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Rice Culture in the Central Plain of Thailand (V)

Possibility of Higher Yield viewed from the Yield Component Surveys in Farmers' Fields

by

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I Introduction

The yield of the unhulled grain of the rice plant is the product of four components when the yield is expressed by weight:

$$Y/m^2 = P/m^2 \times S/P \times F/100 \times T/1{,}000$$

where Y/m^2 is weight (grams) of unhulled grain per square meter,

P/m^2 is the number of panicles per square meter,

S/P is the number of spikelets per panicle,

F is the percentage of filled grain, and

T is one thousand grain weight (grams of unhulled grain).

P/m^2 can be divided further where transplanting is practiced:

$$P/m^2 = P/H \times H/m^2$$

where P/H is the number of panicles per hill, and

H/m^2 is the number of hills per square meter.

By measuring the yield components of a sample, one can obtain a set of figures consisting of Y/m^2, P/m^2, S/P, F and T. This set of figures is hereafter called a "pattern" of the components. The pattern of the components differs from one location to another as yields differ, and even at the similar yield level, various patterns are possible. However, if a sufficiently large number of samples is collected in an area, they can be classified into several groups according to similarities in the pattern of the components, and also, one or more patterns of the components can be generalized for a certain yield level. If this can be done successfully for relatively high yielding plots among samples, a pattern or patterns thus presented would be one of the most feasible patterns of the components to be aimed for in raising the yield level. Thus, the survey of the yield components would present a possible pattern of components for higher yield, and some inference can be made as to how such pattern could be attained.

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II Surveys and Experiments

The discussion in this paper on the possibility for higher yield is based on several field surveys conducted by various researchers including the authors, and some experiments related to them.

Surveys

1 Northern Thailand Rice, mainly glutinous, is grown in narrow basins in this mountainous region of the country. A survey of the yield components was undertaken by T. WATABE during the main season of 1965. A total of 34 samples was collected in the Chiang Mai, Chiang Rai, Lampang, Phrae and Nan Basins. Among them, 11 and 14 fields were typical single- and double-cropping fields, respectively. The yield components of these 25 fields were reported in; Tadayo WATABE, *Glutinous Rice in Northern Thailand*, Reports on Research in Southeast Asia, Natural Science Series N-2, The Center for Southeast Asian Studies, Kyoto University, 1967, 160 pp.

2 Central Plain of Thailand In the main season of 1966, the authors conducted a preliminary survey which covered the whole Central Plain. The samples were collected from 23 transplanted and 8 broadcast fields, but only the data for the former 23 samples are used in this paper. The result in detail is seen in; Hayao FUKUI and Eiichi TAKAHASHI, "Rice Culture in the Central Plain of Thailand," *Tonan Ajia Kenkyu (The Southeast Asian Studies)*, Vol. 6, No. 4, 1969. pp. 292-320.

3 Saraburi-Ayutthaya This area was surveyed by the authors in two successive years, 1967-1968. The result of the first year has been reported in; Hayao FUKUI and Eiichi TAKAHASHI, "Rice Culture in the Central Plain of Thailand (II)," *Tonan Ajia Kenkyu (The Southeast Asian Studies)*, Vo. 7, No. 2, 1969. pp. 177-190.

The 1968 result is summarized in Appendix I at the end of this report.

4 Province Wellesley in Malaysia A total of 17 samples were taken, 6 in the northern, 5 in the middle and 6 in the southern part of this province by M. MORIYA. The result and the discussion appear in; M. MORIYA, "On the Productivity of *Indica* Varieties Based on Field Survey," *Tonan Ajia no Inasaku (Rice Cultivation in Southeast Asia)*, Nippon Sakumotsu Gakkai (Japanese Society of Crop Science), 1968. pp. 110-119.

5 High-Yield Plots Survey in Northern and Central Thailand During the harvesting season of 1968, the senior author with the assistance of Messrs. K. YONEBAYASHI and S. FUJIWARA investigated several high-yielding fields in the northern and central parts of Thailand. The method employed for measuring the yield components was similar to that used in the former surveys in the Saraburi-Ayutthaya area. The result is summarized in Appendix II.

