A New Double-Cropping System Proposed to Overcome Instability of Rice Production in the Muda Irrigation Area of Malaysia

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Introduction

Since 1978, the Tropical Agriculture Research Center has been carrying out a cooperative research programme with the Muda Agriculture Development Authority (MADA) to establish an advanced rice double-cropping system in the Muda irrigation area.

The existing rice double-cropping system in the Muda irrigation area is a continuous year-round cultivation with irregular staggering and overlapping cropping schedules. The Muda area is presently facing a difficult problem of extremely unstable rice yields due to serious damages caused by rice tungro disease and brown planthopper (BPH), *Nilaparvata lugens* (Stål). This problem is likely to jeopardize the rice double cropping in the Muda area.

In this paper a new double-cropping system to overcome these problems is presented.

Existing rice double-cropping in the Muda irrigation area

The Muda irrigation area, the largest paddy area in Malaysia, is a single flat area of about 95,000 ha. Most soils are ill-drained blackish

Table 1. Meteorological condition in the Muda area

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Mean daily max. temp. (°C)*	32.7	34.3	34.5	33.9	32.6	31.8	31.6	31.6	31.1	31.3	31.3	31.4
Mean daily min. temp. (°C)*	21.5	22.0	22.7	23.7	24.2	24.0	23.6	23.3	23.4	23.4	23.1	22.5
Highest max. temp. (°C)*	37.6	37.6	37.6	36.8	36.1	36.2	34.9	34.8	34.5	34.8	34.2	34.4
Lowest min. temp. (°C)*	17.4	18.6	18.3	21.3	21.2	21.9	21.3	20.8	21.2	21.7	20.0	19.5
Mean daily sunshine (h)*	8.55	8.58	8.54	8.38	7.10	5.95	6.35	6.11	5.43	5.40	5.47	6.49
Mean daily solar radiation (cal/cm²/day)**	376	387	397	395	352	330	345	337	337	319	310	323
Monthly rainfall (mm)***	45.0	59.3	112.2	192.7	240.4	184.7	199.2	216.0	296.6	299.1	220.7	88.5

* Average of 13 years from 1968 to 1980 at Kepala Batas meteorological observation station.
** Average of 9 years from 1971 to 1981 excluding 1976 and 1977 (no record) at ACRBD 4 observation yard.
*** Average of 30 years from 1951 to 1980 at Kepala Batas meteorological observation station.

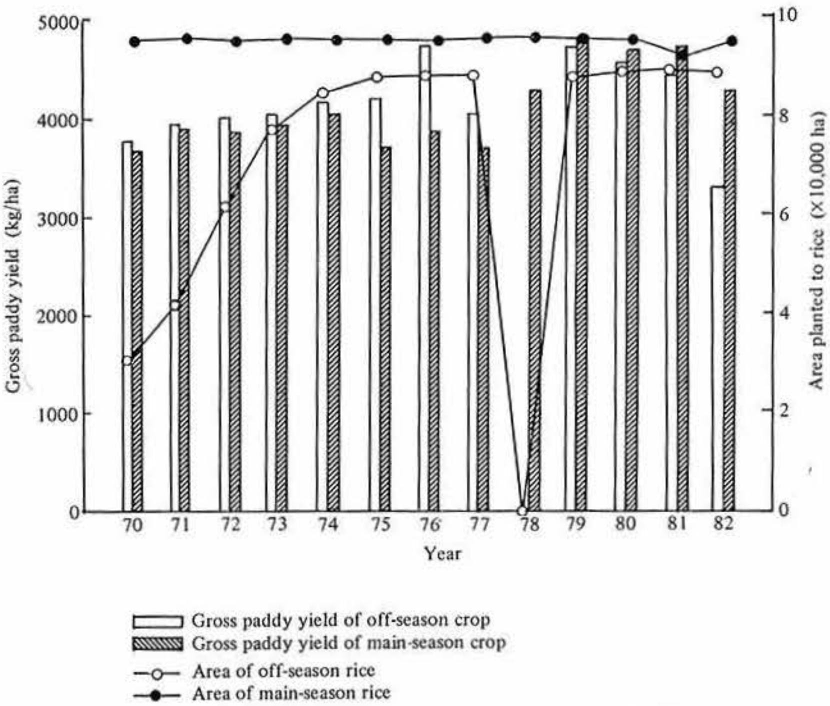


Fig. 1. Rice cropping area and yield in the Muda irrigation area
Source of data: Lapuran Penyiasatan Pengeluaran Padi (Hasil) 1982/83, MADA.

heavy clay soil derived from marine alluvium. The average annual precipitation amounts to around 2,200 mm, falling mainly from April to November with two peaks in May and in September to October. There is a distinct dry period from January to February (Table 1).

