東北タイの天水田におけるイネの収量に変異をもたらす要因の分析

誌名	日本作物學會紀事
ISSN	00111848
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巻/号	57巻4号
掲載ページ	p. 773-781
発行年月	1988年12月

Japan. Jour. Crop Sci. 57(4) : 773—781 (1988)

Effects of Environmental and Technical Factors on Rice Yield in Rain-fed Paddy Fields of Northeast Thailand

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Received April 30, 1988

Abstract: Relationship between rice yield and several factors which would be concerned with variability of rice yield for rain-fed paddy field in Don Daeng village in Northeast Thailand was discussed. In 1981, a drought year, the mean value of yield of the upper topographically paddy field was only 63% compared to that of lower paddy field. Water condition was the most dominant factor affecting rice yield. Three factors, water condition, soil fertility and varieties cultivated, explained 45% of yield variation among paddy fields in evaluation using quantification scaling type 1.

In 1983, a bumper year, two factors, fertilizer application and crops in the former year, and above 3 factors could explain only 17% of grain yield variation. On the other hand, these five factors could explain 47% of variation of straw weight per unit area. Partial correlation coefficient between soil fertility and straw weight was the highest value among those between other factors and straw weight. Adoption of improved variety may be usefull for increasing yield, as well as establishment of irrigation facilities.
Key words: Rain-fed cultivation, Rain-fed paddy field, Rice, Soil fertility, Thailand, Variety, Water condition, Yield.

東北タイの天水田におけるイネの収量に変異をもたらす要因の分析：宮川修一・黒田俊郎*（岐阜大学農学部・*岡山大学農学部）

要　旨：東北タイの天水田稲作の実態を知るため，コンケン市近傍の農村ドンデーン村で 1981 年と 1983 年に農家水田の収量調査を行った．その結果同一村内でも水田の筆間の収量の変異がきわめて大きいことがわかった．1981 年は雨期の後半に雨量が不足気味であったため，保水性の劣っている地形的に高位の水田では低位の水田に比較して 63% の収量しか得られなかった．種々の要因を数量化したところ，各水田の水条件，土壌肥沃度および栽培品種の 3 要因により，収量の変異の 45% が説明可能であった．特に水条件と収量との偏相関係数は 0.465 で要因間では最大を示した．1983 年は降雨量が多く平均収量は 1981 年より増加し，水田間の変異は縮小した．上記 3 要因のほか，各水田の前年の作柄ならびに当年の施肥の有無を数量化して収量の変異の貢献度を調べたが，5 要因でも 17% が説明できたに過ぎなかった．一方，ワラ重についてはこの 5 要因によって 47% が説明可能であり，要因のうちでは土壌肥沃度の関与の程度が最大であった．以上のことから，降雨量の変動が大きいこの地域では，灌漑施設の整備が望まれるとともに，収穫指数の高い品種または栽培方法の導入が必要であると考えられた．
キーワード：イネ，収量，タイ国，天水栽培，天水田，土壌肥沃度，品種，水条件．

Previously, we reported the results of yield survey conducted in 1981 and 1983 on farmers' paddy fields in Don Daeng village in Northeast Thailand[5]. In our paper, we elucidated that the cause of lower rice yields compared with those in other parts of Thailand, arised from tremendous variability within individual paddy fields and within the cropping years examined.

The objectives of this report are to clarify the relationship between rice yield and major factors which might influence, and to search for the main cause of yield variability in this village.

Several factors, such as rice variety, transplanting time, field water condition, soil fertility, fertilizer application and yields of previous year, were considered to bring about variability of rice yields in this village. Insect pest, disease and weed control after transplanting were not taken into account for this analysis, because they have a minimal effect on rice yield in this village.

Materials and Methods

1. *Research site*

Don Daeng village lies about 15 km from Khon Kaen city which is located in the center of Northeast Thailand. Paddy lands in Don Daeng are distributed mostly in the alluvial plain between the Chi river in the north and low hills stretching in the southern part of village compound.