Experiments

1 Characteristics of the Farmers' Varieties in Saraburi-Ayutthaya In the study of

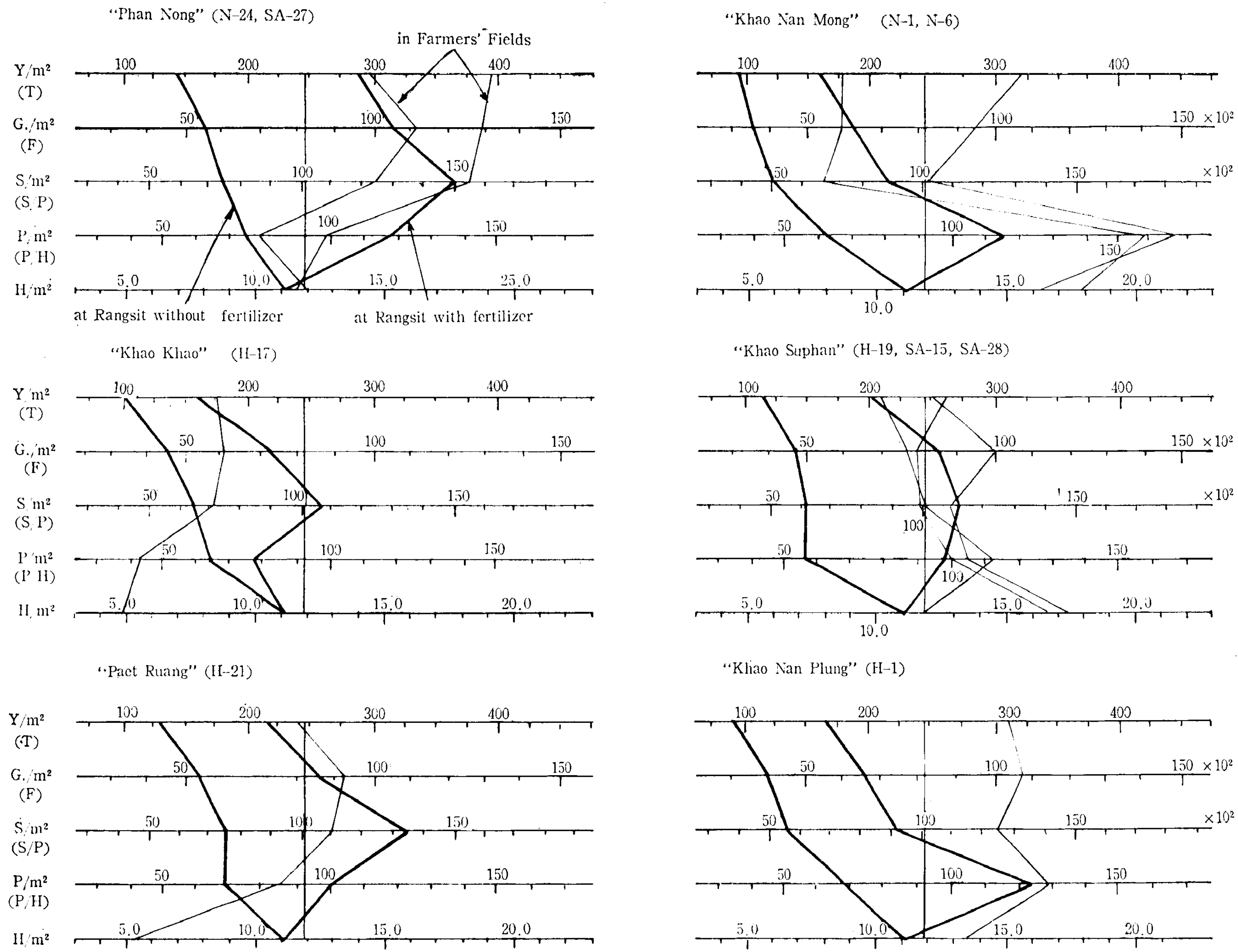

Fig. 1 Yield Components of Some Varieties in Farmers' Fields and at Rangsit Station

the Saraburi-Ayutthaya area in 1967, the plant samples were collected from 30 locations and the seeds were also stocked. Among them, 15 varieties were chosen and planted at the Rangsit Rice Experiment Station in the wet season of the following year. The seeds were sown on July 5 and transplanted at 30×30 cm spacing (3 plants per hill) one month later. There were two treatments, unfertilized and fertilized; the latter received N 30, P_2O_5 80 and K_2O 80 kg/ha as basal, and 10 kg/ha each of N on October 16, 24 and 30. The experiment was replicated four times. Thus, there were four blocks and each block consisted of 15 sub-plots, each of which was made up of three rows 9 meters long. The earliest variety flowered on November 4, and the latest on November 23. The harvest took place one month after flowering. The result is shown in Fig. 1 and Table 6.

III Possibility of the Yield Level of 3-4 ton/ha

A yield level lower than 3 ton/ha seems most common in Thailand. (Table 1) Areas where yields higher than 3 ton/ha are not unusual can be found in northern Thailand and in some provinces in the Central Plain, for instance, Phetchabun and Samut Prakan. (Fukui, H. and E. Takahashi, 1969 a) However, yields higher than 4 ton/ha are exceptional even in these areas. Consequently, the data obtained through the field surverys in Thailand are expected to give some information as to how the present common yield level, that is, 2-3 ton/ha, could be raised to the relatively higher level of 3-4 ton/ha. A possible pattern of the yield components for a yield level higher than 4 ton/ha must be sought in some other sources.

