Japan. Jour. Crop Sci. 57(3) : 527—534 (1988)

Variability of Yield and Yield Components of Rice in Rain-fed Paddy Fields of Northeast Thailand*

Shuichi MIYAGAWA and Toshiro KURODA**
(Faculty of Agriculture, Gifu University, Gifu 501-11, Japan ;
***Faculty of Agriculture, Okayama University, Okayama 700, Japan)*
Received October 31, 1987

Abstract : Rice production in Northeast Thailand tends to show both low yield per unit land and unstable crops. The objective of this report is to clarify the actual situation of the rice cultivation. One typical rice growing village, Don Daeng which is located 15 km from Khon Kaen city was chosen for the study. A survery of growth of rice, yield and its components was carried out in the village. Thirty one and 30patchs were selected as sample paddy fields in 1981 and 1983, respectively.

Rice cultivation of this village depends upon traditional local varieties and rain-fed paddy fields without fertilizer. In 1981, unhusked grain yield was so low as the mean value of 181.6g/m^2 due to drought. The yield showed a positive correlation with the each component. On the other hand, in 1983 the yield increased to 236.3g/m^2 as the mean value due to enough rain fall, and showed a correlation with the number of panicles per square meter.

The growth and yield tremendously fluctuated among paddy fields in both years. The yield correlated positively with the straw weight and the leaf area index, and negatively with the light transmission rate under a plant canopy. Moreover, concentrations of nitrogen, phosphorus and potassium were remarkably low. These results seem to suggest that increases in leaf area index and the number of spikelets per unit area by vigorous vegetative growth lead to a yield increase.
Key words : Rain-fed cultivation, Rain-fed paddy field, Rice, Thailand, Yield, Yield components.

東北タイの天水田におけるイネの収量とその変異：宮川修一・黒田俊郎*（岐阜大学農学部・*岡山大学農学部）

要　旨：タイ国において，最もイネの収量が低く，作柄も不安定であるといわれている東北地方の稲作の実態を知るため，1981年と1983年にコンケン市から約15 km 離れた典型的な稲作農村のひとつ，ドンデーン村において，農家圃場でのイネの生育と収量・収量構成要素を調査した．1981年には農家水田31筆，1983年には同30筆を調査対象に選んだ．

この村の稲作は全く天水田に依存しており，在来型品種を無施肥で栽培するのが慣行である．旱ばつ年であった1981年の籾収量は平均181.6 g/m^2 ときわめて低かった．収量は各収量構成要素と有意な正の相関を示し，特に1穂穎花数と高い相関を示した．

降雨量の多かった1983年では収量は平均236.3 g/m^2 まで上昇した．この年の収量は穂数/m^2 と比較的高い正の相関を示した．

筆間の生育ならびに収量の変異はきわめて大きく，分げつ量は少なく，籾とわらにおける窒素・リン酸・カリの含有率も低かった．収量は，わら重，出穂期の葉面積指数と正の相関を示し，群落内の光透過率とは負の相関を示した．これらのことから，この村の場合には栄養生長をさらに旺盛にして，葉面積指数ならびに単位面積あたり穎花数をさらに増加させることが多収につながるものとみられた．
キーワード：イネ，収量，収量構成要素，タイ国，天水栽培，天水田．

Although Thailand is a rice exporting country, rice yield in the northeastern area tends to be lower and less stable than any other part of this country. It is due to shortage of irrigation facilities and also to poor soil fertility. Undeveloped rice culture in this region poses serious socio-economic problems. In order to obtain information on the farming system, especially on rice cultivation, the authers studied the specific problems for about twelve months staying in one village called Don Daeng. This paper presents part of the results of the field study in the village. The objective of this report is to clarify the actual situation of rice growing in farmers' fields, to analyze the relation between yield and its components and to understand the characteristics of rice yield formation by comparing with the results of other yield surveys in related areas.