Rice double-cropping started in 1970 on 31.9% of the whole Muda area. The double-cropping area rapidly increased to 92.5% by 1975, and since then has remained relatively constant[5] (Fig. 1).

At the beginning of double-cropping, the cropping season was scheduled to be from February to July for the off season crop (dry season crop) and from September to January for the main season crop (wet season crop). However, actual cropping time was markedly delayed year after year with a great variation among field-plots due to insufficient irrigation water, delayed arrival of water to fields and farm labor shortage. The delayed and diversified cropping time brought about an ineffective use of irrigation water. The off season crop in 1978 was not grown due to severe drought and lack of reservoir water (Fig. 1).

Average yield of both off and main season crops, estimated at around 3.7 t/ha of gross paddy at the initial stage of double-cropping with a tendency of slightly higher yields in the off season crop, showed an increasing tendency year by year until 1974. After that with the spread of double-cropping to the whole area, unstable yields began to occur due to water and labor shortages. From 1979 to 1981, very high yields were obtained, due to increased rates of application of fertilizer, which has been offered free by the government since 1979 (Fig. 1). On the other hand, the first occurrence of BPH and GLH (green leaf hopper) was recorded in 1973.[2] In the off season of 1981, rice tungro made its first appearance, mainly in the southern parts of the area, and it spread to all parts of the Muda area in the off season of 1982.[3] Consequently the off season yield in 1982 was 20 to 30% lower than that in 1981 (Table 2 and Fig. 1).

Table 2. Comparison of yields and their C.V.* between a normal year and a year of crop damage by rice tungro in some areas in the Muda irrigation area

Area	Normal year, 1981		Year of damage, 1982	
	Yield**	C.V.	Yield**	C.V.
	kg/ha	%	kg/ha	%
A 4	5, 702	11. 7	4, 634	12. 6
B 1	4, 826	14. 9	2, 174	75. 1
B 4	5, 139	21. 0	3, 740	15. 0
C 2	4, 374	18. 5	4, 287	17. 1
C 4	4, 873	9. 2	3, 437	18. 6
D 3	4, 574	22. 3	3, 281	50. 1
D 4	3, 875	19. 9	4, 324	10. 4
E 2	4, 259	25. 1	3, 815	21. 1
E 3	3, 273	38. 9	3, 303	21. 7
F 3	3, 668	24. 0	2, 639	39. 6
F 4	3, 708	14. 4	3, 367	17. 9
G 4	3, 438	35. 5	2, 985	32. 3
Average	4, 309	21. 4	3, 499	27. 6

* C.V.: Coefficient of variation
** Yield (gross paddy): Result of crop-cutting survey made by MADA on about 15 farmers' fields in each area.

Major constraints to stable double-cropping of rice

1) *Problems related to water supply*

Delay of arrival of irrigation water to fields is caused by low canal density, insufficient irrigation water, and poor water management. At present, tertiary irrigation canals are being constructed under the MUDA II project, whereby the canal density will be increased to around 35 m per ha from the present density of around 11 m per ha. The distribution of water to fields will considerably be improved in the future by the construction of these tertiary canals.

For irrigation in a lowland flat area, it is necessary to keep a certain constant water level at the head of intake. In the Muda area, however, due to shortage of irrigation water and poor water management, the water level at the head is extremely unstable. Under such a condition, the tertiary canals may not function fully or efficiently even after the completion of tertiary facilities. To solve this problem, an integrated water management must be established by taking into account all factors of water supply and demand.

As new development of water sources is not likely to be available in the near future, efficiency of water use must be increased by the following means.

(1) Use of varieties with shorter growing periods (less than 130 days).
(2) A systematic staggered cropping in the whole area. In each unit area, varieties with a similar growth duration must be simultaneously planted.
(3) Separated irrigation to nursery plots from main fields.
(4) Shorter presaturation* period, preferably 15 days for nursery plots and 20 days for main fields.
(5) Exclusive nursery plots for the 2nd season crop.
(6) Suspension of tertiary drainage construction except in areas with very poor drainage.
(7) Recycling of irrigation water.

2) *Labor shortage*

At present, the harvesting operation, which requires the largest amount of labor, has been mechanized on nearly 95% of the area.