Table 1 Yield Components of Rice Plants Grown in Farmers' Fields

Country	Area and Year	N=	Y/m² (gr/m²)	T (gr)	F (%)	S/P	P/m²	P/H	H/m²
				95% confidence intervals					
Thailand	North 1965	25	267-339	33.3-36.4	73-78	150-179	78-99	7.8-11.0	9.1-11.2
Thailand	Central Plain 1966	23	193-273	26.3-29.1	74-81	86-122	93-123	7.0-9.4	11.5-17.3
Thailand	Saraburi-Ayutthaya 1967	30	181-237	27.0-28.6	75-81	94-118	84-106	7.4-8.9	10.6-13.1
Thailand	do. 1968	29	223-261	26.1-28.9	81-86	113-142	79-98	7.1-8.5	10.4-13.2
Malaysia	Province Wellesley	17	261-380	21.2-24.7	74-85	113-171	85-113	13.1-18.1	6.2-6.9
					averages				
Japan	Whole Country 1963-1965*		(398)**			78.7	321	17.0	18.9

* Ministry of Agriculture and Forestry, 1966
** Yield in brown rice

"Content or Container"?

The yield can also be expressed by the following formula:

$$Y/m^2 = S/m^2 \times F/100 \times T/1{,}000$$

where S/m^2 is the number of spikelets per square meter. In the course of the growth of the rice plant, the number and size of spikelets are determined during the vegetative and early reproductive growth stages. In these spikelets, starch is accumulated during the later growth stages. Thus, the yield components can be grouped into two categories: one consists of those which determine the total volume of the "container" to be filled by starch, and the other consists of those which are concerned with starch accumulation, that is, "content". P/m^2 and S/P, the product of which is S/m^2, are grouped into the former while F and T are grouped into the latter.*

1 Averages of F In the surveys referred to in this report, the averages of F values were normally 75–80 per cent. (Table 1) As some plants damaged by partial drought, insects, diseases, and so forth were also included in the samples, the averages for normal plants would be still better. The F values in the temperate zone, such as in Japan, do not exceed those in Thailand. It is concluded, therefore, that the F value in Thailand is sufficiently high at the commonly-observed yield level.

2 Averages of T The relatively large T in northern Thailand is considered due to the characteristics of glutinous varieties, the grain shape of which is long but still more round than that of the non-glutinous rice common in the Central Plain. The three surveys in the central part of Thailand showed a similar range of T, which indicated similarity of the varieties commonly used in this region. They are typically large and slender. Smaller T in Malaysia might be due also to the varietal character. Thus the T value among the other components seems least affected by the surrounding conditions, and mostly determined by the varietal characteristics. Consequently, the increase of this component by the improvement of cultivation techniques will not contribute significantly to the yield increase.

3 Coefficients of Variation of F and T The coefficients of variation of both F and T were remarkably smaller than those of any other components. (Table 2) This indicates a smaller possibility of contribution by either or both of these components to a

Table 2 Coefficients of Variation in Yield Components

Area and Year	N=	Y/m^2	P/m^2	H/m^2	P/H	S/P	F	T
			Per-cent					
Northern Thailand 1965	25	29	29	26	41	21	9	11
Saraburi-Ayutthaya 1967	30	36	31	28	24	31	11	8
Saraburi-Ayutthaya 1968	29	21	28	31	23	31	8	14
P. Wellesley	17	36	27	11	31	24	13	15

* The size of the individual spikelet can not be indicated properly by any of the components mentioned above. T can be considered as an index partly of starch accumulation and partly of the size of spikelet.

substantial increase of the yield.

4 Correlation F did not show even a slight sign of the correlation with S/m^2, indicating the unlikeliness of deterioration of F caused by an excess number of spikelets. (Table 3) This fact, together with the nature of the T value as mentioned previously, might explain the consistently high correlation between S/m^2 and Y/m^2.

Table 3 Correlation Coefficients between $Y/m^2 - S/m^2$ and S/m^2–F

Area	N	Correlation coefficient (r) between	
		Y/m^2–S/m^2	S/m^2–F
Northern Thailand 1965	25	0.839**	0.152
Central Plain 1966	23	0.852**	0.238
Saraburi-Ayutthaya 1968	30	0.907**	0.254
P. Wellesley	17	0.870**	0.199

** Significant at 0.01

5 Conclusion Based on the discussions of the survey referred to above, it is concluded that the importance of the "container" greatly exceeds that of the "content". At a yield level of lower than 4 ton/ha, any technical innovations that aim at an increase of S/m^2 would not affect F and T adversely. This conclusion is supported by the result of a field experiment by the authors. (Fukui, H. and E. Takahashi, 1970)

Classification of Samples

The conclusion of the previous section was that the "container" forming processes are far more vital than the "content" forming processes to the attainment of a high yield. S/m^2, which is an approximate index of the "container" forming processes, is the product of S/P by P/m^2.

$$S/m^2 = S/P \times P/m^2$$

Therefore, the search for a possible pattern of the components for higher yield means primarily the search for a possible combination of S/P and P/m^2 to find a greater S/m^2. In other words, the relative significance of the contribution of S/P, and P/m^2 to greater S/m^2 is to be compared.