The outline of rice cultivation practices in this village is as follows[4,8,10]. Rice can be grown only in rainy season in the rain-fed paddy field with the help of animal power,

* A part of this work was presented at the 174th meeting of the Crop Science Society of Japan held in October, 1982.

using native photosensitive varieties. Glutinous rice varieties of grain type B classified by the grain length and width, are planted in approximately 90% of the total paddy area, transplanted usually during the period from June to August and harvested in the period of November to December. Little or no fertilizers nor chemicals are applied. Moreover, no weeding operation can be seen until harvesting. Rice is seldom sold. The fluctuation of rice production in the village is extremely large.

Materials and Methods

1. *Research site*

Don Daeng village lies about 15 km from Khon Kean city which is located in the center of Northeast Thailand. Paddy fields in Don Daeng are distributed mostly in the alluvial plain between the Chi river and low hills stretching in the southern part of the village compound. The plain portion consists of numerous swales with higher ground as levees surrounding them. Water condition varies considerably among paddy plots due to difference of their location on this peculiar landform[4]. Soil texture in these paddy fields can generally be categolized as loam or clay loam. Soil fertility is lower than that of the central plain of Thailand[3].

The field survey for rice growth and yield was done twice, for the period from July 1981 to January 1982 and from June to December 1983, respectively.

2. *Methods*

In 1981, 31 plots were chosen for the study of growth and yield components, by considering different physical conditions of the fields. The number of tillers and plant height were recorded in each plot every two weeks. Light intensity under the crop canopy was measured with a lux meter (Tokyo Photo Electric) at the heading stage to obtain light transmission rate (LTR). At harvest, the number of panicles of 10 hills was counted at 13 different points along diagonals in each plot. Then, 65 hills, *i. e.*, 5 hills per point, were harvested and threshed. Air-dried straws and unhusked grains were weighed at 2 months after harvests.

The yield components were measured by the following procedures. The weight of grains of the 65 hills sampled in each plot was measured first. Then, it was corrected by the ratio of the average number of panicles of the 65 hills to that of 130 hills. The yield per square meter was calculated by multiplying the grain weight per hill by planting density measured as described hereafter. The air-dried grains were separated into fully ripened and unripened grains by salty water with specific gravity, 1.03, which seems to be suitable for the large-shaped glutinous varieties of samples in this study and many other varieties than Japanese ones[6]. These two fractions, fully ripened and unripened, were weighed and the number of spikelets were counted separately. From the total number of spikelets of the two fractions and the total number of panicles of the 65 samples, the mean number of spikelets per panicle was calculated. The percentage of unfertilized grains among empty grains was determined by Matsushima's method[9]. With the air-dried samples, nitrogen, phosphorus and potassium contents were determined, by means of the semi-micro Kjeldahl, colorimetric and flame photometric methods, respectively.

The rice hills of 215 plots were sampled so as to cover various land conditions in Don Daeng village. At each plot, 100 hills, namely, 50 hills each along diagonals, were cut at ground surface level and their total fresh weight were weighed. After threshing, the weight of fresh, unrefined grains was measured. The fresh weight of straw was obtained by subtracting the grain weight from the total weight. About 20g of grains and straws were air-dried for 2 months for measuring dry weight. A quadrat of 2.5m^2 was placed in a plot and the number of hills was counted. The mean of four replications per plot gave planting density. The grain yield per hill was multiplied by planting density to obtain the yield per unit land square meter. In this paper, rice grain yield is given in terms of the grain yield before winnowing since winnowing is not commonly practiced in Don Daeng village. Yield was corrected with moisture content as 14%.

In 1983, 32 plots were chosen for the study of growth characters. The changes of the tiller number and plant height were recorded, and LTR at the heading stage was measuerd with the same procedures as in 1981. At the heading stage, leaf area per hill was determined by summing up each leaf area which was estimated as the product of leaf blade length, width and 0.7. Althogh it is not confirmed, whether the coefficient, 0.7, which is used for japonica varieties[5], is applicable to indica varieties or not, it is convenient for a speedy estimation of leaf area. Leaf area index (LAI) was obtained by multiplying planting density and mean value of 3 hills' leaf area.

For yield survey 174 plots inclusive of those 32 plots, were chosen grain and straw weights per m^2 were determined by the same procedure for 215 plots in 1981. The number of panicles was counted for each 100 hills. Other yield components were measured using the same procedure as in 1981.

