial standing water thoroughly leaked in half a day before the treatment (use of plastic sheet or soil conditioner), it persisted with time in both treatments (use of plastic sheet and soil conditioner) (Fig. 7).

Deep tillage with a bottom plough was found to be beneficial to the soil conditions and growth of rice. Depth of tillage with a bottom plough was 35–40 cm with 100% reversal rate of soil ploughing, resulting in the exposure of the clayish soil in the deep layer on the top.

Fig. 6. Construction of water-impermeable dikes using a soil conditioner

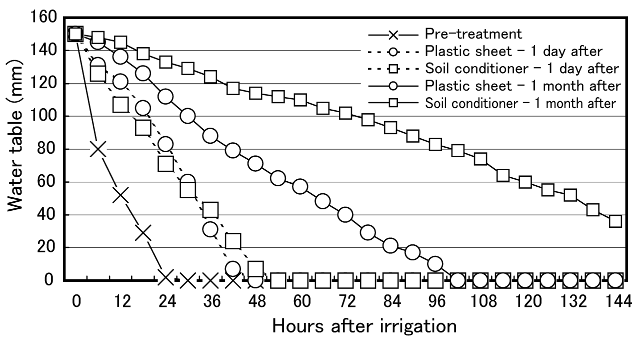

Fig. 7. Changes in the water table level following the construction of dikes

The uniform ploughsole which was formed with the blade of the bottom plough exerted a beneficial effect on the water-holding capacity of the paddy field. Difference in soil hardness was clearly observed between the treatments with the bottom plough and conventional disk plough. In the field for which the bottom plough was used, root penetration (<10 kg/cm^2) was observed up to a soil depth of 30 cm which was deeper than that with disk plough tillage where the thickness of the layer with root penetration was less than 15 cm. The total dry weight, number of spikelets and grain weight showed higher values in the rice plants when the bottom plough tillage was used compared with disk plough tillage (Table 4). The enlargement of the root zone accompanied by the availability of a nutrient-rich clayish subsoil may account for the enhanced growth and yield of rice when bottom plough tillage was conducted.

5. Efficient use of agri-byproducts

To facilitate land preparation for the cultivation of the crops introduced after rice, harvest of rice with a binding harvester enabled to remove the rice plants from the paddy field. Bound straw after threshing was easily transported to the vegetable area as material for mulching.

Incorporation of rice husks improved the soil physical properties with a reduction of the compactness of the sandy soil, which was eventually beneficial to the growth of crops. Moreover, mulching with rice husks was effective in promoting the growth of vegetables, presumably due to the prevention of excess water evaporation and to the decrease of the temperature of the soil surface under tropical conditions. It also suppressed the emergence of weeds, which alleviated laborious hand weeding in vegetable cultivation (Table 5).

A simple and practical method of producing charcoal rice husks was developed by fumigating rice husks under anaerobic conditions (Fig. 8). Charcoal rice husks exhibited a large capacity of water absorption with slightly alkaline properties, which functioned as a suitable soil conditioner for the acid sandy soils prevailing in Northeast Thailand.

Table 4. Yield components of KDML105 depending on the tillage systems (2001)

Tillage	Top dressing	Total weight (gdw/hill)	No.of spikelets (/hill)	Grain weight (g/hill)
Disk plough (control)	−	45.0 (100)	884 (100)	16.3 (100)
	+	59.5 (132)	1,035 (117)	21.6 (133)
Bottom plough	−	70.7 (157)	1,268 (143)	24.8 (152)
	+	70.5 (157)	1,272 (144)	27.4 (168)

Notes: 1) Fertilizer application: Basal, 40 kgN/ha; top dressing, 30 kg/ha at PI stage. 2) The numbers in the parentheses represent the percentage to the values obtained in the control.