As the first approach to this question, the samples from the Saraburi-Ayutthaya area were classified simply according to the yield level, and the mean values of S/P and P/m^2 of high and low yield plots were compared. But in neither S/P nor P/m^2 were any significant differences found between groups classified in this way. In other words, greater or smaller S/P or P/m^2 was not necessarily related to high or low yield. This indicates a wide range of plant types among the samples,—some had larger but fewer panicles, and some others smaller but more numerous panicles—and also shows that a plant type is not a determining factor of the yield level,—the former plant type is not always a better yielder than the latter and vice versa.

Therefore, as the first step, the samples should be classified according to the plant type and then the contribution of P/m^2 and S/P to S/m^2 should be compared for each type. Actually such a classification of the samples had been attempted in several studies previously reported.

1 Northern Thailand Twenty-five samples collected in northern Thailand by T. WATABE were divided into two groups according to whether the rice is grown once or twice a year at the corresponding location. Examining these two groups from the viewpoint of the yield components as seen in Table 4, the single-cropping fields were found to be characterized by significantly greater H/m^2 and smaller P/H than those of the double-cropping fields. S/P tended to be less in the single- than in the double-cropping fields.

Table 4 Yield Components Averaged by Classification according to Various Criteria*

	N	Y/m^2	S/P	P/m^2	P/H	H/m^2
Northern Thailand 1965						
Single cropping fields	11	273	150	87	7.0	12.3
Double cropping fields	14	328	175	90	11.2	8.4
$D_{.05}$		72	28	22	2.8	1.5
Central Plain 1966						
A	7	293	124	106	10.8	10.0
B	11	183	100	91	7.7	12.1
C	5	260	87	148	5.7	25.7
$D_{.05}$		112	55	35	2.9	3.4

* The criteria are as follows; single or double cropping field for northern Thailand, planting density and total dry matter produced by one hill for the Central Plain.

2 Central Plain Twenty-three samples of the transplanted fields were divided into three groups according to their positions on a graph with the total dry weight per hill on the vertical and H/m^2 on the horizontal line. (FUKUI, H. and E. TAKAHASHI, 1969 a) The yield components were similarly examined. (Table 4) The *type C* was characterized by significantly greater H/m^2, smaller P/H, and larger P/m^2 than the others.

3 Saraburi-Ayutthaya 1967 Thirty samples were divided into six groups according to the graphically-presented pattern of the yield components. (FUKUI, H. and E. TAKAHASHI, 1969b) The components to which particular attention was paid were S/P and P/H among others. The *types A, B* and *C* roughly corresponded to the "*panicle number*" type, and the *types D, E* and *F* to the "*panicle weight*" type.

4 Conclusion The criteria for classification were different for each study. Regardless of the different criteria used, however, the means of several components of one group or type were significantly different from those of the other group or groups. This suggests that the various plant types of the rice plant at different locations can also be distinguished by comparing the yield components. The yield components themselves

could be used as the criteria for classification of the samples of various plant types.

Classification of the Two-Year Samples in Saraburi-Ayutthaya

The comparison in the yield components of various plant types as stated above suggested that the greater H/m² was, the smaller P/H became and vice versa. Similarly the greater P/m² was, the smaller S/P tended to be. Schematically, the following two extremes can be recognized :

(I) smaller H/m²—greater P/H—smaller P/m²—greater S/P

(II) greater H/m²—smaller P/H—greater P/m²—smaller S/P

The pattern of the yield components of each of the 59 samples in Saraburi-Ayutthaya during 1967-1968 was drawn on graphs after the manner given in the previous report. (Fukui, H. and E. Takahashi, 1969 b) They were classified into three types according to the shapes of their slanted lines on graphs. The *types A* and *C* roughly corresponded to (I) and (II), respectively, and the *type B* was intermediate between them. The examination of the components determining the "container" revealed that most of the samples grouped into *type A* had S/P greater than 150, and those of the *type C* smaller than 100; while S/P of *type B* was between 100 and 150.

1 Classification by S/P As the S/P was found to be a good criterion for classification of the samples in Saraburi-Ayutthaya, the samples were divided into three groups by this criterion. (Table 5) Significant differences among the three groups were observed in P/m² and H/m², and in S/P, while the Y/m² of *type C* was significantly different from those of the other two types. On the contrary, P/H did not significantly differ among the types. In other words, H/m² was the main factor determining P/m², and S/P was inversely proportional to P/m².