However, mechanization of transplanting has some problems to be solved before it can be adopted on a large scale. In reaction to the labor shortages for transplanting, direct sowing culture has been spreading rapidly among farmers (Table 3).

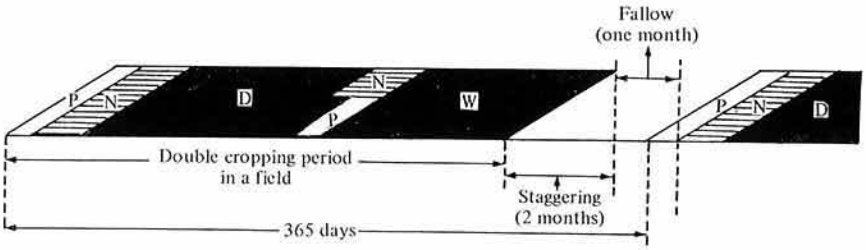
3) *Disease and insect pests*

Crop damages caused by rice tungro disease and BPH are the main cause of unstable yields in this area. At present, the use of resistant varieties and chemical control are partially adopted. However, there is a risk of undesirable outcomes such as possible development of new bio-types,[4] resistance of insects to insecticides[6] and resurgence of insects in chemical control area.[6] It is therefore recommended to develop an integrated approach including agronomic control.

* Presaturation : Field soils have to be saturated with water for field preparation.

Table 3. Yearly changes in area of direct sowing culture in the Muda irrigation area (ha)

Cropping season	1977	1978	1979	1980	1981	1982	1983
Off	9	17	32	662	4,136	18,575	34,331
Main	0	85	181	858	6,415	22,112	
Total	9	102	231	1,520	10,551	40,687	



P: Presaturation period
N: Nursery period
D: Dry season crop
W: Wet season crop

Fig. 2. A new double-cropping system with one month of fallow and two months for staggering of croppings.

A new double-cropping system

As the most effective agronomic method to overcome the unstable double-cropping in the Muda area, which are mainly caused by insufficient irrigation water, and the serious seasonal occurrence of BPH and tungro virus, the authors propose a new double-cropping system, which allows perfect fallow of one month period simultaneously practiced over the whole Muda area, and a two-month period for systematic staggering cropping (Fig. 2).

This new system was formulated by examining the ecology of BPH and GLH, allowable length of the rice growing duration, and the practical possibility of completing the systematic staggering cropping within a two-month period under limitations in water distribution to paddy fields, presaturation of field soils, and in farm mechanization. The system mentioned below would be applicable to the Muda area.

1) *Effect of the one-month fallow on BPH and GLH*

BPH completes its life cycle in about a month (35 days composed of egg period : about 6 days, nymphal period: about 11 days, and adult period: about 18 days[1]) in tropical wetland areas where a suitable food source is present.[6] However, when no feeding plant is available, it dies out in a few hours,[1,6] although the egg survives. The main host plant of BPH is *Oryza sativa*, but several *Oryza* species serve as potential host plants for BPH.[1,6]

The main host plant of GLH (*Nephotettix virescens*) is *Oryza sativa* and other *Oryza* species also serve as alternate host plants.[1] The life cycle of GLH in the fields is about 40 days with egg period of about 6 days, nymphal period of about 21 days and adult period of about 13 days.[1] When no feeding plant is available it dies out in a few hours although the egg survives. Viruliferous nymph and adult can transmit the virus for only 1 to 5 days after virus acquisition.[7]

On the basis of such ecological characteristics of BPH and GLH, it can be said that a period longer than 6 days at least, without any host plants, including potential host plants, will be needed to control BPH and GLH. However, to kill all the host plants, including rice stubbles, ratoons, volunteer rice plants, and weeds such as other *Oryza* species in the area, a much longer period is needed. Therefore, the fallow period of about a month at the beginning of the dry