Daily rainfall was recorded from the beginning of the survey.

Results and Discussion

Monthly rainfall in Don Daeng village and its neighboring town is shown in Table 1. The total rainfall was critical for ordinary rice cultivation. Rainfall was concentrated during the period from May to October. Rainfall in 1981 was less than that in 1983, especially in August and September. Growth injury caused by drought was observed in part of the paddy field located at a high elevation. It can be said that this year-to-year fluctuation of rainfall is salient in this region. In this village, severe drought and flooding during rice growing season decreased its rice production so often in the past[4]. It can be seen that the mean value of grain weight in the plots is very low and the difference among plots is also greater (Table 2). The maximum value of grain weight was 17 times greater than the minimun value in 1981, and 8 times greater than in 1983 as well. The difference of straw weight in the different plots was larger than that of grain weight. Grain and straw weights, and grain-straw ratio were greater in 1983 than those in 1981. However, the maximum values of grain weight of two years were almost the same, though the minimun value in 1983 increased. The coefficient of variation (CV) in grain weight diminished in 1983. Actually, the percentage of plots with less than 150 g/m^2 of grain weight reached 61% in 1981, but reduced to 31% in 1983. On the contrary, the maximum weight of straw increased remarkably. These tendency of yield fluctuation in Don Daeng rice fields was confirmed by the standing crop survey for about 2,500 plots in two years[8].

The results of yield components survey are shown in Table 3. Comparing with two years, it is clear that most of components differed remarkably between two years. Especially, the number of spikelets/panicle, the number of spikelets/m^2, percentage of ripened grains and 1000-grain weight increased remarkably in 1983.

The number of panicles/hill was very low in

Table 1. Monthly rainfall (mm) at Don Daeng and Tha Phra.*

Year	Location	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1981	Don Daeng	—	—	—	—	—	—	—	102	86	89	24	0	—
	Tha Phra	0	2	20	56	262	140	201	95	72	114	35	0	997
1983	Don Daeng	7	10	23	13	44	257	100	359	148	153	21	0	1135
	Tha Phra	7	5	4	23	95	258	98	357	185	201	8	0	1241

* The site of the Agricultural Research Station at 5 km west from Don Daeng.

Table 2. Comparison of the grain and straw weight.

	Year	N	Mean	Max.	Min.	CV
Grain weight	1981	215	181.6	562.8	32.9	44.2
(g/m^2)	1983	174	236.3	531.7	65.7	32.2
Straw weight	1981	215	249.1	912.6	50.3	56.4
(g/m^2)	1983	173	319.1	1511.3	60.2	62.0
Grain-straw	1981	215	78.3	152.6	33.0	27.6
ratio (%)	1983	173	85.9	203.6	21.7	31.8

Note : N ; number of samples, CV ; coefficient of variation (%).

Table 3. Comparison of the values of yield components.

Components	Year	N	Mean	Max.	Min.	CV
Number of hills/m²	1981	215	11.9	18.3	5.7	18.4
	1983	174	12.4	17.4	5.3	15.8
Number of panicles/hill	1981	30	5.5	9.2	3.5	22.7
	1983	174	5.9	13.2	2.9	26.8
Number of spikelets/panicle	1981	30	86.3	196.1	33.9	44.8
	1983	174	108.3	186.1	33.8	25.1
Number of spikelets/m²	1981	30	5186	9930	1866	44.7
	1983	174	7731	19549	2230	34.5
Percentage of ripened grain	1981	30	63.0	81.4	9.4	23.0
	1983	174	74.4	91.6	39.5	11.3
1000-grain weight (g)	1981	30	32.4	37.7	17.4	17.2
	1983	174	36.3	48.7	23.1	12.0

Note : N ; number of samples, CV ; coefficient of variation (%).

Table 4. Comparison of maximum tiller number, percentage of produtive culms and plant length.