Table 5 Yield Components Averaged by Type A, B and C for 59 Samples in Saraburi-Ayutthaya, 1967–1968

	N=	Y/m²	S/P	P/m²	P/H	H/m²
Type A	11	263	174	69	7.7	9.1
Type B	26	241	123	87	8.1	11.2
Type C	22	188	80	109	7.9	14.0
$D_{.05}$		47	13	18	1.5	2.3

2 Varietal Characteristics as the Cause of Different Yield Component Patterns As the immediate causes of the striking differences of the component pattern among the three types, two factors can be considered responsible ; one is the planting density customarily adopted by farmers, and the other is the characteristics of the varieties used. Greater P/m² and smaller S/P may be a result of dense planting, or may simply be attributed to a varietal character distinguished by having smaller panicles which thus makes dense planting necessary.

The S/P of 6 out of the 15 varieties, the growth performances of which were compared under the experimental conditions, was found to remain unchanged regardless of the place in which it was grown. The varieties which held smaller panicles in farmers' fields in Saraburi-Ayutthaya also held smaller ones even at the much wider spacing employed at the Rangsit Experiment Station. In these varieties, the varietal characteristics themselves seem to be the cause of smaller or larger S/P. The density of the planting has little effect. The other varieties among the 15 examined consisted mainly of varieties called "Chek Choey", S/P of which was normally 120-130 under the conditions at the station. (Table 6) In farmers' fields, it was as great as, or even greater than that at the station in many cases. However, in some other cases in farmers' fields, S/P of the same variety was considerably smaller. This was difficult to attribute

Table 6 Comparison of Spikelet Number per Panicle in Farmers' Fields, and at Rangsit Station

At Rangsit		In Farmers' Fields "Normal"		In Farmers' Fields "Abnormal"	
Variety "Chek Choey"					
Without fertilizer					
N- 9	128	N- 8	130	N- 5	93
N-10	123	N- 9	166	N-13	93
N-11	126	N-10	125	N-15	103
N-30	133	N-11	135	N-26	74
H- 4	133	N-14	127	N-30	69
H- 6	141	N-21	123	H- 6	79
N-21	110	N-31	124	H-13	82
		H- 4	111	H-20	97
		SA- 6	135	SA- 5	86
With fertilizer		SA- 7	143	SA-14	104
N- 9	138	SA- 8	110	SA-20	92
N-10	128	SA- 9	111	SA-36	79
N-11	117	SA-10	134		
N-30	128	SA-11	122		
H- 4	141	SA-12	138		
H- 6	138	SA-22	155		
N-21	134	SA-23	181		
		SA-24	229		
		SA-25	186		
		SA-31	116		
		SA-32	154		
		SA-33	110		
		SA-34	129		
Variety "Thon Ma-eng"					
Without fertilizer					
N-27	124			N-27	66
With fertilizer					
N-27	112				

to varietal characteristics. Similarly, very small S/P of a variety called "Thon Ma-eng" in farmers' fields was considered not attributable to the varietal characteristics because the same variety possessed much greater S/P at the Rangsit Station.

3 Separation of "Abnormally" Grown Plants Most of the samples whose S/P was considerably smaller in the farmers' fields than at the station were classified into the *type C*. Therefore, the samples belonging to this type can be further divided into two subgroups: one consists of 11 samples, S/P of which was similar regardless of where they were grown, and the other consists of 11 samples holding smaller S/P in farmers' fields than at the station. Small S/P of the latter subgroup in farmers' fields was not caused by the characteristics of the varieties, because the same varieties could hold large panicles at a wider spacing under the experimental condition.

Among the 11 samples grouped into the latter subgroup only three were from the 1968 survey and the rest were from the 1967. The year 1967 was very dry, the driest in several tens of years in Thailand. The study area of Saraburi-Ayutthaya also suffered from severe drought. Water shortage at the beginning of the wet season delayed the transplanting. Dense planting is the common practice of the farmers in this region when transplanting is delayed. Y/m^2 and P/m^2 of these crops were significantly smaller than those of the other 11 samples which always had a small S/P irrespective of spacing. (Table 7) It can be safely inferred that the smaller S/P in farmers' fields than at the station was partly caused by the dense planting which was a countermeasure to the

Table 7 Yield Components of "Normally" and "Abnormally" Grown Plants among Type C in Saraburi-Ayutthaya, 1967-1968

	"Normal"	"Abnormal"	l. s. d. $_{.05}$
N=	11	11	
Y/m^2	216	159	54
S/P	75	85	14
P/m^2	125	93	22
P/H	9.1	7.3	1.9
H/m^2	15.3	12.7	2.4

Table 8 Yield Components Averaged according to Type A, B and C after Eliminating "Abnormally" Grown Plants in Saraburi-Ayutthaya, 1967-1968

	Type A	Type B	Type C	$D_{.05}$
N=	11	24	11	
Y/m^2	263	243	216	55
S/P	174	125	75	15
P/m^2	69	86	125	19
P/H	7.7	8.1	9.1	2.1
H/m^2	9.1	11.0	15.3	2.8

water shortage at the beginning of the wet season, and partly caused by the drought conditions during various growth stages. Consequently these samples can be said to have grown "abnormally" and do not figure in our further discussion. (Table 8)

"Panicle Number" or "Spikelet Number per Panicle"?