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

2. *Yield and yield components*

In 1981, 31 plots were chosen for the study of yield and its components. Beside of these 31 plots, grain and straw weight per unit area were measured in 215 plots at the harvest. In 1983, 174 plots were chosen for yield and yield components survey. Yield measurements were taken by the same method as that described as in previous report[5]. Yield components were also analyzed by the same method as mentioned in the report.

3. *Environmental factors*

The village of Don Daeng was located on the boundary of the alluvial plain along the Chi river and the elevated surface. Therefore, Don Daeng's farmland consisted of two kinds of land topographically: plain and hill portions.

The paddy fields were classified into 17 units in detail by soil scientists, using data of leveling survey and aerial photos. After that, 17 units were summarized into 3 types, such as lower, middle and upper paddy field. Lower paddy field was located in the following landform units; hollow, bottom, head slope and shallow trough. The middle paddy field was in the side slope unit. The upper paddy field was distributed in units of wash-out, hill top, remnant flat, elevation-levee, elevation-flat and elevation-ridge.

For fertility evaluation of top soils, nine chemical properties, *i.e.*, EC, pH, exchangeable-Ca, -Mg, -K, available SiO_2, total-C, mineralized NH_4-N and total P_2O_5, were measured in the surface soils of 246 paddy fields where yields were surveyed. As a result, they were classified into 9 clusters by the method of cluster analysis*. Class 2, 1, 3, 7, in fertile order, were mainly distributed in the plain portion and were characterized by lower EC and higher pH than the others. The class 6, 5, 9, 4, 8, in fertile order, were found almost in hill portion and characterized by higher EC and lower pH than those in the plain region. The soil of class 6 was most fertile and heaviest-textured among all classes. Soils of classes 2, 1, 3, 6, and 5 were found in the lower part of the landform. Class 4 was found in the middle or lower part of the hill portion. Class 7 and 8 were the least fertile and most coarse-textured, and was distributed in the upper part of the landform.

The rates of daily water consumption in each paddy plots were entimated by our co-worker hydrologists from three kinds of datum, *i.e.*, daily rainfall, plot-wise survey of the water conditions which was carried out every ten days covering about 6,000 plots in 1981, and 2,000 plots in 1983, and measurements of daily water consumption in 35 plots in 1983[2)]**. The values of the rate were distributed from 0 to 30 mm/day. These values might be determined mostly by the water retention ability of each paddy fields, so that larger value of the rate showed lesser ability of water holding in the field. The rates were very closely related to the topographic unit. Rain water was stored at paddy plot in first and then moved to other plots according to its topographical position. The rate values for the plots which were located in the upper paddy area were greater than that of plots in the lower paddy area. Entire paddy fields were thus classified into 4 categories: water logging (rate$\leqq$6), accumlating (rate=7), intermediate (rate=8) and draining zone (rate$\geqq$9)[4)].

4. *Cultural practices*

Varieties cultivated, fertilizer application and the previous year's yield were identified through interviews with farmers. Survey on the fertilizer application was carried out for its kind, dressing quantity and using date. The yields in the previous year were divided into 4 grades; no planting, no crop (due to some kind of damage after transplanting), poor crop and good crop. These survey were conducted for each of the about 8,000 paddy plots.

* Hattori, T. and H. Matsufuji 1985. Landform and soil. In A Rice-growing Village Revisited: An Integrated Study of Rural Development in Northeast Thailand. (Eds.) H. Fukui, Y. Kaida and M. Kuchiba. Kyoto University. 109—123.

** Kohno, Y. and Y. Kaida 1985 Hydrograph. In A Rice-growing Village Revisited: An Integrated Study of Rural Development in Northeast Thailand. (Eds.) H. Fukui, Y. Kaida and M. Kuchiba. Kyoto University. 132—148.

Table 1. Mean grain weight of paddy fields classified by topography.

