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Rice culture in the Central Plain of Thailand

Subdivision of the Central Plain and the yield components survey of 1966

by

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Introduction

The "Central Plain" in this report denotes the vast alluvial plain spreading from Chai Nat* southwards to the Gulf of Thailand. This area corresponds approximately to the area defined by Pendleton as the "Bangkok Plain".**[1,2]

There are a number of reports on the physiographic, climatic and hydrologic conditions in general as well as the socio-economic status of the rice growing farmers of this plain.[1~16] Therefore, only three points of interest concerning rice culture and related conditions in the Central Plain as a whole are mentioned here.

First, some statistics on rice culture in the twenty Changwat (Provinces) in the Central Plain are shown in Table 1 and compared with those of the whole kingdom. The plain includes about two million hectares of paddy fields producing some three and half million metric tons of rough rice*** annually. This comprises roughly one third of the total production of Thailand. The average yield is 1.8 metric tons per hectare which is more or less the same as that of other southeast Asian countries. Almost all the varieties are non-glutinous. Roughly half of the two million hectares or so of paddy fields are directly sown fields, and more than two thirds of the total directly sown fields in the country occurs in the Central Plain.

Second, the Central Plain of Thailand is a paddy area in the delta which devel-

* The romanized spelling of the names of Changwat (Province) and Amphoe (District) followed *Governmenmt Gazette* (*Ratcha Kitcha Nubeksa*), No. 84-56, June 23, 1967, Bangkok.

** The "Central Region" or ภาคกลาง which often appears in the publications of the Thai government includes Changwat Tak and Uttaradit to the north, Phetchabun to the north-east, Trat to the south-east bordering on Cambodia and Prachuap Khiri Khan to the south-west.

*** Conversion rate of 'paddy' to 'rice' is 66 percent for Thailand according to the "Official figures revised by FAO Consultative Sub-Committee on the Economic Aspects of Rice," D. H. Grist, *Rice* (4th ed.; London : Longmans, Green and Co., Ltd., 1965).

Table 1 Some statistical data on rice area and production 1963

	holding area ×1,000ha	cultivated area ×1,000ha	harvested area ×1,000ha	paddy production ×1,000 metric tons	average yield* kg/ha
whole kingdom	7,295	6,601	6,354	10,029	1,578
total of 19 changwat in the Central Plain**	2,000	1,955	1,922	3,452	1,796

	directly sown area ×1,000ha	transplanted area ×1,000ha	non-glutinous rice area ×1,000ha	glutinous rice area ×1,000ha
whole kingdom	1,569	5,032	4,278	2,323
total of 19 changwat in the Central Plain	1,018	937	1,921	34

* Production divided by harvested area

** Ang Thong, Chachoengsao, Chai Nat, Kanchanaburi, Lop Buri, Nakhon Nayok, Nakhon Pathom, Nonthaburi, Pathum Thani, Phra Nakhon, Phra Nakhon Si Ayutthaya, Prachin Buri, Ratchaburi, Samut Prakan, Samut Songkhram, Saraburi, Sing Buri, Suphan Buri, and Thon Buri.

Data from *Census of Agriculture 1963*, the National Statistical Office, Bangkok

oped on the lower reaches of the great rivers in continental southeast Asia. These deltaic paddy areas, found from Viet Nam to Bengal, have the common factors summarized below.[2,3,11,14,17,18]

(a) The paddy soils are those formed on the deposits transported by the great rivers. Their sedimetation is conditioned by marine or brackish water regime at the lower reaches. Thus, the paddy soil are usually grouped into three broad categories, namely, the soils on fresh, brackish and marine water alluvia.

(b) The prevailing climate is characterized by distinct dry and rainy seasons which not only determine the basic pattern of the rice cultivation itself but also influence the soil formation.

Thus, the pattern of rice culture in these deltaic areas differs from that of archipelago southeast Asia — the Malay peninsula, Indonesia and the Philippines — and also from that of the mountainous areas of the continent — Laos, northern Thailand and Burma.

Thirdly, most of the reproductive growth phases of the main season rice in this region are actually spent under dry season conditions which commence in mid-October. The end of the rainy season is more distinct than its beginning and furthermore the maximum rainfall observed near the end of the rainy season does not necessarily accompany the maximum rainy days of maximum cloudiness.[9]

I Subdivision of the Central Plain

There are only a few reports on the regional differences within the Central Plain. Some of them are mimeographs written in Thai whose distribution is limited. Apart from these printed materials, some unprinted figures were also collected from various Thai government departments. Before proposing our subdivision, the facts and figures upon which the subdivision is based is briefly introduced.

Pendleton et al. and the Land Development Department publications were the main reference concerning the physiography and soil conditions. The following two maps are available.

(a) Thailand, scale 1/2,500,000, showing "Soil Associations." Data from Rice Department and Land Development Department. Printed by the Royal Thai Survey Department.

(b) Thailand, scale 1/2,500,000, showing "General Soil Conditions." Simplified from the General Soil Map of Thailand, scale 1/1,250,000 by F. R. Moormann and S. Rojanasoonthon. Printed by the Royal Thai Survey Department, 1967.

More details on the subject are found in S. Montrakul's compilation[3] of the works of Pendleton et al. and the soil survey reports of the Land Development. In the former, the data from the chemical and mechanical analysis of the soils collected

Table 2 Summary of chemical analysis of paddy soils in the Central Plain (Pendleton[1])

	organic carbon %	total nitrogen %	C/N	1% citric acid soluble K₂O %	1% citric acid soluble P_2O_5 %	1N HCl soluble P_2O_5%
no. of samples	45	45	45	20	38	27
mean	1.68	0.22	8.95	0.007	0.006	0.087
max.	6.07	0.43	14.26	0.013	0.017	0.25
min.	0.44	0.06	4.22	0.002	0.001	0.001
95% C.I.	2.09-1.27	0.24-0.20	9.71-8.19	0.008-0.005	0.007-0.004	0.113-0.061
C.V. (%)	12.1	4.2	4.2	9.0	13.6	14.6

	pH by		exchangeable bases, mg equivalent/100g				
	indicator	metre	Ca	Mg	K	Na	total
no. of samples	16	22	21	21	21	21	21
mean	4.7	4.98	10.0	5.6	0.6	0.9	17.0
max.	7.5	6.40	20.5	20.0	1.9	1.9	29.9
min.	3.9	3.43	2.1	0.5	0.1	0.1	7.0
95% C.I.	5.1-4.2	5.39-4.56	15.1-4.9	7.7-3.5	0.8-0.4	1.3-0.5	20.3-13.7
C.V. (%)	4.3	4.0	24.4	18.2	18.0	22.3	9.3