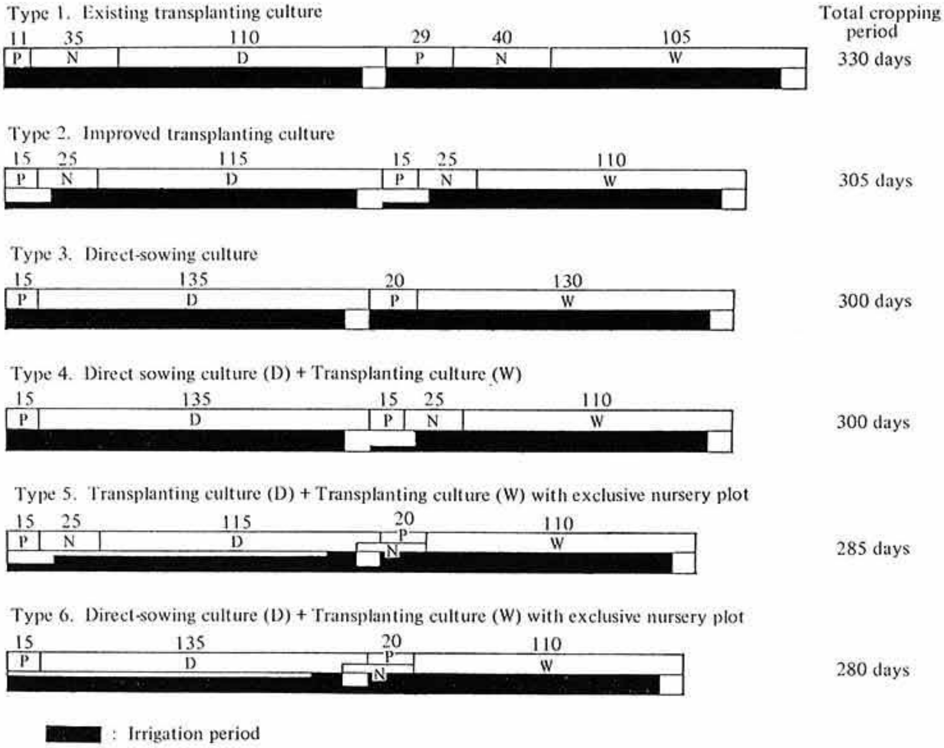


Fig. 3. Cropping period of different types of rice cultivation in double-cropping

Note: 1) P: presaturation period, N: Nursery period, D: Dry season crop, W: Wet season crop

2) Except type 1 and 3, all other types adopted an improved transplanting culture with a short nursery period and separate irrigation to nursery beds.

season will be needed to control both BPH and GLH.

2) *Length of cultivating period of various types of double cropping*

As shown in Fig. 2, the perfect fallow period of 1 month is inserted between the end of harvest of the wet season crop and the beginning of seedling raising for the following dry season crop. In this connection, the length of the cultivating period, including presaturation period and nursery period, was examined for various types of double-cropping of Setanjung (MR-1), a representative high yielding variety with the longest growing period (140 days in the dry season and 135 days in the wet season in the Muda area). As shown in Fig. 3, the existing transplanting culture requires a total of 330 days for double cropping, but improvements of cultural practices, particularly the adoption of direct-sowing culture or the use of exclusive nursery plots can markedly reduce the double-cropping period. The use of exclusive nursery plots for the wet season crop can reduce the double-cropping period to 285 days, and the combination of direct-sowing culture of the dry season crop and exclusive nursery plots for the wet season crop to 280 days, leaving as much as about 80 days to be used for the fallow and staggering period for cropping.

3) *Staggering period*

As the applicability of the proposed new double cropping system to the Muda area depends on whether or not the system allows a sufficient length of period for staggering of cropping, the staggering period for cropping was calculated by the following equation, using the data shown in Fig. 3:

$$S=(365+P)-(D+F)$$

Table 4. Staggering period allowable in the double-cropping of rice with one-month period of fallowing, when Setanjung (A) or an early-maturing variety (B) is used

Cultural types*	365+P (days)	Double-cropping period+30** (days)		Allowable staggering period (days)	
		A	B***	A	B***
1	376	360	340	16	36
2	380	335	315	45	65
3	380	330	310	50	70
4	380	330	310	50	70
5	380	315	295	65	85
6	380	310	290	70	90

* Cultural types: See Fig. 3
** 30 (days) for fallowing
*** Earlier than A by 10 days.

Table 5. Estimated labor input for farm operations

Farm activities	hr/ha	No. of days required to cover the whole area
Raising seedlings in nursery	30	2.6
Preparation of main field	50	4.4
Transplanting	150	13.1
Sowing for direct sowing culture	10	0.9
Harvesting by combine	1	45.1
Transportation of harvested crop	27	2.3
Winnowing and drying	27	2.4

Necessary number of days for the whole Muda area was calculated on the basis of:
1) Whole Muda area: 94,800 ha*
2) Available local labor supply in the area: 180,700 persons*
3) Average working hours per day: 6 hr/day
4) Working efficiency of a combine: 6 ha/day
5) Number of combines in the area: 350.
* Quoted from "Feasibility report on tertiary irrigation facilities for intensive agricultural development in the Muda irrigation scheme, Malaysia", 1977, MADA.