In the previous section the samples in Saraburi-Ayutthaya were classified into *types A, B* and *C* according to the plant type, using S/P as the criterion. As the samples classified into a certain type had a similar pattern of the components, it then became possible to seek a possible pattern of the components to attain higher yield for each type.

In the following discussion, the pattern of the yield components of the "low" and "high" yield plots are compared for each of *types A, B* and *C*. The "low" yield plots were represented by farmers' fields of lower than 3 ton/ha yield in the Saraburi-Ayutthaya surveys in 1967-1968. The "high" yield plots were represented by the fields of 3-4 ton/ha yield in the Saraburi-Ayutthaya surveys in the same years, in the preliminary survey in the Central Plain in 1966, and in the high yield plots survey in 1968. (Table 9)

Table 9 Comparison in Yield Components between "High"* and "Low"** yield in Farmers' Fields

	N=	Y/m^2	S/Y	S/m^2	S/P	P/m^2	P/H	H/m^2
Type A				×100				
"Low"	9	241	47	112	173	66	7.6	8.9
"High"	6	354	45	160	186	88	9.0	10.5
l. s. d. .05		47	7	24	31	20	2.1	4.0
Type B								
"Low"	20	227	44	100	124	82	8.3	10.2
"High"	14	342	41	141	127	111	8.7	14.1
l. s. d. .05		26	5	17	8	14	1.8	2.9
Type C								
"Low"	9	194	47	86	74	120	8.1	15.4
"High"	5	339	40	135	83	164	9.4	19.5
l. s. d. .05		56	14	24	21	28	3.1	6.9

* The samples of 3-4 ton/ha yield in the surveys in Central Plain, 1966, and Saraburi-Ayutthaya, 1967-1968, and of the "High Yield Plots" in Northern and Central Thailand were averaged according to Type A, B and C.

** The samples of less than 3 ton/ha yield in Saraburi-Ayutthaya, 1967-1968 after eliminating the abnormally-grown samples were similarly averaged.

1 Type A There was no significant difference in S/Y, the number of spikelets needed for unit grain yield, between the "high" and "low" yield fields in *type A* nor in the other types. This is a consequence of the insignificance of the contribution of F and T to the grain yield, irrespective of the yield level. Therefore, higher yield level of 3-4 ton/ha, roughly 50 per cent higher than 2-3 ton/ha, was brought about by the

similarly greater S/m^2. Greater S/m^2 resulted mainly from greater P/m^2 rather than from greater S/P. In P/H and H/m^2, which determine P/m^2, no significant difference was observed between the "high" and "low" yield plots. Greater P/m^2 resulted partly from greater P/H and partly from greater H/m^2.

2 Type B Just as in the case of *type A*, the rise in yield level from 2-3 to 3-4 ton/ha required an approximately proportional increase of S/m^2. This was attained mainly by greater P/m^2. However, as there was a significant difference in H/m^2 between the "high" and "low" yield plots, greater P/m^2 was considered to result mainly from greater H/m^2 in the "high" yield plots.

3 Type C The trend of the yield components in the "high" and "low" yield plots was similar to those in the other two types. A greater S/m^2 resulted mainly from greater P/m^2, which seemed to be brought about partly by greater P/H and partly by that of H/m^2.

4 Conclusion The conclusion is that in any type of the yield components, S/m^2 should be increased to cause a rise in the yield level from 2-3 to 3-4 ton/ha, and it was enough to increase S/m^2 approximately in proportion to the yield increase, because of the relatively insignificant contribution of F and T. It was commonly observed in the three types that P/m^2 was far more important than S/P in bringing about an increase of S/m^2. However, the P/m^2 needed for 3-4 ton/ha level of grain yield differed greatly among the types : less than 100 seemed sufficient for *type A* while more than 100 seemed neccessary for *type B*, and 150 or more for *type C*. The role of P/H and H/m^2 in attaining these levels of P/m^2 could not be defined clearly from the results of the surveys referred to. Only in the case of *type B*, a greater contribution of H/m^2 than P/H was suggested.