	Year	N	Mean	Max.	Min.	CV
Maximum tiller number/hill	1981	30	10.2	24.9	4.5	39.5
	1983	32	10.7	33.7	4.5	57.6
Percentage of productive culms	1981	30	69.4	100.0	42.4	22.6
	1983	32	73.7	97.0	56.0	13.5
Plant length at harvest (cm)	1981	30	136	179	85	20.8
	1983	33	163	217	109	17.2

Note : N ; number of samples, CV ; coefficient of variation (%).

Table 5. Leaf area index and light transmission rate at heading stage.

	Year	N	Mean	Max.	Min.	CV
leaf area index (LAI)	1983	33	1.1	4.9	0.3	79.2
Light transmission rate (LTR, %)	1981	16	46.8	78.0	24.3	32.5
	1983	32	24.0	82.0	0.6	78.7

Note : N ; number of samples, CV ; coefficient of variation (%).

both years, and its change was smaller than those of other components.

Lower value of the number of panicles/hill was due to low maximum tiller number/hill (Table 4). Its maximum value was only 33.7, and the variance was greater than that in the number of panicles/hill. Its minimum value, 4.5 means little tillering after transplanting in the plot. The mean value of percentages of productive culms reached about 70. The range of variations of plant length at harvest was also larger.

The rice plants in Don Daeng as a whole are characterized by a poor dry matter production, a small number of panicles and concomitantly, a small number of spikelets/m². It should also be noted that the percentage of matured grains was very low in drought years such as 1981. Dry matter production of rice plant community was very low, with small LAI and high LTR at the heading stage (Table 5). It means that the canopy formation, namely vegetative growth is usually very poor in the paddy field in Don Daeng. Moreover, each value scattered widely.

The nutritional status of the rice plants at harvesting was very unfavorable for rice production (Table 6). Compared with the results obtained at IRRI[14] in the same tropical area, nitrogen and potassium concentration in the grain and phosphrus concentration in the straw were almost the same. However, nitrogen and potassium concentration of straw were almost half of them and phosphorus concentration of grain was very low. The variance among plots were large, especially in

Table 6. Nitrogen, phosphorus and potassium concentration of plant at harvesting stage.

		N	Mean	Max.	Min.	CV
Nitrogen (total N, %)	grain (a)	30	0.93	1.23	0.77	11.4
	grain (b)	30	0.95	1.24	0.79	11.2
	straw	30	0.24	0.49	0.11	37.4
Phosphorus (P_2O_5, %)	grain (a)	30	0.051	0.102	0.017	37.9
	grain (b)	30	0.051	0.100	0.018	35.9
	straw	30	0.106	0.369	0.012	87.0
Potassium (K_2O, %)	grain (a)	30	0.35	0.49	0.18	21.5
	grain (b)	30	0.36	0.50	0.18	20.7
	straw	30	1.75	2.72	0.62	25.5

Note : N ; number of samples, CV ; coefficient of variation (%), (a) ; full ripened grain, (b) ; un-winnowed grain.

Table 7. Correlation coefficients which relate to the yield's traits.

	No. of hills /m²	No. of panicles /hill	No. of panicles /m²	No. of spikelets /panicle	No. of spikelets /m²
Number of hills/m²	—	**−0.538****	**0.298**	**−0.581*****	**−0.419***
Number of panicles/hill	−0.005	—	**0.622*****	**0.367***	**0.628*****
Number of panicles/m²	0.528***	0.830***	—	**−0.140**	**0.306**
Number of spikelets/panicle	−0.412***	−0.030	−0.263**	—	**0.880*****
Number of spikelets/m²	0.188	0.740***	0.718***	0.454***	—
Percentage of ripened grain	0.145	0.132	0.222*	−0.160	0.069
1000-grain weight	−0.064	−0.301**	−0.326***	0.002	−0.275**
Grain weight/m²	0.212*	0.644***	0.638***	0.406***	0.899***
Straw weight/m²	−0.076	0.385***	0.280**	0.484***	0.608***