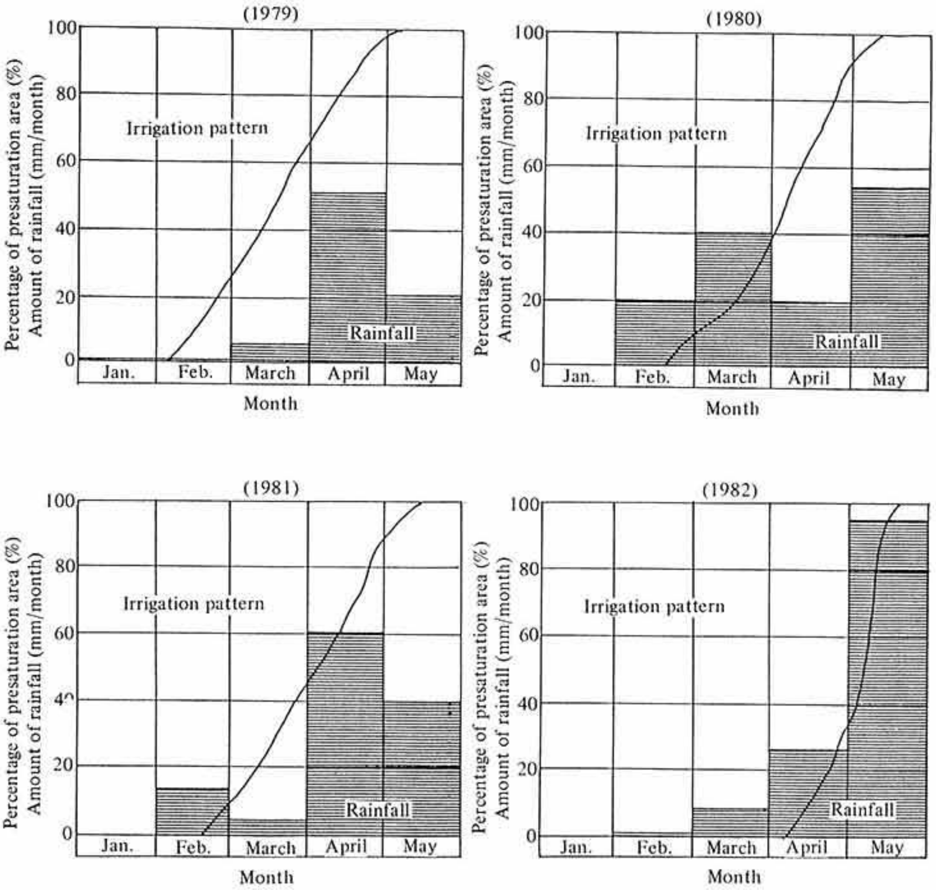
where S: staggering period (days), D: double-cropping period (days), F: fallow period of 30 days, P: presaturation period for the following dry season crop. It can be used for the fallow (see Fig. 2).

The result is given in Table 4. The staggering periods ranged from 16 days to 70 days for the various types of cultivation of Setanjung. When a variety with a growth period shorter than Setanjung by 10 days is used, the staggering period ranged from 36 days to 90 days.

On the other hand, the minimum staggering period required in the Muda area is determined either by the period for the completion of a farm operation, which requires the longest working period in the whole Muda area, or the period for the completion of presaturation in the whole Muda area prior to the dry season cropping.

(1) Minimum staggering period needed to complete farm operations

Table 5 shows the labor input per ha of major farm operations, and the number of days required to cover the whole Muda area. Harvesting operation needs the greatest number of days, 45.1 days, to finish up in the whole Muda area, assuming that the total area is 94,800 ha, working efficiency of a combine is 6 ha/day (net working hr/day is 6 hr) and a total of 350 combines are available in the area. According to the survey by Toyama,[9] actual working efficiency of a combine is only 4 ha/day throughout a season. Such a low efficiency may largely be attributed to frequent moving of combine from field to field due to lack of uniformity in maturing stage among the fields. When the systematic staggering of cropping is adopted, the working efficiency of 6 ha/day can easily be obtained and hence the staggering period of about 1.5 months will be enough to complete harvesting in the whole area.



Source of data : Irrigation pattern - Engineering Division, MADA
Amount of rainfall - Telok Chengai Station, C. P. C.