Data summarized from Table 3

Table 3 Some chemical properties of paddy soils in the Central Plain (Pendleton[1])

area	series no.	texture	C %	N %	C/N	1% citric acid soluble	
						K_2O %	P_2O_5 %
BP	642		1.01	0.10	9.75		
	787		6.07	0.65	9.27		0.017
	786		5.33	0.38	14.05		0.003
BK	646	Cl.	2.31	0.19	12.13		
	305	Cl.	0.445	0.079	5.63	0.012	0.001
	946	Cl.	0.95	0.13	7.31		0.004
MB	638	Cl.	1.08	0.11	9.61		
	785		0.67	0.098	6.88		tr.
BL	302	Cl.	0.906	0.151	6.00	0.007	0.001
	300	Cl.	1.196	0.164	7.29	0.013	0.007
	301	Si. Lm.	0.648	0.106	6.11	0.007	0.003
	944	Cl.	0.96	0.15	6.40		0.001
	945	Cl.	1.14	0.17	6.71		0.006
OK	221	Cl.	1.448	0.343	4.22	0.004	0.004
	222		2.451	0.233	10.52	0.009	0.003
	224		4.956	0.427	11.61	0.007	0.006
	782	Cl. Lm.	3.88	0.32	12.30		0.005
	783		3.79	0.32	11.85		0.006
	784	Cl.	1.12	0.19	5.81		0.001
CN	288	Cl.	1.452	0.162	8.96	0.007	0.007
	293		0.572	0.103	5.55	0.005	0.002
	296	Si. Lm.	0.683	0.109	6.27	0.005	0.007
	836	Si. Lm.	0.62	0.083	7.51		0.011
	838	Si. Lm.	0.97	0.12	7.87		0.010
	828	Cl.	2.06	0.20	10.54		0.013
	829	Si. Cl. Lm.	1.59	0.13	12.07		0.007
	286	Si. Lm.	0.807	0.098	8.24	0.005	0.001
	297	Cl.	0.695	0.116	5.99	0.007	0.003
AT	826		1.73	0.17	10.16		0.009
	844	Cl.	2.42	0.20	12.39		0.004
	613		0.97	0.099	9.82		
	827		1.48	0.16	9.10		0.010
	831	Si. Lm.	1.11	0.14	7.99		0.012
WT	493					0.007	0.005
	518	Si. Lm.					tr.
	276	Cl.	1.689	0.176	10.11	0.008	0.003
	278	Lm.	0.666	0.072	9.25	0.006	0.001
	282	Sa. Lm.	0.437	0.058	7.53	0.004	0.001
PB	621		1.05	0.18	5.80		
	622		1.71	0.15	11.73		
	623	Si. Lm.	0.82	0.10	8.23		
	624	Cl.	1.61	0.11	14.26		
	631	Cl.	1.80	0.18	10.25		
	632	Cl.	1.38	0.17	8.18		
	474	Si. Lm.	0.979	0.118	8.27	0.004	0.002
	478	Cl.	4.828	0.349	13.83	0.002	0.013
SW	209	Si. Lm.	1.186	0.128	9.26	0.005	0.013
	506	Cl. Lm.					
	497	Cl.				0.006	0.003

Table 3 (continued)

area	series no.	N HCl soluble P_2O_5 %	pH by indicator	pH by electrode	exchangeable bases me/100g dry soil Ca	Mg	K	Na	total
BP	642	0.25							
	787	0.22		3.43	2.6	8.8	1.9	4.0	17.2
	786	0.061		3.77	6.0	20.0	1.4	2.6	29.9
BK	646	0.23							
	305		4.2						
	946	0.031		4.96	10.7	8.1	0.3	0.2	19.3
MB	638	0.056							
	785	0.030		4.02	2.1	8.4	0.8	1.9	13.1
BL	302		4.3						
	300		4.9						
	301		4.9						
	944	tr.		5.44	16.2	11.9	0.5	0.9	29.6
	945	tr.		4.45	7.6	2.6	0.2	0.1	10.5
OK	221		4.1						
	222		4.6						
	224		3.9						
	782	0.10		3.69	5.6	0.5	0.6	0.8	7.4
	783	0.076		3.68	8.8	0.9	1.2	0.7	11.6
	784	0.040			4.3	12.3	1.4	1.7	19.6
CN	288		4.6						
	293		4.7						
	296		4.5						
	836	0.078		6.40	5.0	1.7	0.2	0.8	7.2
	838	0.17		5.42	7.4	2.3	0.6	0.8	11.1
	828	0.096		5.51	20.5	4.4	0.5	0.5	25.8
	829	0.038		4.96	8.5	2.5	0.1	0.2	11.3
	286		4.6						
	297		4.5						
AT	826	0.13		4.46	18.5	4.4	0.5	0.9	24.4
	844	0.059		4.86	15.4	5.4	0.4	0.4	21.6
	613	0.084							
	827	0.13		4.99	16.1	4.3	0.9	0.5	21.8
	831	0.13		5.40	10.3	4.7	0.3	0.7	16.0
WT	493			6.22	7.7	3.1	0.2	0.4	11.7
	518			5.96	6.0	3.0	0.1	0.5	7.0
	276		4.6						
	278		4.4						
	282		4.3						
PB	621	0.042							
	622	0.042							
	623	0.1							
	624	0.067							
	631	0.056							
	632	0.039							
	474			5.18					
	478			4.22					
SW	209		7.5						
	506			6.39	18.3	5.4	0.3	0.4	24.4
	497			6.39	13.0	3.0	0.2	0.2	16.5

from all over the country are tabulated though not fully evaluated. Included among the data, that concerning the surface soils of paddy fields in the Central Plain was selected and arranged according to location, as shown in Table 2 and Table 3. Of the SSR series of the latter, numbering sixty-one up to December 1967, those relating to the Central Plain were consulted.[4,19~29] However, these are for the most part report on areas consisting mainly of fresh water alluvial soils. Little information is available on the brackish and marine alluvial areas. The senior author received various information personally from W. van der Kevie and F. R. Moormann who are presently conducting soil surveys in these areas.

The Rice Department has been conducting the "Simple Fertilizer Trials on Rice in Farmers' Fields" (SFTRFF) since 1958, of which basic concept, method and some summarized results appeared in the reports.[30~39] In all these report, however, the whole country was divided into four broad regions, northern, northeastern, central and southern; and the results were averaged and discussed for each of these regions. In the present study, the results obtained at each experiment site in the Central Plain were abstracted by the authors from the original data* on which those summarized reports were based, and rearranged according to the twelve areas proposed in this report.[40] The experiment site is usually selected on the principle of one site for each Amphoe (District) whose main crop is rice. Frequently the experiment was repeated at the same or adjacent location in the same Amphoe over successive years. In such cases, the average result of more than two soil analyses for one Amphoe is represented as