	1981 (drought year)		1983 (bumper year)	
	g/m^2	plots	g/m^2	plots
Lower paddy field	234.8±74.7* a**	62	241.4±74.1	49
Middle paddy field	179.3±90.2 b	58	244.3±88.4	47
Upper paddy field	148.2±56.2 c	95	228.3±69.4	78

* : S.D.

** : Mean values within a column not followed by the same letter differ significantly at the 0.05 probability level.

Transplanting, heading and harvesting dates were recorded every ten days from July to December for each of about 8,000 plots in 1981, and also about 5,000 plots in 1983.

Results and Discussion

1. *Yields of paddy fields classified by landform units*

No difference could be found among 3 types of paddy fields in the bumper year of 1983 (Table 1). There was adequate rain to get good crops in this year. In 1981, the differences in yield among paddy types were significant. The yield of the upper paddy field was about 63% of that of the lower paddy field in 1981. As compared with the yield of 1983, yield of middle and upper paddy fields were about 73% and 65% respectively. The yield of lower paddy field was the highest among them, and it did not change in both year.

In general, lower paddy field could be characterized with much water, fertile soil and with earlier planting using late maturing varieties. On the contrary, upper paddy field was characterized with much less water, inferior soil fertility and with later planting using early maturing variety or non-glutinous varieties[4].

These combinations among the location, environment elements and cultural practices were usualy observed in rain-fed rice area in Northeast Thailand[6,7]. Polthanee and Marten pointed out that higher yield could be obtained in lower paddy field than in upper paddy field because of longer growth duration of rice variety and higher soil moisture contents maintained for longer period[6]. On the other hand, there might be more danger of destruction of crops by flooding in lower paddy field than in upper paddy field[4]. Similar fluctuation of rice yield by topographical position of paddy field were reported in rain-fed rice lands in Phillipines[3].

2. *Yielding ability of varieties*

Analysis of genetic yielding abilities proved to be quite difficult; they were identified by local names in every plot, because there were so many synonym and/or homonym among varieties in the farmers fields. Rice varieties were classified into 4 groups by their maturity; early, medium, late and extremely late, though the extremely late varieties were planted only in a few plots in this village, and all of them were classified into glutinous or non-glutinous varieties. Most of the non-glutinous varieties were medium maturity varieties, and were different from glutinous ones on plant type. It might be better to summarize whole rice varieties as 4 groups; early, medium and late varieties of glutinous rice, and non-glutinouse rice. Planted area were 4.3, 40.6, 43.5 and 10.5%, respectively totaling about 5,000 plots in 1983[4].

Some traits of each variety group was shown in Table 2, which was surveyed in 1983 of no drought year. The number of panicles/hill, the number of spikelets/m^2 and percentage of ripened grain of glutinous rice were less than those of non-glutinous rice. But 1,000 grain weight of glutinous rice was much greater than that of non-glutinous one. The number of spikelets/panicle of late maturing variety was the largest among rice variety groups with different maturity. It could be said that glutinous varieties, especially late maturing one, were panicle weight type, but non-glutinous varieties resembled panicle number type.

Late maturing varieties grew vigorousely in vegetative growth phase, but their yield was less than those of medium maturing varieties and non-glutinous rice, because of smaller values of the number of hill/m^2, the number of panicles/hill and percentage of ripened grain. Late maturing varieties were planted in fertile water-logged paddy fields located at the lower part of the landform. The yielding ability of early maturing varieties was the least among the 4 rice groups. It may be due to its short growth period and less fertile soil where these varieties used to be planted.

When yields of the two years were compared, the values of late maturing varieties were almost identical. In contrast, yields of other varieties, especially non-glutinous varieties, changed extremely. This different in yield among variety groups was the result of differences of circumstances of the planted fields of each variety.

3. *Cropping season and yields*

Transplanting time in this village was very variable every year. In 1983, in most fields transplanting was during the period from late June to early September. The busiest season for transplasting was middle and late July in 1981, and early and middle August in 1983.