Possibility of Increasing Panicle Number

Unless all the conceivable factors determining the "high" and "low" yield plots are throughly analyzed, it is impossible to show conclusively what factor or what combination of factors has brought about greater P/m^2 in the "high" yield plots. The following three factors, however, are probably most important ; varietal characteristics, soil fertility and planting density. Although the last factor, planting density, was one of the characteristic features differentiating the three types, it was considered as contributing only partly to greater P/m^2 in the cases of *types A* and *C*, but somewhat more significantly in the case of *type B*. Field experiments on the effect of nitrogen on the yield components have indicated that the yield increase with increasing doses of nitrogen was significant, and could be attributed mostly to P/m^2 increase. (FUKUI, H. and E. TAKAHASHI, 1970) Generally speaking, P/m^2 is the component least specific to the varieties, and the one most easily affected by changes of cultivation methods, including fertilizer application. The same experiment also indicated the difficulty of increasing P/m^2 beyond a certain level even with a large dose of nitrogen because of the death of young tillers during the vegetative lag phase. Therefore, it is possible to state that P/m^2 can be increased either by dense planting in some cases, or by improving soil fertility at least to a certain level by means of fertilizer application. The critical level of P/m^2 at which the rate of increase with increase of nitrogen slows down, depends on the characteristics of the varieties used.

Greater P/m^2 will not affect S/P adversely as indicated by the insignificant difference in S/P between the "high" and "low" yield plots. The fact that lower S/P was related to higher P/m^2 for some of the samples in Saraburi-Ayutthaya was explained by the fact that lower S/P was caused by varietal characteristics, rather than by an excessively high P/m^2.

Possibility of S/P Increase

On the one hand, S/P in the "high" yield plot was not significantly larger than that of the "low" yield plot in any of the three types. On the other hand, S/P was found to be quite specific to each variety under farmers' fields conditions. Therefore, the significant increase of S/P could occur only when the varieties with smaller S/P were replaced by those with larger S/P. The introduction of a new variety holding larger S/P, means the shift of *type C* to *B*, and *type B* to *A*. The great advantage of this is that a smaller P/m^2 is needed for higher yield.

Conclusion

The "container" forming processes are far more vital to higher yield than the "content" forming processes. The reasons are: (a) F is sufficiently high in farmers' fields even under the present condition, (b) T is so strongly specific to varieties that it cannot be changed significantly without replacing the varieties themselves, (c) the coefficients of variation of F and T were remarkably lower than those of the other components, (d) no significant correlation was found between F and S/m^2, while a consistently significant correlation was found between S/m^2 and Y/m^2. The result of the field experiments also verified this conclusion. Therefore, the immediate practical measures to attain higher yield are to increase S/m^2 in so far as the rise of the yield level from 2–3 to 3–4 ton/ha is aimed for with the use of native varieties.

S/m^2 can be increased by increasing P/m^2 because S/P was rather specific to each variety and was less affected by P/m^2. P/m^2 in the "high" yield plots was in fact, always significantly greater than in the "low" yield plots. However, greater P/m^2 is not the sole means for attaining greater S/m^2. The selection of varieties holding greater S/P will also result in greater S/m^2. The advantage of obtaining greater S/m^2 by adopting the varieties holding greater S/P, is that the P/m^2 needed for a certain level of S/m^2 or Y/m^2 is much lower than the P/m^2 needed by those with smaller S/P. Because the factor limiting yield when the amount of nitrogen is increased is the failure of P/m^2 to respond to a higher dose of nitrogen, the selection of varieties with greater

S/P will make it easier to obtain sufficiently great S/m^2 for higher yield.

IV Summary

The studies of yield components of the rice plant in farmers' fields in Thailand and Malaysia were summarized. A yield level lower than 3 ton/ha was most common, followed by a level between 3 and 4 ton/ha. The pattern of the yield components in high and low yielding fields was investigated comparatively, and common patterns of high yielding fields were sought.

The two components concerned with the "content" forming processes, namely, the percentage of filled grain, and the one thousand grain weight, were found to have much less importance to the yield level than those concerned with "container" forming processes which are approximately represented by the number of spikelets per unit area. Deterioration of the "content" by excess volume of the "container" did not occur at the yield levels under discussion.

There were distinct differences of plant type among the samples. They were classified into *types A, B* and *C*, using the number of spikelets per panicle as the criterion (more than 150 for *type A*, 100-150 for *type B*, and less than 100 for *type C*), so that, each group consisted of samples of similar plant type, but not neccessarily of similar yield level. Then, for each type, the patterns of the yield components determining the number of spikelets per unit area, namely, the number of spikelets per panicle and the number of panicles per unit area, were compared as to high and low yielding fields. In every type, the number of panicles per unit area was found to be a significant contributor to higher yield. The number of panicles per unit area needed for a yield level of 3-4 ton/ha was less than 100, 100-150, and more than 150, for *types A, B* and *C*, respectively. The contribution of the two components determining the number of panicles per unit area, namely, the number of panicles per hill and that of hills per unit area, to produce a greater number of panicles per unit area was also compared but no decisive conclusion was obtained.

Several of the farmers' varieties were planted at the experimental station and growth performance was compared. It was found that the number of spikelets per panicle was quite specific to a variety, and was affected by the surrounding conditions and the cultivation methods, to a much smaller extent than the number of panicles was. A greater number of panicles per unit area did not necessarily reduce the number of spikelets per panicle.