Table 4 Summarized result by area of chemical analysis of paddy soils (SFTRFF[32])

area	no. of samples	95% confidence intervals			
		pH	O. M. %	available P ppm	exchangeable K ppm
BP	6	3.3-5.7	0.86-6.04	0.0-281.4	73-348
BK	30	4.6-5.2	2.30-3.18	7.7-27.4	157-264
MB	16	4.1-4.5	2.38-3.04	4.8- 8.9	70-107
BL	28	4.8-5.2	0.98-3.18	5.0- 9.4	66-83
OK	8	4.1-5.5	1.35-3.17	6.0-13.5	47-71
CN	20	5.1-5.5	1.59-2.21	9.8-18.2	49-67
AT	23	5.0-5.3	1.56-1.96	16.2-25.6	50-75
SB	9	4.8-5.5	0.97-1.92	0.5-11.5	28-73
WT	10	5.2-6.1	1.72-3.08	2.3-53.6	62-132
PB	12	5.0-5.3	0.76-1.70	1.8- 9.3	23-58
SW	14	6.0-7.0	1.90-2.20	15.2-31.6	47-114
LP	4	5.7-7.3	0.29-3.25	2.7-23.3	12-80

* By courtesy of Mr. Sujin Suthanee, Technical Division, Rice Department.

a single result for one Amphoe.[40] This data is further rearranged according to the twelve areas explained in Table 4. As for the fertilizer experiment itself, however, the several results obtained in one Amphoe were not averaged but instead were just rearranged according to their location as shown in Tables 5 and 6.

Figures for the area and production of paddy in each Amphoe in the Central Plain over the five years from 1962 to 1966 were obtained from the unpublished records kept in the Rice Department.* The average yield of paddy per unit area was calculated for each Amphoe from these figures and mapped. (Map 1)

Statistics for the directly sown and transplanted paddy area were obtained from

Table 5 Summary result of SFTRFF in the Central Plain

average of 118 locations during the period 1960–1965

	treatments**								
	check	N_2	P_4	N_2P_4	N_4P_4	N_6P_4	N_8P_4	$N_8P_4K_4$	
average yield*	344	384	402	428	433	444	453	451	kg/rai
	(100)	(112)	(117)	(124)	(126)	(129)	(132)	(131)	

*Analysis of variance

source of variation	d.f.	s. s.	m. s.	F.
treatment	7	1,201,926	171,704	6.03
error	936	26,646,204	28,468	
total	943	27,848,130		

LSD(0.05)=43kg/rai

**Treatments

	kg/rai		
	N	P_2O_5	K_2O
check	0	0	0
N_2	2	0	0
P_4	0	4	0
N_2P_4	2	4	0
N_4P_4	4	4	0
N_6P_4	6	4	0
N_8P_4	8	4	0
$N_8P_4K_4$	8	4	4

N as ammonium sulphate
P_2O_5 as super phosphate
K_2O as potassium chloride

* By courtesy of Mr. Nuj Bunyaratphan, Statistical Section, Rice Department.

the "Census of Agriculture, 1963" conducted by the National Statistics Office. But they are expressed on Changwat basis only. Therefore, the figures per Amphoe had to be abstracted again from the original data kept in the Statistics Office. (See Map 2.) Reference was also made to data from soil analyses obtained by the staff of the Technical Division of the Rice Department.[41,42]

The report on the paddy soils in Thailand by K. Kawaguchi and K. Kyuma of Kyoto University, who have been working on this subject since 1963, will soon be published. Although no data was cited directly from their work, the authors are grateful for their comments and suggestions.

On the basis of these collected materials and the authors' own observation, a provisional subdivision of the Central Plain into the twelve areas is proposed here for the better understanding of the rice culture in this region. They are :
(1) Bang Pakong Area (BP) (2) Bangkok Area (BK) (3) Min Buri Area (MB)
(4) Bang Len Area (BL) (5) Ongkharak Area (OK) (6) Chai Nat Area (CN)
(7) Ang Thong Area (AT) (8) Saraburi Area (SB) (9) Western Area (WT)
(10) Prachin Buri Area (PB) (11) South-western Area (SW) (12) Lop Buri Area (LB)

Map 3 shows the provisional boundaries of these twelve areas.

1. The Bang Pakong Area :

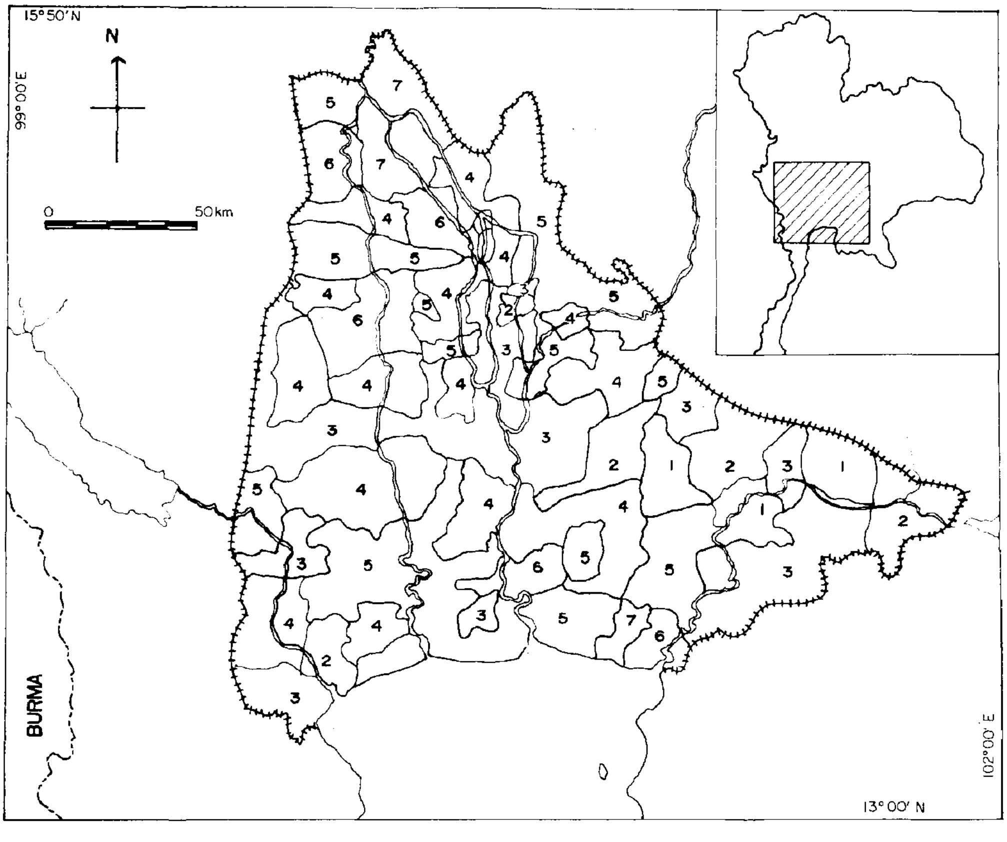
This area occupies the south-eastern corner of the Central Plain or the western