Fig. 4. Irrigation pattern of presaturation for the off season crop in the Muda irrigation area

(2) Minimum staggering period needed for presaturation

According to the data of the past 4 years (Fig. 4), the presaturation period for the whole Muda area for the dry season crop ranged from about 1.5 to 3 months depending on the amounts of precipitation before and during the presaturation. However, as the canal density is going to be increased from 11 m/ha at present to 35 m/ha in the Muda area, it is estimated that the presatura tion period can be shortened to about 2 months with increased canal density and good water management.

Thus, it can be concluded that the type of cultivation which can be adopted to the proposed new double cropping system is "transplanting culture with exclusive nursery plots for the wet season crop" when Setanjung is grown (Table 4). However, when a variety with growth period shorter by 10 days than Setanjung is grown, all cultural types except the existing one can be put into practice.

Therefore, the future varieties in this area must have a growth period shorter than 130 days.

4) *water requirement of the new double-cropping system*

The water requirement of different cultural types is shown in terms of irrigation days in Table 6. A large amount of water can be saved by the improved cultural types as compared with the existing farmers' cultural type.

Table 6. Irrigation period for different cultural types in the double cropping of rice
(No. of days/area of main field)

Cultural types	Off season crop				Main season crop				Total
	Nursery		Main field		Nursery		Main field		
	P	N	P	M	P	N	P	M	
1	←—— 46 ——→			100	←—— 69 ——→			95	310
2	1(15)	1(25)	19(0)	105	1(15)	1(25)	19(0)	100	247 (285)
3	←—— 15 ——→			125	←—— 20 ——→			120	280
4	←—— 15 ——→			125	1	1	19	100	261
5	1	1	19	100	1	1	19	100	242
6	←—— 14 ——→			119	1	1	19	100	254

1) Cultural types: see Fig. 3.
2) P: Presaturation, N: Nursery, M: Main field,
3) Irrigation period for nursery was calculated as irrigation period × 0.05 (ratio of nursery area to main field area).
4) ( ): in case of no separate irrigation to nursery plot.

The greatest reduction in water requirement was found in the "Transplanting culture (dry season crop) followed by transplanting culture with exclusive nursery plot (wet season crop)" which showed 242 days of irrigation as compared to 310 days of the existing cultural type. Separate irrigation to the nursery plot (247 days in total irrigation days) brought about saving of irrigation water by about 13% as compared with no separate irrigation (285 days).

In addition it is expected that the systematic staggering of cropping adopted in the whole area and the use of varieties with shorter growth period will further reduce water consumption.

Conclusion

On the basis of the technical analysis of various constraints to rice production in the Muda area, where double-cropping of rice prevails, the authors propose a new double-cropping system with the purpose of overcoming major constraints to high and stable yields of rice. The new system is composed of the first cropping (dry season rice), the second cropping (wet season rice), perfect fallow of one month period simultaneously practiced over the whole Muda area during the dry season after the second cropping, and a systematic staggering of cropping in the whole area in the period of two months.

The fallow of one month simultaneously practiced over the whole area during the dry season aims at controlling GLH, the major vector of rice tungro virus and BPH, because BPH and tungro disease are the most serious constraint to rice production in the Muda area in recent years. Besides, the fallow period contributes to an increase in rice yields by the effect of air drying of the soil[8] and to the promotion of mechanization through the increased soil bearing capacity of the paddy fields.[10] A systematic staggering of croppings can increase not only efficiencies in the use of irrigation water but also working efficiencies of farm machines.

Applicability of this new system to the Muda area was examined from the standpoint of rice varieties to be used, and cultural methods of rice (existing or improved methods) to know whether or not the system can afford a sufficient length of period required for the fallowing and the staggering of croppings over the whole area. It was proved that this system can be applied to Setanjung, a representative high-yielding variety with the longest growth period (135–140 days) among the varieties cultivated at present in the area, by adopting an improved cultural method, i.e., the use of exclusive nursery. When varieties with growth period of 130 days or less are used, this system can be applied to any cultural types, except the existing cultural type which requires much more time to complete the cropping cycle.

Implementation of this system depends on the program to increase canal density in the Muda area to about 35 m/ha and the establishment of integrated water management, which is now in progress.

It must be emphasized that the benefits of this new system may not be obtained fully unless the system is practiced by taking the whole Muda area as a single unit.

Finally, the authors believe that the principle of this system will be useful to other rice-growing areas facing similar problems as those of the Muda area.

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