	% of ripened grain	1000 grain wt.	Grain wt.	Straw wt.
Number of hills/m²	**−0.221**	**0.193**	**−0.418***	**−0.313**
Number of panicles/hill	**0.428***	**0.157**	**0.613*****	**0.430***
Number of panicles/m²	**0.343**	**0.068**	**0.308**	**0.212**
Number of spikelets/panicle	**0.208**	**0.466****	**0.833*****	**0.814*****
Number of spikelets/m²	**0.350**	**0.483****	**0.963*****	**0.841*****
Parcentage of ripened grain	—	**0.408***	**0.467****	**0.177**
1000-grain weight	−0.243*	—	**0.647*****	**0.554****
Grain weight/m²	0.119	0.079	—	**0.841*****
Straw weight/m²	−0.078	0.015	0.642***	—

Note : The boled letters and the Roman indicate the values in 1981, 1983, respectively. Coefficients asterisked are significant at 0.1% (***), 1% (**) and 5% (*) level.

phosphorus concentration of straw.

In conclusion, the rice growth, yield and its components in Don Daeng village varied extremely among plots even in a single year, and between both years as well. This instability and variability were caused by the circumstances of rice cultivation *per se*, such as water regime of each plot which have different traits according to the various landforms. This is the major problem to be studied in detail for further improvement in rice growing.

As Table 7 shows, the yield components were found to be correlated positively in most cases, with grain weight. Particularly, the correlation between the grain weight/m² and the number of spikelets/m², and that between grain weight/m² and the number of spikelets/panicle were quite significant in 1981. In 1983,

Table 8. Correlation coefficient among yield components and growth indices.

	1981		1983		
	% of productive culms	LTR	% of productive culms	LTR	LAI
Number of hills/m²	−0.141	0.198	−0.369*	−0.090	−0.127
Number of panicles/hill	−0.087	−0.614***	−0.118	−0.604***	0.601***
Number of panicles/m²	−0.248	−0.429*	−0.459*	−0.566**	0.595**
Number of spikelets/panicle	0.301	−0.431*	0.438*	−0.262	0.302
Number of spikelets/m²	0.254	−0.609***	−0.202	−0.695***	0.817***
Percentage of ripened grain	0.048	−0.262	−0.380*	0.270	−0.076
1000-grain weight	0.266	−0.408*	0.377*	0.066	−0.124
Grain weight/m²	0.280	−0.699***	−0.150	−0.701***	0.831***
Straw weight/m²	0.039	−0.701***	0.031	−0.539**	0.549**
Percentage of productive culms	—	0.552**	—	−0.119	−0.225
Light transmission rate	—	—	—	—	−0.548**

Note: The values were obtained using 30 (1981), and 31 samples (1983), respectively.
Coefficients asterisked are significant at 0.1% (***), 1% (**) and 5% (*) level.

however, the correlations between grain weight/m² and the number of spikelets/m², and grain weight/m² and the number of panicles/m² or /hill were quite significant. Exceptionally, correlation between grain weight/m² and the number of hills/m² in 1981 was negative. In 1981, the number of spikelets/m² was limited by the number of spikelets/panicle. On the contrary, it was influenced by the number of panicles/m² in 1983. As shown in Table 3, the range of variance of the number of spikelets/panicle was diminished, and that of the number of panicles/m² became greater in 1983 than in 1981. The mean value of the number of spikelets/panicle decreased in 1981 due to shortage of rainfall. The drought affected not only the number of spikelets/panicle but also the percentage of ripened grains and 1000-grain weight at the same time in some cases. The correlation coefficient between the percentage of ripened grains and that of unfertilized grains became −0.642***. It can be said that the low percentage of ripening was mostly caused by drought injury in flower organs.

A greater number of spikelets did not cause a decrease in the percentage of ripened grains and 1000-grain weight, even though in a bumper year, 1983. Moreover, the grain weight correlated to the straw weight quite significantly.

In general, vigorous vegetative growth does not necessarily bring about a high grain yield. In Don Daeng, however, it appeared that poor vegetative growth was a direct cause of the low grain yield. In order to improve yield in this village, it may still be useful to adopt the strategy of increasing the number of spikelets per unit area by increasing the number of panicles/hill, principaly.