Table 5. Effects of rice husk mulching on the growth of vegetables and weeds

Treatment	Vegetables (gfw/plant)		Weeds (/m^2)	
	Lettuce	Cabbage	No.	Dry weight (g)
Rice husk-mulching	95.9 (236)	326.3 (152)	41 (26)	4.3 (14)
No-mulching	40.7 (100)	214.4 (100)	157 (100)	31.8 (100)

Notes: 1) Rice husks were applied (0.65 m^3/100 m^2) after transplanting of vegetable seedlings. 2) The numbers in the parentheses represent the percentage to the values obtained when mulching was not performed.

6. Water-saving cultivation of vegetables and fruits

Hood tunnel cultivation with air- and water-permeable sheets accelerated the growth of vegetables (lettuce, cabbage and cauliflower) by providing stable humidity and soil moisture conditions throughout the growth period. In addition, hood tunnel cultivation reduced the damage associated with insects and diseases (Fig. 9).

Crop cultivation with vinyl-mulching was effective in suppressing the proliferation of weeds, maintaining appropriate soil moisture conditions without excess humidity or dryness and preserving the soil structure at

Fig. 8. Production of charcoal rice husks

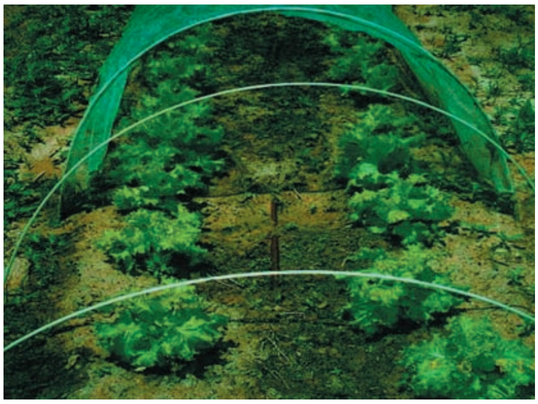

Fig. 9. Hood tunnel cultivation of vegetables

Table 6. Growth of groundnut and soil properties under vinyl-mulching cultivation

Treatment	Dry weight (g/hill)	Soil moisture (%)		Soil hardness (kg/cm^2)	
		10 cm depth	20 cm depth	10 cm depth	20 cm depth
Vinyl-mulching	45.0	3.90	4.93	3.80	9.30
No-mulching	25.0	10.62	9.65	6.10	12.70

Note: Soil properties recorded in August and dry weight of groundnut in October 1999.

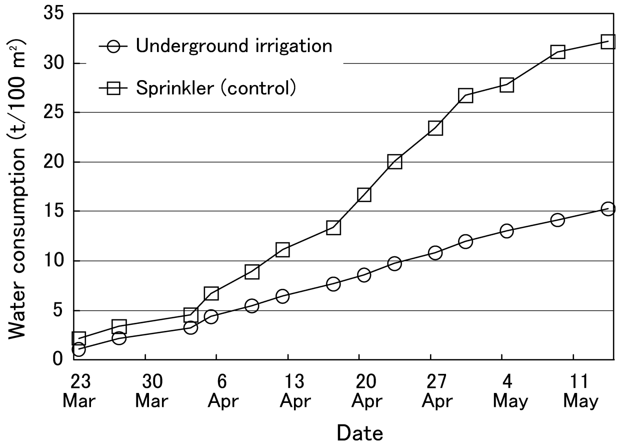

Fig. 10. Water consumption in sweet corn cultivation

the time of seeding. This was especially suitable for the growth of underground crops such as groundnut (Table 6).

Underground drip irrigation systems, which utilize water from farm ponds to irrigate vegetables and fruits were superior to the conventional sprinkler system in terms of both water consumption efficiency and uniformity of crop growth (Fig . 10).

Conclusion

A multidisciplinary approach was adopted with the collaboration of researchers from various specialized fields to develop technologies for lowland cropping in Northeast Thailand. While each technology can be used individually in specific situations, mutual relationships can be depicted in the diagram shown in Fig. 11. The components enabling to overcome the constraints were combined organically to obtain sustainable cropping systems.