Table 6 Summarized rusult of SFTRFF in the Central Plain average of different areas during the period 1960-1965

area	no. of trials	check	N_2	P_4	N_2P_4	N_4P_4	N_6P_4	N_8P_4	$N_8P_4K_4$	LSD (0.05) for the comparison in the same area
				kg/rai						
BP	3	484	540	612	632	672	710	772	777	58
BK	22	283	294	323	346	339	346	334	341	62
MB	10	375	394	432	449	467	454	454	484	68
BL	21	260	297	301	328	347	354	365	384	78
OK	3	320	350	411	352	447	409	464	468	132
CN	13	403	480	439	475	480	500	496	483	154
AT	15	509	572	610	639	628	648	656	646	95
SB	6	377	430	440	475	509	508	535	514	109
WT	6	325	339	354	420	431	409	448	423	86
PB	7	242	284	305	320	349	385	367	379	250
SW	8	338	384	430	413	368	438	446	447	122
LB	4	320	385	355	483	410	390	443	312	137
mean		344	384	402	428	433	444	453	451	
LSD (0.05) for the comparison of the same treatment		116	130	129	129	128	132	128	127	

portion of the river mouth of the Prachin (or Bang Pakong) River, and consists mainly of Amphoe Bang Pakong of Changwat Chachoengsao and Amphoe Bang Bo of Changwat Samut Prakan. The whole area is on the marine alluvial plain but only limited damage from salinity is sustained because the water flow is effectively regulated by the embankment parallel to the coastline and its lockgates. The average yield of this area is assessed by the Rice Department at 350-450 kg/rai* the best in the Central Plain together with the Chai Nat Area. Transplanting is the usual method employed in this area. In Amphoe Bang Pakong, harvesting is completed by mid-December, much earlier than the nearby Amphoe. In Amphoe Bang Bo, by contrast, it may continue into February.

The surface soils in this area, particularly in Amphoe Bang Bo, often show the extremely low pH of 3.5 or even lower, as demonstrated by Pendleton and SFTRFF.



1 Less than 149 kg　2 150–199 kg　3 200–249 kg　4 250–299 kg
5 300–349 kg　6 350–399 kg　7 400–450 kg/rai　(1 rai=1,600m²)

Map 1 Average yield of paddy rice by Amphoe in the Central Plain
(Average of 1962–1966)
Data from Rice Department

* 1 rai=0.16 ha or 1,600 sq.m.

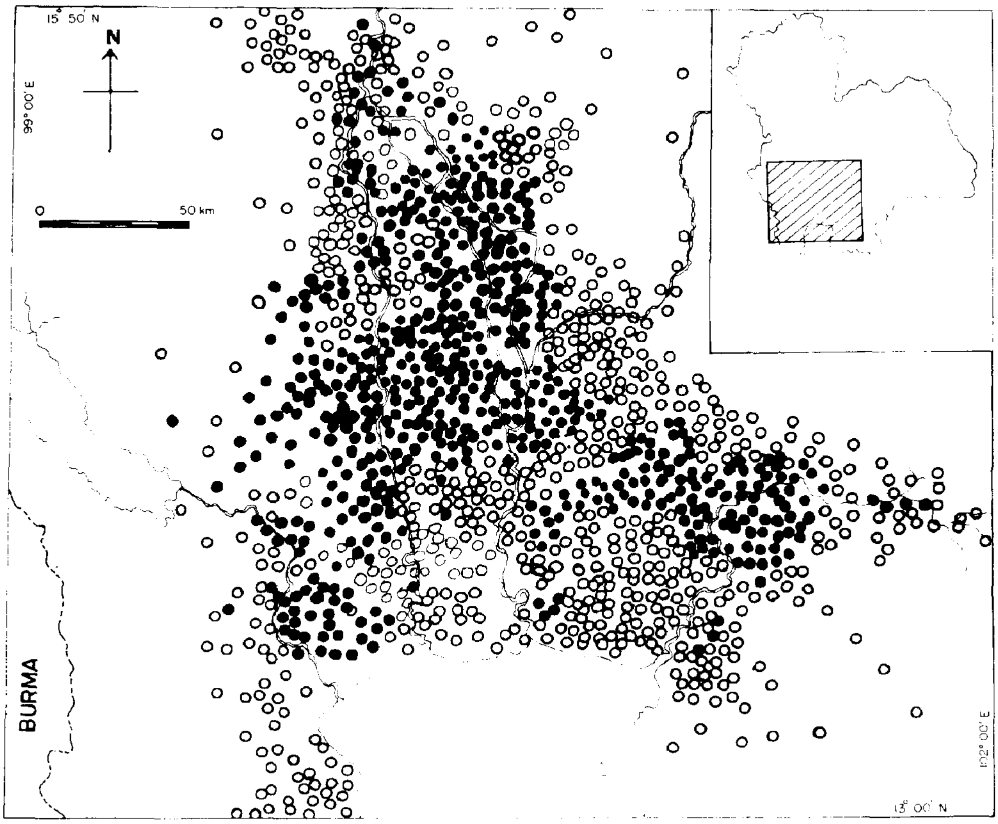
These very low pH, however, seem to be caused by some rapidly dissolving acid substances in the air-dry soil. Therefore, the pH of these soils is likely to be higher when measured several hours after making a water suspension of air-dry soil. The soils in the fields during the rice growing season may have a still higher pH both for the above reason and also because of the strong reduction caused by the submergence.

The available phosphorus content of the soils in this area is the highest in the whole Central Plain. Analyses of the exchangeable bases show the characteristics of the marine sediments, i.e., lower Ca and higher Mg, K, and Na.

Only three fertilizer experiments were reported on by SFTRFF in this area. One of them showed a yield of 1,232 kg/rai (7,700 kg/ha) in the $N_8P_4K_4$ plot, the highest in the Central Plain.

2. The Bangkok Area

This area occupies most of the marine alluvium except the south-western and south-eastern corners of the Central Plain. The northern tip of this area is Changwat Pathum Thani along the main stream of the Chao Phraya River, and from there the