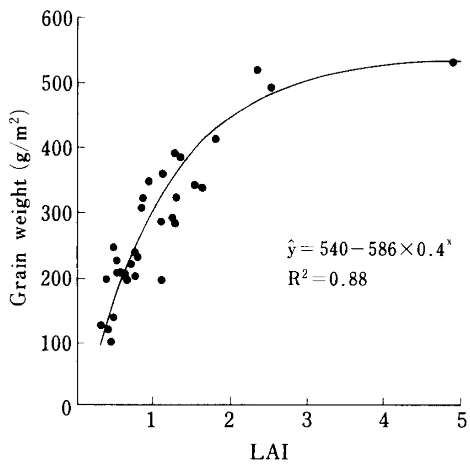

Fig. 1. Relationship between leaf area index (LAI) and grain weight (g/m²) in 1983.

The correlation between the percentage of productive culms and other components was little significant (Table 8). LAI was positively, but LTR was negatively correlated with the grain weight/m², straw weight/m², the number of panicles/hill and the number of spikelets/m². It can be said that the rice community which had lower LTR value had more yielding potential in this village. However, Fig. 1 shows that the rate of yield increase became small when LAI became larger than about 2. It was suggested that there might be a saturating value of LAI. When the farmers try to increase yield by increasing LAI more than 2 using fertilizer, they have to introduce the rice varieties with improved plant type.

It was found that grain yield was negatively correlated with the nitrogen concentration in grain ($r=-0.419^{*}$) and straw ($r=-0.319$), and positively correlated with potassium concentration in grain ($r=0.512^{**}$). The distribution of nitrogen in the various parts of the plant at harvest was as follows: 34% in the straw, 10% in the unripened grains and 56% in the ripened grains. Similar results were reported so far in Bangken Rice Experiment Station in Thailand[7)].

On the whole, it may be effective to make rice plants more vigorous by using fertilizer, in order to get more yield in this village. But it should be noted that field conditions of this village differ widely in various points, *e.g.* manifold landform, water regime and soil fertility. Moreover, the amount of rainfall and its distribution in rainy season fluctuate remarkably year by year. On the other hand, improving water condition by constructing irrigation canal like that in the left bank of Chi river may be difficult in near future in this village. Therefore, there may be risks with using fertilizer here. It may be more practical for improving yield in Don Daeng to examine the various circumstances in paddy fields.

When compared with other yield surveys conducted in the farmers' fields in Thailand[1,2,15,16)] and Malaysia[11,12,13)], the characteristics of rice yield in Don Daeng can be discribed as follows. The grain yield of Don Daeng in 1981 was slightly higher than that of in Chai Nat (153g/m^2 [15)]) in Thailand, but lower than that in any other place, *e.g.* Central Plain (213g/m^2 [1)], 209g/m^2 [2)]) and northern part (272g/m^2 in single cropping fields, 378g/m^2 in double cropping fields[16)]) in Thailand, and in Malaysia (321g/m^2 [11)], 323g/m^2 in off season and 304g/m^2 in main season[12)], 318$\sim$444g/m^2 [13)]). The value in 1983 reached on intermediate level of them, however, it is still lower than those in northern Thailand and Malaysia. The number of hills/m^2 was almost same in any surveys. The number of panicles/m^2, the number of spikelets/panicle and the percentage of ripened grains in Don Daeng were less than those in Thailand and Malaysia. 1000-grain weight was nearly equal to that of northern Thailand. As previously described, in this village, large grain and B type verieties were dominant as well as in northen Thailand. The relationship between grain weight and most of yield components in 1981 was similar to that in Malaysia and central plain of Thailand, but obviously different from that in northern Thailand. Nevertheless, the correlation coefficients between grain weight and the number of spikelets/panicle, and 1000-grain weight were significantly larger than those of Malaysia and central plain in Thailand. On the contrary, relationship between grain weight and yield components in 1983 was strikingly similar to that in northern Thailand, except for the positive correlation between grain weight and the number of hills/m^2 in Don Daeng.

In conclusion, rice yield potential in Don Daeng is not inferior to that in central Thailand, but practical yield is governed entirely by rainfall during the cropping season.