Efficient and stable production of rice was the first priority since rice is the main crop to sustain farmers'

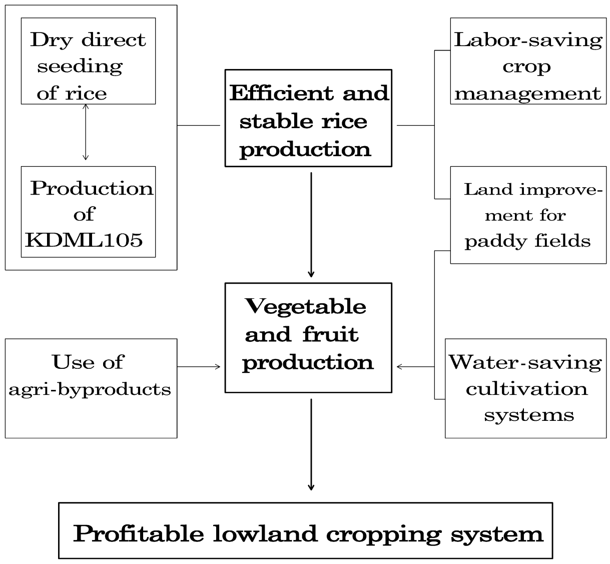

Fig. 11. Technology components for sustainable lowland cropping systems

livelihood in Northeast Thailand. Development of dry direct seeding cultivation and stable production of KDML105 were the 2 main targets, while land improvement and labor-saving crop management contributed to the promotion of rice production. The objective of the introduction of cash crops such as vegetables and fruits was to increase the income of the farmers through the utilization of the high potential of paddy ecosystems. Development of a water-saving cultivation system along with the use of agri-byproducts enabled the development of diversified activities.

Development of various kinds of technologies for each component is the first step to widen the range of choices. Selection of technologies is the next step before the application to production sites. Thorough consideration based on careful analysis is necessary since each site has specific natural and social conditions in which economic evaluation of each technology is most important[1]. Systematization is the final step to adapt the techniques to local conditions through collaboration with the farmers.

References

1. Caldwell, J. S. (2000) Potential of farming systems research for the development of sustainable agriculture. *In* Proceedings "Linkages between Biological and Social Science Research in Northeast Thailand Comprehensive Project" Khon Kaen, Thailand, June 2000, 19–25.
2. Fujimori, S. (1995) Land reform technologies for paddy fields (1). *Agric. Hort*. **70**, 47–53 [In Japanese].
3. Konchan, S. & Kono, Y. (1996) Spread of direct seeded

lowland rice in Northeast Thailand: Farmers' adaptation to economic growth. *Southeast Asian Stud*. **l33**, 523–546.

4. Morita, H. & Kabaki, N. (2002) Effects of soil moisture condition on emergence of weeds and rice plant from rainfed paddy fields in Northeastern Thailand. *Weed Biol. Manage*., **2** [In press].
5. Oka, M. (1997) JIRCAS Comprehensive research project — A comprehensive study on sustainable agricultural systems in Northeast Thailand — *In* JIRCAS Working Report "Development of Sustainable Agricultural Systems in Northeast Thailand". eds. Oka, M. & Ando, S., JIRCAS, Tsukuba, Japan, 1–18 [In Japanese].
6. Poapongsakorn, N., Ruhs, M. & Tangjitwisuth, S. (1998) Problems and outlook of agriculture in Thailand. *In* Proceedings of the 4th JIRCAS International Symposium "Sustainable agricultural development compatible with environmental conservation in Asia", eds. Horiuchi, H. & Tsubota, K., JIRCAS, Tsukuba, Japan, 45–62.
7. Wada, H. (1994) Improvement of problem soils in Northeast Thailand. AICAF, **16**, 32–47.