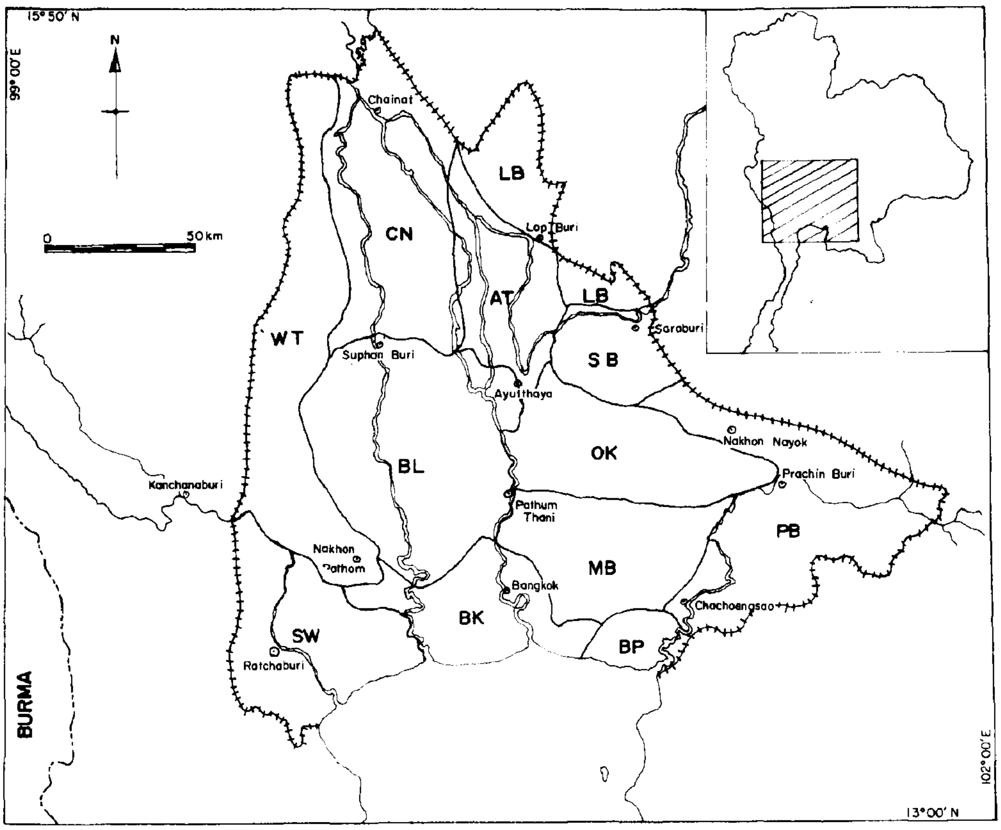
o Transplanted field ● Directly Sown field

One circle represents 10,000 rai or 1,600 ha.

Map 2 Distribution of transplanted and directly sown paddy fields in the Central Plain (Based on Agriculture Census, 1963) boundary between this area and the brackish water alluvial plain extends downwards to the south-west and south-east. This area covers the larger part of Changwat Phra Nakhon, Nonthaburi, Thon Buri, Samut Sakhon and the southern parts of Changwat Nakhon Pathom and Samut Prakan.

The rice plant in some places of the coastal portion of this area is directly influenced by salinity. The average yield is 300-400 kg/rai, the second highest in the Central Plain; roughly speaking, the yield is higher in the eastern part and lower in the western part. The transplanting method predominates in both parts. Harvesting takes place latest in the plain, starting in the middle of December in the northern part and ending in February in the southern coastal portion.

The pH of the paddy soils usually falls within the range of 5.0 to 5.5 with the exception of the soils near the coast which have the very low pH for those reasons mentioned previously, and the soils of lower pH in the northeastern sector, Amphoe Bang Khen and Bang Kapi, which is adjacent to the strongly acid brackish water alluvium. Organic matter content usually amounts to two to three percent, but the soils near the coast contain more. Phosphorus contents seem lower in the north and higher in the south. The results of SFTRFF clearly show the greater effect of



Map 3 Twelve proposed areas in the Central Plain

phosphorus than nitrogen. The Bang Khen Rice Experiment Station is located in the middle of this area while the Rangsit Experiment Station is about 30 km to the northeast. The soil at the latter stations is strongly acid clay of brackish water alluvial origin. Various fertilizer experiments conducted at these two stations have well established that at the Bang Khen Station, the single effect of phosphorus is significant while at the Rangsit Station the fertilizer application is effective only when both nitrogen and phosphorus are applied. This agrees with the SFTRFF results. According to Wisit's experiment on the ammonium release by different paddy soils under submergence[42], the Bang Pakong and Bang Khen soils release more ammonia immediately after submergence although the initial content of ammonium nitrogen in these soils is not high.

3. The Min Buri Area

This area is located between the Chao Phraya River to the west and the Prachin River to the east, bordering to the south on the marine alluvial plain of the BK and BP areas and to the north on the more acid OK area. The whole area is on the brackish water alluvium. The average yield is 250-350 kg/rai, fairly good for the Central Plain. The south-eastern sector produces a slightly better yield. Most of the area consists of transplanted fields except Amphoe Bang Nam Prieo in the northeast where direct sowing predominates. The 95% confidence intervals from the SFTRFF data are 4.1-4.5 for pH, 2.38-3.04% for organic matter percentage, and 4.8-8.9 ppm for available phosphorus by Bray No. 2 solution. In other words, the soils are strongly acid and contain a relatively large amount of organic matter (second highest to the coastal area), and medium to low available phosphorus. The SFTRFF shows that 60-70 kg/rai increase in yield is common and the effect of phosphorus alone is greater than that of nitrogen.

4. The Bang Len Area

The Bang Len area is on the vast brackish water alluvial plain on the west bank of the Chao Phraya River, extending westwards beyond the Suphan River. Its northern boundary roughly follows the line connecting Suphan Buri and Pa Mok of Changwat Ayutthaya, which also constitutes the boundary between fresh and brackish water alluvia. The south borders on the BK area. It includes Changwat Nakhon Pathom except the two Amphoe of Sam Phran and Kamphaeng Saen, the south-eastern part of Changwat Suphan Buri, and the parts of Changwat Ayutthaya and Pathum Thani, west of the Chao Phraya River.

The average yield is 200-300 kg/rai, and is higher in the southern than in the northern sector. Direct sowing is practised over about two thirds of the area; the transplanted fields are distributed between the Chao Phraya and the Suphan Rivers in the south of Changwat Ayutthaya.

The soil pH is usually around 5.0 but some soils taken from the paddy fields closer to the Chao Phraya River show lower values. The organic matter and available phosphorus content of the soils in this area are almost the same as those from the MB area—both areas are on the brackish water alluvial plain. However, the soils from the transplanted fields in Changwat Pathum Thani contain somewhat less organic matter.

SFTRFF tests carried out in this area indicate that the area shows rather different response to fertilizers than do other marine or brackish water alluvial areas. The effect of either nitrogen alone, N_2 plot, or phosphorus, P_4 plot, is about 40 kg/rai only and the 70 kg/rai increase in yield could not be attained until the application of both elements, N_2P_4 plot.

5. The Ongkharak Area

Here a strongly acid cat clay has developed to the maximum possible extent on the brackish water alluvial plain. It spreads between the Chao Phraya and Prachin Rivers, bordering very distinctly to the north on the terraces of the Pasak River and to the south on the MB area. It covers some parts of Changwat Pathum Thani, Ayutthaya, and Nakhon Nayok.

This area and the northern part of the BL area form the most recent reclaimed paddy field in the Central Plain. Absentee landlordism is reportedly most common here. The average yield is 100-250 kg/rai, the poorest in the Central Plain. Direct sowing methods are generally employed. The low yield in this area probably results from such agronomical reasons as poor soil conditions and direct sowing methods, etc. and also from socio-economical reasons such as the high percentage of tenancy and large area per family.