Progress of this work was completely dependent upon rainfall distribution in rainy season. However, heading and harvesting times were almost the same in both years, because of the varieties' strong photosensitivity[4].

Correlation coefficients between transplanting time and grain yield were very low ($r=-0.18$ in 1981 and -0.04 in 1983). Also, correlation coefficients between growth duration (from transplasting time to harvesting time) and grain yield were very low ($r=0.11$ in 1981 and 1983). In both years, there was no difference among yields of any transplasting time during a period from late June to late August. Any peak did not appear in distribution of yield against transplanting time.

However, no yield was greater than 200 g/m^2 when rice varieties were transplanted late as in September. It was probably safe to say that too late transplanting would result in less vegetative growth and its would cause less grain yield concomitantly. The grain weight correlated to the straw weight quite significantly in this village[5].

Sugimoto pointed out referring to some rice yield experiments in Thailand that the highest yield could be attained in the case of growth duration of about 150 days[8]. In this village, this growth period was made possible by transplanting sometime between late July and early August for late maturing varieties and between early and middle July for medium maturing varieties.

4. *Effect of water condition*

In every variety, ear formation and emergence occurred in September and Octorber in Don Daeng. From measurement of daily precipitation[5], total rainfall in September and Octorber of 1981 amounted to 86 and 89 mm respectively. In 1983, those were 148 and 153 mm. Drought damage was observed in upper

Table 2. Comparison of some traits among rice variety groups (1983).

Variety group	No. of hills /m^2	No. of panicls /hill	No. of spikelets /panicle	No. of spikelets /m^2	% of ripened grain	1,000 grain wt. g	Grain wt. g/m^2
Glutinous							
Late	11.7	5.6 b*	123.2 a	7,888 b	70.9 c	36.7 a	238.4 ab
Medium	12.6	5.7 b	108.9 b	7,589 b	75.1 b	37.4 a	241.4 a
Early	12.4	6.0 b	94.1 c	6,848 b	73.9 bc	36.1 a	209.8 b
Non-glutionus	12.9	8.5 a	100.5 bc	11,099 a	83.9 a	28.6 b	283.4 a

Variety group	Grain-straw ratio	Culm length cm	N	Heading time	1981 Grain wt. g/m^2	1981 N
Glutinous						
Late	57.0 c	125.6 a	41	early Nov.	241.2 a	49
Medium	90.4 b	117.1 b	81	late Oct.	164.2 b	134
Early	103.5 a	100.6 c	40	early Oct.	198.1 ab	8
Non-glutinous	96.8 ab	102.3 c	12	late Oct.	143.2 b	21

Note - N : The number of samples.
* : Values within a column not followed by the same letter differ significantly at the 0.05 probabilty level.

paddy fields in 1981.

Table 3 shows no differnces among yields of all water condition zones in 1983, but significantly large variation among them in 1981. The grain yields of all varieties within the draining zone were extremely lower than in the water logging zone or accumulating zone. The former was only 30% of the non-glutinous rice grown in the water logging zone. This might be caused by the reduction in the number of panicles/hill, the number of spikelets/panicle, percentage of ripened grain and/or 1,000 grain weight (Table 4). The values of standard deviation were relatively large in the intermediate and draining zone.

It was suggested that water regime of every paddy field, determined mostly by their togographic location would result in the fluctuation of growth and yield more directly in 1981. On the contrary, the effects of variation in water condition might be hidden behiend other factors, *i.e.*, soil fertility, in 1983.

5. *Effects of soil fertility*

Table 5 shows the effects of soil fertility on grain yield in 1983. Mean values of yield of class 6 and 5 were the highest of all. The yield variability among soil classes was so large in hill region. Fewer differences existed among yields from different soil classes in the plain region. Soil of class 6 had the highest contents of exchangeable-Ca, -Mg, -K, total-C and mineralized NH_4-N. Available SiO_2 was abundantly found in this soil following class 9 soil, though yield data in 1983 was lacking.