More panicles per unit area, which was found to be a direct cause of higher yield in every group of the plant type, can be obtained by fertilization, or dense planting, or both. However, as the field experiment on the effect of nitrogen application showed, the increase of panicle number by nitrogen application has a limit because of the death of young tillers during the vegetative lag phase. The varieties holding many spikelets

per panicle have an advantage, because fewer panicles are needed for higher yield. Therefore, the replacement of varieties with few spikelets per panicle by those with many spikelets per panicle will make it easier to secure a certain number of panicles per unit area. It was concluded that fertilization, and dense planting in some casses, will result in more panicles per unit area, more spikelets per unit area, and in higher yield ; and this can be made easier by using varieties with a greater number of spikelets per panicle.

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Appendix I Yield and Yield Components of 29 Farmers' Fields in Saraburi-Ayutthaya Area, 1968

Nos.	H/m²	P/H	P/m²	S/P	S/m²	F	G/m²*	T	Y/m²
					×100		×100		
SA-19	16.2	6.6	107	122	130	88.6	115	28.7	331
SA- 3	7.9	8.7	68	194	132	87.0	115	28.4	326
SA-16	13.6	7.8	107	132	141	80.3	113	27.3	310
SA-18	14.6	5.8	85	159	134	87.8	118	25.3	299
SA-27	12.0	6.6	79	157	124	89.8	111	26.6	295
SA-22	8.4	10.7	90	154	138	82.3	114	25.4	289
SA-11	10.0	9.8	98	122	120	65.6	79	36.6	289
SA- 8	13.1	8.4	110	110	121	86.3	104	26.9	281
SA- 5	14.8	10.1	150	86	128	87.3	112	24.6	276

SA-12	9.8	9.1	88	138	122	81.6	99	27.2	270
SA-28	16.8	6.0	100	92	99	86.3	80	32.9	262
SA-25	8.0	8.8	71	186	131	90.0	118	22.1	261
SA- 9	11.0	9.3	102	111	114	80.4	91	27.8	254
SA-15	17.5	6.0	105	104	110	91.2	100	25.2	252
SA-31	8.0	10.8	86	116	101	90.9	91	26.4	241
SA-23	7.5	7.7	58	181	105	82.3	86	27.7	239
SA-33	11.6	5.3	62	110	67	85.2	57	38.7	222
SA-34	9.5	7.8	74	128	95	73.2	70	31.8	221
SA-35	7.8	11.8	91	97	88	89.6	79	27.9	220
SA- 6	9.4	7.9	74	135	99	79.9	80	27.5	218
SA- 7	8.9	8.4	74	143	106	78.7	83	26.1	218
SA-32	8.5	7.0	60	154	92	86.7	80	26.4	210
SA-36	14.1	7.6	107	79	84	89.8	76	26.9	204
SA-14	16.4	6.2	101	104	105	68.7	72	25.9	186
SA-24	7.2	6.4	47	229	107	75.8	81	22.0	178
SA- 1	18.2	8.0	145	57	83	91.1	76	22.9	174
SA- 2	18.2	5.7	104	70	73	91.6	67	25.6	172
SA-20	12.8	6.5	82	92	76	85.9	66	25.8	169
SA-10	10.2	4.6	47	134	63	73.0	46	31.0	143
Average	11.79	7.77	88.7	127.4	106.6	83.7	89.0	27.5	241.8
s. d.	3.59	1.80	24.6	39.0	22.0	7.0	20.0	3.7	50.5
C. V. (%)	30.5	23.1	27.8	30.6	20.7	8.4	22.5	13.6	20.9

* Number of filled grain per sq. m.

Appendix II Yield and Yield Components of High Yield Plots in the North and Central of Thailand, 1968

N=14

Nos.	H/m^2	P/H	P/m^2	S/P	S/m^2 ×100	F	G/m^2 ×100	T	Y/m^2
HY-16	25.0	9.1	228	127	290	82.6	239	23.3	557
HY-13	18.5	6.4	118	134	159	87.7	139	29.1	405
HY- 5	11.0	9.9	109	147	161	90.1	145	26.2	380
HY-14	14.6	9.9	144	115	165	89.3	148	25.5	376
HY-12	18.6	6.4	118	156	185	87.7	162	23.2	375
HY- 3	6.3	13.0	82	177	145	85.7	124	28.6	355
HY-11	9.3	13.3	123	126	156	79.4	124	28.5	352
HY- 6	10.4	8.8	92	187	172	93.0	160	22.0	351
HY-15	12.2	14.7	179	77	138	92.5	128	27.0	345
HY- 9	7.4	13.7	101	115	116	86.8	101	34.2	344
HY- 1	25.0	4.5	112	117	131	92.0	120	28.5	343
HY-17	23.8	6.4	152	90	137	93.1	127	26.4	337
HY- 8	6.5	11.4	74	133	98	91.3	90	37.0	332
HY-10	10.5	8.9	94	114	106	87.7	93	33.3	311