The few soil analyses made in this area indicate that they are not inferior to other brackish water alluvial areas. Wisit shows that one soil sampled at Wang Noi, Changwat Ayutthaya in this area did not release ammonia until more than 10 days after submergence, but after 80 days the amount of ammonia released was the highest among six Central Plain soils examined.[42] More information is needed to explain fully these poor soil conditions in the OK area. Factors regulating decomposition of organic matter could be a key consideration.

6. The Chai Nat Area

The riverine alluvial plain of the Chao Phraya River and its distributaries is divided into two areas: the CN area and the AT area. The CN area covers the upper and western part of this fresh water alluvial plain. It consists of Changwat Chai Nat, the western halves of Changwat Sing Buri and Ang Thong, and the north-eastern part of Changwat Suphan Buri.

The common pattern of the riverine alluvial plain between Chai Nat and Pa Mok, about 15 km north of Ayutthaya, is that large and small water channels, includ-

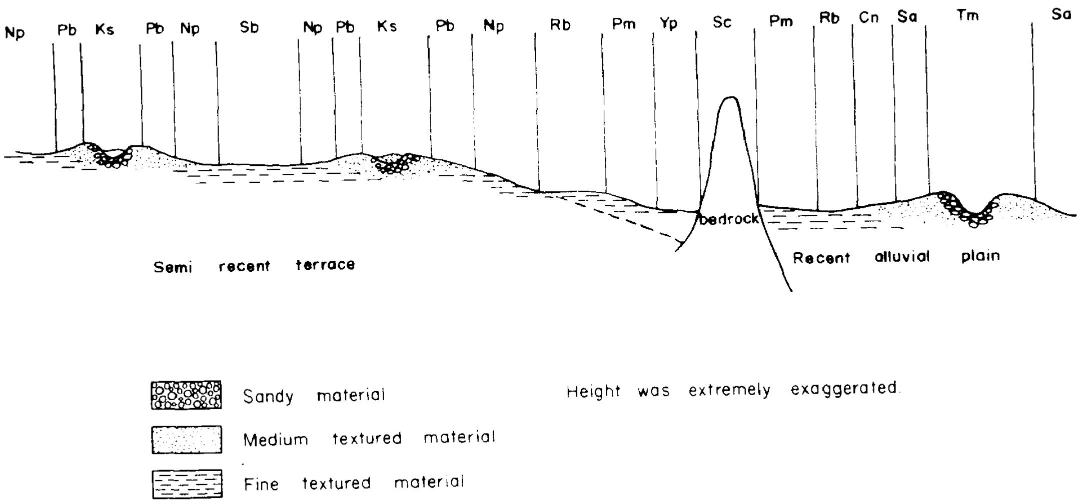


Fig. 1 Schematic E-W cross section through the Boromdhart irrigation tract, showing the relation between soil series and geomorphology

(By courtesy of Mr. W. Van der Kevie, copied from the Soil Survey Report No. 39 of Land Development Department, Chao Phraya Irrigation Project III, "Report on the Soil Survey in the Boromdhart Tract," Aug. 1965, Bangkok.)

ing those that have been silted up, have natural levees and river basins. The soils on the levees are youngest and coarsest in texture. And the higher or the older the channels are, the more leached out the soils along them become. (See Fig. 1.)

This natural levees and river basin pattern is common to a number of sites along the older and newer streams in this area, with corresponding soil differences. Comparing this area as a whole with the AT area, the CN area is higher in elevation and particularly the western part of the CN area seems to have developed on older deposits.

The average yield is 300-450 kg/rai, equalling the BP area as the best in the Central Plain. The best yield is attained in the northern Amphoe Manorm, Muang and Sanphaya of Changwat Chai Nat, followed by the area between the Suphan and the Noi Rivers where the yield is better than the area along the main stream of the Chao Phraya River. Direct sowing exceeds transplanting. Their distribution is not well-defined, probably because the rice is transplanted on or near the river levee where the water is shallow and directly sown in river basins having a deeper water level.

In contrast with marine or brackish water alluvial areas, the soil organic matter seldom exceeds two per cent while the available phosphorus is usually above 10 ppm. The results of the SFTRFF coincide well with those of soil analysis : the effects of phosphorus alone, P_4 plot, and nitrogen alone, N_2 plot, are ca. 40 kg and 80 kg per rai respectively, and the increase by both elements, N_2P_4 plot, does not exceed ca. 80 kg/rai.

7. The Ang Thong Area

This is the deep water area along the main stream of the Chao Phraya River. To the north it reaches the Lop Buri River and to Amphoe Pa Mok, Changwat Ayutthaya in the south, bordering to the west on the CN area roughly along the Noi River and to the east rather distinctly on the LB or SB area. The area consists of the eastern parts of Changwat Sing Buri and Ang Thong, the north-eastern part of Changwat Ayutthaya, and Amphoe Tha Wung of Changwat Lop Buri.

The whole area is on the recent river alluvium of the Chao Phraya River and its distributaries, and most part of the area is flooded to a depth of 2-5 metres by the end of the rainy season. So-called "floating rice" is normally directly sown. The average yield is 150-300 kg/rai and the northeastern part of Changwat Ayutthaya is a particularly low-yield area. The average yield of the SFTRFF check plots of 15 sites in this area is 509 kg/rai. This figure is a great deal higher than the average yield and might be the result either of inadequate selection of the experimetal sites or the fact that in the fertilizer trials all the rice was transplanted although in the AT area direct sowing is common practice, or both. SFTRFF soil analyses also show that the soils here are as good as, or better than, those in the CN area.

8. The Saraburi Area

The main bodies in this area are those soils developed on the lower terraces of the Pasak River, one of the tributaries of the Chao Phraya River, which enters the Central Plain from the eastern highlands. The area covers Changwat Saraburi and the eastern part of Changwat Ayutthaya. The water level of the Pasak River is quite low even during the rainy season, and the river levees show only poor development. It flows westwards from the town of Saraburi beyond Tha Rua and turns south joining the Chao Phraya River near Ayutthaya.

The average yield is 250-350 kg/rai, moderate for the Central Plain. All the paddy fields are transplanted and enclosed within high dikes. Termite mounds abound. Rice cultivation seems to be the most intensive in the Central Plain. Harvesting continues for one and a half months from the middle of November. Organic matter and available phosphorus content is low. According to the soil series reports of the Land Development Department, the texture of the surface soils of the Manorom and Hin Kong series are coarser than "clay loam." But as seen in other reports of soil analysis referred to in this paper, most of the paddy soils in this area have "clay" to "clay loam" texture.