In comparison of yield components, the number of spikelets/m², the number of panicles/hill and the number of spikelets/panicle were widely varied among classes. The maximum values of these three components were 11,403 (class 6), 9.1 (class 6) and 154.8 (class 6), and the minimum ones were 7,236 (class 1), 5.3 (class 4) and 100.6 (class 8), respectively. On the other hand, there was less differences in the number of panicles/m² and the percentage of ripened grains. The maximum values of these two components were 86. 4 (class 5) and 76.5 (class 3), and minimum ones were 66.5 (class 4) and 66.7 (class 4). It is possible to say that the variability of grain yield among classes was dependent upon variability of the number of spikelets/panicle, namely dependent upon the number of spikelets/m².

6. *Effect of fertilizer application*

In 1983, about 30 farmers used chemical fertilizer in a month after transplanting in this village. Fertilizer was applied to 38. 4ha, which was 9% of the entire rice planted area. Most of the farmers used ammonium sulfate. The average yield in the manured paddy fields was 248.4 g/m², which was not significantly different from 234.9 g/m² of non-manured paddy fields. It was not recognized that fertilizer application increased the values of yield components and straw weight. The quantity of fertilizer was about 10 kg/ha in nitrogen on the average. It was too little for improving yield. The government recommended to apply 187.5 kg/ha (30 kg/rai) of the chemical fertilizer 16-16-8 in these area[7]. In Don Daeng, they used about 30% of the recommended quantity.

7. *Effect of crop in previous year*

In 1980, 98% of the whole paddy fields area

Table 3. Comparison of mean grain weight among 4 water condition (1981).

Variety group	Water logging zone	Accumulating zone	Intermediate zone	Draining zone
Glutinous	g/m²	g/m²	g/m²	g/m²
Late	275.2±94.4* (19)	227.4±44.7 (22)	193.5±102.5 (5)	128.7 (1)
Medium	253.8±80.4 (5)	191.7±59.6 (29)	154.4±60.1 (73)	134.7±44.1 (17)
Early	—	247.3±56.3 (4)	229.4±37.3 (2)	96.7 (1)
Non-glutinous	338.6±274.7 (2)	180.5 (1)	137.0±54.6 (8)	101.9±34.3 (9)
Mean	278.3±106.1 a**	209.5±56.2 b	157.7±63.2 c	124.3±42.2 d
Mean (1983)	247.8±70.4	225.3±89.2	236.9±64.2	232.7±79.8

Note : Values in parentheses show the number of plots.
* : S.D.
** : Mean values within a line not followed by the same letter differ significantly at the 0.05 probability level.

was planted. However, harvesting was impossible for 90% of the fields due to destructive flooding. There was no difference among paddy fields in the effect of crop in 1980 on the yield in 1981.

In 1982, no planting or no harvesting was done in almost all of paddy fields in the draining zone and intermediate zone of water condition, or the upper paddy fields classified by landform. Those area were 14 and 17% of all, respectively. On the contrary, many good crop was obtained in the fields of the water logging zone, or lower paddy fields. The area was 22% of all, while that of poor crop paddy fields was 47%. These were the result of a rainfall shortage in that year.

In Table 6, the yield of "no planting" plot in class 8 was almost the same as that of higher fertility class of 6 and 5. But the yield of "poor crop" plot was less than "no planting" plot in that class, and soil fertility of the class was the least of all, as previously described. In other classes, although similar results were not obtained, these facts might be attributed farrowing.

8. *Numerical evaluation of several factors relating to rice yield*

Quantification scaling type 1 was applied to evaluate the effect of environmental aand technical factors on yields. Partial correlation coefficients among grain and straw weight, and factors were shown in Table 7. In 1981, nearly half of the yield variability could be explained by the presence of 3 grain-yield determing factors: water condition (the dominant factor), soil fertility class, and variety group. For straw weight, factors of variety and soil fertility class were more dominant than water condition. It was suggested that vegetative growth in 1981 was comparatively good in spite of rainfall shortage, but grain weight was decreased by drought at panicle formation or grain filling stage.