Acknowledgements

We wish to express our gratitude to Prof. Hayao Fukui, the Center for Southeast Asian Studies, Kyoto University for his encouragement from the beginning of this study and to Mr. Kanha Bunpromma, Faculty of Agriculture, Khon Kaen University for his generous support during our stay in Thailand and to Mr. Supit Puhual, Mrs. Hiromi Naruse and Mr. Seigo Tamaki for their excellent skillful technical assistance and to all villagers in Don Daeng for their kindness shown during the field survey.

This work was supported in part by a Grant-in-Aid from the Ministry of Education, Science and Culture of Japan.

References

1. Fukui, H. and E. Takahashi 1969. Rice culture in the central plain of Thailand. Subdivision of the central plain and the yield components survey of 1966. Southeast Asian Studies 6 : 962—990.
2. ———— and ———— 1969.———— II. Yield components survey in the Saraburi-Ayutthaya area. 1967. Southeast Asian Studies 7 : 177—190.
3. Hattori, T. and H. Matsufuji 1985. Landform and soil. In A Rice Growing Village Revisited : An Integrated Study of Rural Development in North-

east Thailand (Ed.) H. Fukui, Y. Kaida and M. Kuchiba, Kyoto University, Kyoto. 109—123.
4. Kaida, Y., K. Hoshikawa and Y. Kohno 1985. Don Daeng village in Northeast Thailand : Instability of rice culture. Southeast Asian Studies 23 : 252—266**.
5. Kawashima, C and T. Hirano 1982. A simple method for measuring leaf area in rice plants. Japan. Jour. Crop Sci. 51 : 393—394*.
6. Kon, T., Y. Komatsu and T. Kataoka 1982 Varietal characters of high-yielding foreign rice. IV. Examination of measuring method of percentage of ripened grain. Japan. Jour. Crop Sci. 51 (Extra issue 2) : 15—16***.
7. Koyama, T., C. Chammek and N. Niamsrichand 1972. Soil-plant nutrition studies on tropical rice. IV. The effect of double-cropping in a rainy season upon the plant growth and soil fertility status of nitrogen in Bangken paddy soil. Soil Sci. Plant Nutr. 18 : 23—29.
8. Kuroda, T. and S. Miyagawa 1987. Don Daeng village in Northeast Thailand : Paddy yield in rain-fed fields. Southeaset Asian Studies 25 : 75—84**.
9. Matsushima, S. and T. Tanaka 1960. Analysis of developmental factors determing yields and its application to yield prediction and culture improvement of lowland rice. IV. Early discrimination of non-fertilized rice grains. Proc. Crop Sci. Soc. Japan. 28 : 365—366**.
10. Miyagawa, S., T. Kuroda, H. Matsufuji and T. Hattori 1985. Don Daeng village in Northeast Thailand : Typology of rice cultivation. Southeast Asian Studies 23 : 235—251**.
11. Moriya, M. 1968. Productivity of indica rice viewed from the field survey. In Rice Cuture in Southeast Asia. Crop Sciene Society of Japan, Tokyo. 110—119***.
12. Nozaki, M. and C. Y. Wong 1978. Studies on technology of cultivation practice of rice double cropping in Malaysia. II. Yield analysis of double cropping paddies in farmars fields. Japan. J. Trop. Agr. 21 : 206—212**.
13. Sugimoto, K. and N. A Sulaiman 1981. Analytical survey on paddy yields in the KADA area of peninsular Malaysia. JARQ 15 : 144—148.
14. Tanaka, A., S. A. Navasero, C. V. Garcia, F. T. Parao and E. Ramirez 1964. Growth habit of the rice plant in the tropics and its effect on nitrogen response. IRRI Techical Bulltin. 3.
15. Watabe, T. 1965. A note on productivity of paddy rice in Thailand. Japan. J. Trop. Agr. 8 : 76—81**.
16. ————1967. Glutinous Rice in Northern Thailand. Yokendo, Tokyo.

* In Japanese.
** In Japanese with English summary.
*** Translated from Japanese by the authors of this paper.