9. The Western Area

This is the western marginal area of the Central Plain covering the western part of Changwat Chai Nat, Suphan Buri and Nakhon Pathom. Rice cultivation here often suffers from drought. The average yield is 200–350 kg/rai, better in the northern half. Transplanting approximately equals direct sowing, and the former method is mainly employed in the northern half. Rice directly sown in the southern half is never the floating variety, and is even shorter than the usual transplanted rice. The number of soil samples analysed is limited. However "Kamphaeng Saen Loam"*, which occupies the southern part of the area, at least seems to be potentially rich in plant nutrients. SFTRFF results show that singly phosphorus or nitrogen are not effective, and that both seem to be needed to obtain significant increase in yield.

10. The Prachin Buri Area

This is the part of the Central Plain which protrudes to the east along the Prachin River. The soils along the river have a heavy texture but those on the higher terraces close to the foot of the northern and south-eastern hills are lighter. The average is a very poor 100–250 kg/rai, in contrast to the nearby high-yield BP and MB areas for example. The yield may differ very much from place to place especially in this area. The heavier texture soils on the river basin of the Prachin River may produce better rice. About half of the area is transplanted and the other half is directly sown. The latter method is practised mainly in Amphoe Ban Sang, Changwat Prachin Buri, bordering on the OK area. The broadcast rice in this area is as short as the transplanted variety. Results of soil analysis also differ from place to place. It seems that the soils along the hills contain very little organic matter and available phosphorus.

11. The South-Western Area

This area lies in the south-western corner of the Central Plain, and includes the Mae Klong River, Changwat Samut Songkhram and some parts of Changwat Kanchanaburi, Nakhon Pathom, Ratchaburi and Samut Sakhon. The average yield is 150–300 kg/rai; the poorest yield within the area is seen in Amphoe Damnoen Saduak on the east bank of the lower Mae Klong River. The proportion of broadcasting to transplanting fields is about one to one. The former are mainly distributed on the eastern side of the Mae Klong River while the latter occur on the opposite side.

This area can be divided into two sub-areas along the Mae Klong River. The eastern sub-area, on the marine alluvium, has a lower average yield and is broadcasting area. By contrast, the western side is on the river alluvium, has higher average yield and is a transplanting area. According to the SFTRFF the single effect of nitrogen, N_2 plot, is greater than that of phosphorus, P_4 plot.

12. The Lop Buri Area

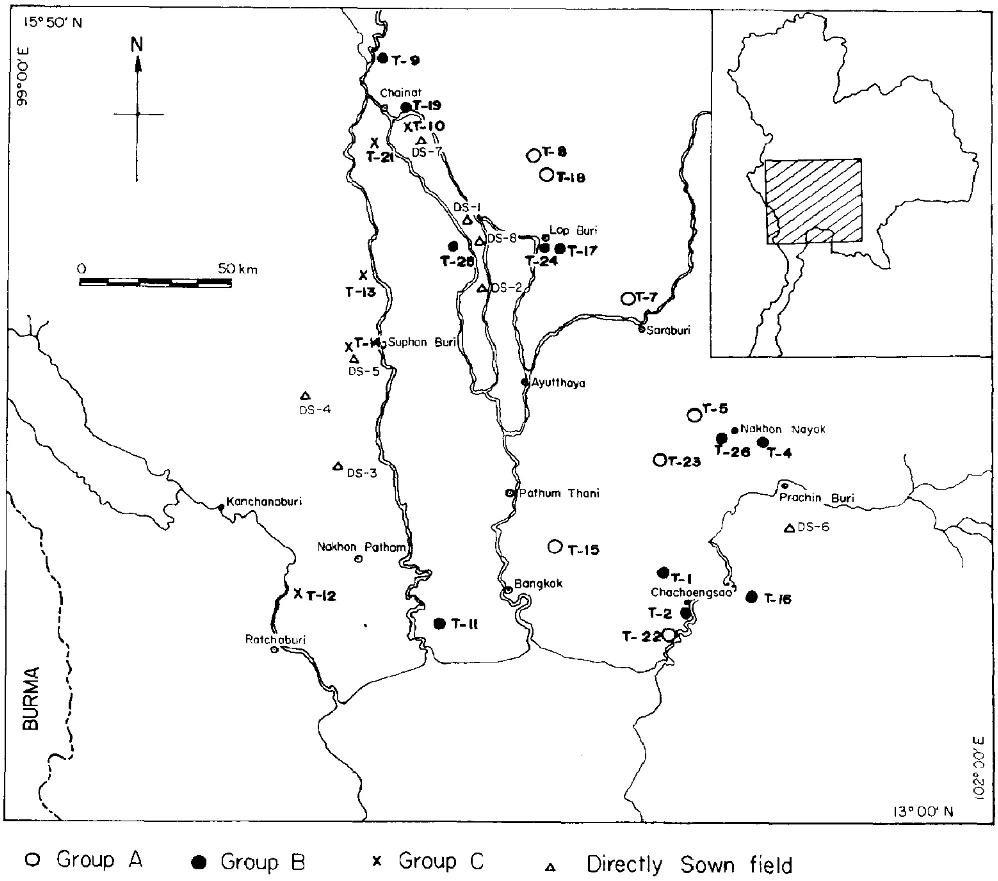
This is the "Grumusol" area of the north-eastern part of the Central Plain, and includes Amphoe Muang and Ban Mi of Changwat Lop Buri. This neutral to slightly

* Defined by Pendleton. See refereces (1), (2) and (3).

alkaline dark coloured body derives from marl and limestone hills. The soil is extremely sticky as montmorillonitic clay predominates. The average yield is 250-350 kg/rai. Almost all the fields are transplanted. The soils usually contain not less than 10 ppm of available phosphorus by Bray No. 2 solution. Wisit reports that about 25% of the total phosphorus in the soil existed in the form of calcium phosphate.[42]

II Yield components survey of 1966

As seen in the previous pages, it is possible to obtain information about the environmental conditions of rice grown in the Central Plain. But there are almost no reports on the rice plant itself except some statistics concerning average yield and the transplanted and directly sown areas by Amphoe. In 1965 Watabe made a simple investigation of the yield and yield components of the rice plant samples harvested from twelve different places in Amphoe Manorom, Changwat Chai Nat.[43] This report may be the only one of its kind for the Central Plain. In November and December



Map 4 Distribution of sampling sites for yield component survey 1966 in the Central Plain

of 1966, the authors surveyed twenty-three transplant and eight directly sown fields in the Central Plain. Results are reported here.

Sampling sites :

As shown in Map 4, the selection of the sites was much influenced by their accessibility. Distribution was not uniform. The twenty-three transplanted sites and eight directly sown fields chosen do not represent the ratio of these two kinds of paddy field in the plain. Many of the transplant sampling sites were chosen in the eastern marginal area of the Central Plain partly because of the distribution of the transplanted fields themselves and partly because the allweather roads usually pass through the higher marginal zone. None of the eight samples taken from the directly sown fields came from the deep water floating rice area. Some were sampled from relatively shallow directly sown fields in the peripheral part, for example Prachin Buri and Suphan Buri. Others came from the directly sown fields close to the river levee, along which the road usually passes.