In 1983, R^2 value (coefficient of determination) of grain weight was very small. The above-mentioned factors may not be enough to explain the variations in grain yields. However, about half of the straw weight variability explained by these factors. The most dominant factor was soil fertility class followed by water condition. It can be said that vegetative growth in 1983 was greatly determined by the soil fertility of the field, but it did not result in grain yield increase because of some physiological problems in plant.

Correlation coefficients between grain and straw weight were 0.841 in 1981 and 0.642 in 1983[5]. In a bumper year such as 1983, huge vegetative growth did not necessarily produce huge grain yield unlike that of a drought year. In fact, Table 2 shows an extremely low grain-straw ratio for late maturing variety. Additionally, its percentage of ripened grains was the lowest. Moreover, we reported previously that rice plant with a leaf area index greater than 2 could not further increase grain yield in this

Table 4. Comparison of yield components among 4 water condition grades (1981).

Variety group	Water condition zone*	N	No. of hills /m²	No. of panicles /hill	No. of spikelets /panicle	% of ripened grain	1,000 grain wt. g
Glutinous							
Late	Water log.	3	9.2±1.7**	7.4±1.6	142.2±3.9	73.0±3.9	35.8±0.3
	Accumu.	6	11.7±0.9	5.4±0.9	106.6±10.7	67.2±1.8	35.4±2.0
	Intermed.	2	7.8±1.1	5.6±0.2	171.8±34.3	62.9±5.7	35.8±0.9
Medium	Accumu.	2	10.4±0.4	4.7±1.3	80.1±6.4	74.1±10.3	36.7±0.4
	Intermed.	6	12.4±1.5	5.5±1.2	57.7±10.8	68.6±6.1	34.7±2.2
Early	Intermed.	5	12.2±1.1	4.5±1.0	66.7±9.9	51.8±26.2	32.7±1.6
	Draining	1	13.0	6.2	43.9	67.7	25.2
Non-glutinous	Intermed.	1	13.8	3.8	69.1	46.3	17.4
	Draining	3	10.2±1.1	5.9±0.2	54.6±27.0	57.9±14.6	21.4±1.8

Note - N : The number of samples.
* : Water log. : water logging zone. Accumu. : accumulating zone. Intermed. : intermediate zone. Draining : draining zone.
** : S.D.

Table 5. Comparison of mean grain weight among soil fertility classes (1983).

Variety group	Soil fertility class in plain region			
	1	2	3	7
Glutinous	g/m²	g/m²	g/m²	g/m²
Late	222.0±44.7* (8)	240.4±45.6 (16)	221.0±50.0 (6)	206.9±64.4(2)
Medium	222.7±68.6 (21)	269.4±104.0(19)	244.3±41.9 (14)	225.5±42.9(8)
Early	209.8±71.6 (9)	203.1±43.4 (7)	223.8±87.6 (8)	206.2±74.8(6)
Non-glutinous	294.3±30.1 (3)	183.0±26.6 (2)	332.1±149.5(4)	—
Mean	225.0±64.7 b**	244.4±79.2 b	245.8±79.0 b	216.0±55.7 b
Mean (1981)	147.8±61.0 d	199.8±88.0 bc	176.6±69.5 cd	151.4±55.1 d

Variety group	Soil fertility class in hill region			
	4	5	6	8
Glutinous	g/m²	g/m²	g/m²	g/m²
Late	200.0 (1)	318.8±87.3(3)	328.2±59.6(2)	—
Medium	242.0±33.9(5)	—	531.7 (1)	212.2±42.4 (5)
Early	—	—	195.5 (1)	288.0 (1)
Non-glutinous	—	—	—	261.5±124.9(2)
Mean	235.0±34.8 b	318.8±87.3 ab	345.9±143.0 a	234.0±65.0 b
Mean (1981)	188.5±67.7 bcd	261.8±55.3 ab	299.5±130.2 a	191.6±41.6 bcd

Note : Values in parentheses show the number of plots.
* : S.D.
** : Mean values within a line not followed by the same letter differ significantly at the 0.05 probability level.

village[5]. There might be no effect of fallow and fertilizer application on yields, as concluded already.

Reffering to some production function analysis carried out in rain-fed rice culture in the Philippines[3], the most important factor affecting farm yield variability was the number of days the plants were water-stressed. This explained 70% of the variability. The proportion of variable cash input, such as chemicals, and varieties was very small. This implies that there is difficulty to improve or stabilize yield by adopting some methods other than irrigation. And also, R^2 value was 0.41 in that study. This value in similar to those in Table 7.

For increasing and stabilizing rice production in Don Daeng village, in the first place, water condition of the upper paddy field or draining zone must be improved. This implies the advantage of agricultural engineering methods such as construction of an irrigation canal and tank, or subsoil compaction. This is known as the "technological adaptation" to the environment[1]. Secondly, improved rice varieties which can produce more panicles per hill must be introduced to the fields which are particularly located in the lower paddy field or water logging and accumulating zone. In those paddy fields, water condition is comparatively favourable even in drought year, and the soil is more fertile. Under those circumstances, indigenous varieties do not have the capacity to produce more number of spikelets per unit area but capacity to produce straw, which is, however, important for feeding water buffaloes that draw plows. If improved varieties are adopted, fertilizer application will result in increased yields more effectively than with present varieties. This is to be so calld "agronomic adaptation"[1].

Achieving the former improving methods may be difficult, without the aid of immense goverment subsidies. But the latter method being easier to carry out. Because improved varieties, for example Hang Yii 71, Nio Sanpatong and Khaao Paak Moo 148 which are glutinous, season bound varieties, has been already released in the Northeast

Table 6. Effect of crop of the previous year on mean grain weight in 1983 in each soil fertility class.

Results in 1982	Soil fertility class in plain region			
	1	2	3	7
	g/m²	g/m²	g/m²	g/m²
No planting	247.7±66.8*(4)	175.0 (1)	186.9±75.0 (2)	—
No crop	219.3±68.7 (10)	216.3±38.2 (4)	227.3±87.6 (7)	183.1±31.5(4)
Poor crop	230.4±65.1 (17)	248.7±56.6 (18)	248.7±39.5 (12)	231.6±62.8(9)
Good crop	228.1±41.7 (4)	265.3±114.8(13)	265.0±105.4(11)	186.8±35.9(2)

Results in 1982	Soil fertility class in hill region			
	4	5	6	8
	g/m²	g/m²	g/m²	g/m²
No planting	206.5 (1)	—	—	268.5±75.1(4)
No crop	267.8 (1)	—	—	213.6±45.4(2)
Poor crop	233.9±37.3(4)	368.7 (1)	—	185.4±17.3(2)
Good crop	—	293.9±107.2(2)	282.9±123.6(2)	—

Note : Values in parentheses show the number of plots.
* : S.D.

Table 7. Partial correlation coefficients between yields and quantified factors relating to yield.

Year	Factors					N	R^2
	Variety group	Water condition zone	Soil fertility class	Crop in 1982	Fertilizer application		
1981 Grain wt.	0.189	0.465***	0.381***	—	—	198	0.448
Straw wt.	0.446***	0.289**	0.433***	—	—	198	0.513
1983 Grain wt.	0.331***	0.185	0.277**	0.122	0.123	121	0.167
Straw wt.	0.229**	0.304**	0.514***	0.146	0.033	120	0.470

Note - N : The number of samples. Coefficients asteristiked are significant at 0.1% (***) and 1% (**) level.

district[9]. These agronomic adaptation strategies may be useful for increasing rice production in a rain-fed rice culture until farm land improvement is realized in this village.

Acknowlegements

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

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