Sampling method :

In the case of the transplanted fields, the number of panicles of 100 to 150 hills was counted along the diagonal line of the field. The mean number of panicles per hill was calculated. Ten sample hills were then harvested so as to make the average number of panicles of the ten hills accord with the calculated mean. For example, when the mean was calculated as 13.3 panicles/hill, seven hills with 13 panicles and 3 hills with 14 panicles were sampled. At each site, the planting density was measured by counting three times the number of hills in one square metre frame. The number of panicles per unit area was calculated by multiplying the average number of hills per square metre by the number of panicles per hill. In the case of the directly sown

Table 7 Summary result of yield and yield components survey in 1966

	95% confidence intervals				
	weight of grain		number of panicles		number of hills
	gr/m^2	gr/hill	/m^2	/hill	/m^2
transplanted fields (23 sites)	193–273	14.4–22.2	93–123	7.0–9.4	11.5–17.3
directly sown fields (8 sites)	105–201	——	90–118	——	——

	number of spikelets /panicle	number of spikelets /hill	fertile grain %	1,000 grain weight gr	plant height cm	total dry weight gr/m^2	total dry weight gr/hill	panicle/straw ratio
T.	86–122	673–1,041	74.4–80.8	26.3–29.1	136–164	636–876	47.4–75.4	0.52–0.65
D.	69–95	——	70.0–88.8	26.3–30.3	133–165	323–657	——	0.52–0.78

fields, a one square metre frame was placed in the middle of the field. All the plants inside the frame were air-dried and the yield components counted or weighed.

Summary of the results:

Table 7 shows the averages and their 95% confidence intervals of the yield and its components of the transplanted and directly sown fields. The average yields of this survey and those of other sources are compared in Table 8. The average yields of the present survey exceed those of the others but the differences are small enough to be explained by the fact that the sampling sites in this survey were chosen only from those fields that appeared to be undamaged. The comparison of the yield components of the twelve samples from the northern part of the Central Plain with

Table 8 Comparison of average paddy yields of Thailand from various sources

source	average yield gr/m^2	area
FUKUI*	213.3	Average of 31 samples in the Central Plain of Thailand, 1966
WATABE**	153.1	Average of 12 samples in Changwat Chai Nat, 1963
Agriculture Census, 1963***		Production divided by area harvested on glutinous transplanted rice
	211.4	in Changwat Chai Nat
	165.7	in whole kingdom
Agricultural Statistics of Thailand, 1965****		Production divided by area planted in the "Central Region"
	181.0	1963/64
	165.4	1964/65
	163.3	1965/66
FAO Production Yearbook, 1965	158.1	Thailand, 1963
Simple Fertilizer Trials on Rice in Farmers' Fields in Thailand*****		Average of control plot of 35 different places in the "Central Region"
	185.0	1958/59
	177.4	of 53 places 1959/60
	173.5	of 31 places 1960/61

* unpublished data
** T. WATABE, *Nettai Nogyo*,, Vol. 8, No. 2, pp. 76–80, 1965
*** National Statistical Office, Bangkok
**** Ministry of Agriculture, Bangkok
***** Technical Division, Department of Rice, Ministry of Agriculture, Bangkok (mimeo.)

the twenty-three samples of the transplanted fields of this study is shown in Table 9. The average yield of the former is 66% of that of the latter. The lower average of the former is attributed to the fewer number of panicles per unit area, which is the result of both fewer number of panicles per unit area and fewer number of panicles per hill. However, the average number of spikelets per panicle is much greater in Watabe's report than in this study i.e., 183 and 104 spikelets per panicle, respectively. The differences between the two studies may be attributed to the different area surveyed and the different methods of counting.

Correlation study between yield and its components:

Table 10 shows the correlation coefficients between the yield and its components

Table 9 Comparison of the results of the yield components surveys by WATABE and FUKUI

	wt. of grain gr/m²	no. of panicles /m²	no. of panicles /hill	no. of hills /m²	no. of spikelets /panicle	fertile grain %	1,000 grain weight gr	surveyed area
By WATABE*	153	79	7.5	12.1	183	80.4	30.0	Average of 12 transplanted fields in Changwat Chai Nat
By FUKUI**	233	108	8.2	14.4	104	77.6	27.7	Average of 23 transplanted fields in the Central Plain

* T. WATABE, *Nettai Nogyo*, Vol. 8, No. 2, pp. 76–80, 1965

** unpublished data

Table 10 Correlation coefficients between yield components (23 transplanted fields in the Central Plain) n=23

yield—no. panicles/m²	0.575*
yield—no. panicles/hill	0.047
yield—no. hills/m²	0.271
no. panicles/hill—no. hills/m²	−0.569*
yield—no. spikelets/panicle	0.423**
no. spikelets/panicle—no. panicle/m²	0.261
no. spikelets/panicle—no. panicle/hill	0.012
no. spikelets/panicle—no. hills/m²	0.250
yield—percent fertile grain	0.236
yield—1,000 grain weight	0.173
yield—total dry weight/m²	0.854*
yield—panicle/straw ratio	0.175
yield—plant height	0.389

* Significant at 1 percent level

** Significant at 5 percent level

as well as those between the components themselves, and is based on the results of twenty-three observations from the transplant fields. There is a highly significant correlation between the yield and the number of panicles per square metre while there is no significant correlation between the yield and either the number of panicles per hill or the number of hills per square metre, which are the factors that determine the number of panicles per square metre. And between these two factors the negative correlation was found to be significant at 5% level. These correlations appear to suggest that the panicle number per unit area is maintained by the higher planting density where more panicles per hill are not to be expected because of the low fertility or the varietal factors etc.; but, by contrast, where the soil conditions and the varietal characteristics favour a greater number of panicles per hill, the number of panicles per unit area is maintained by such manner rather than the high planting density.

It should be noted that strict attention should be paid to the interpretation of the results of field survey. For instance, the results given above cannot answer such questions as whether the yield will be increased by increasing or decreasing the planting density under given conditions at any given site. They merely state that fact that where a higher yield is obtained, more panicles per unit area are found, or the denser the planting, the less panicles per hill.

Significant correlation between the yield and the number of spikelets per panicle was also noticed. But no significant correlation was found between the number of spikelets per panicle, and either the number of panicles per unit area, per hill or the planting density. Field experiments conducted at certain sites using certain variety, the number of spikelets per panicle usually decreases when the number of panicles is increased by the denser population or the increased application of fertilizers. The lack of correlation between the number of spikelets per panicle and the number of panicles can be explained as follows: the initiation of the small and weak tillers at the later stage of the vegetative growth phase is suppressed either by the low soil fertility or by the varietal characteristics of the rice plants grown in the Central Plain where the application of any kind of fertilizer is still uncommon. Thus the number of spikelets seems to depend on the varietal factors rather than the number of panicles.

No significant correlation was found between the yield and the other components.

Classification of the plant type:

The yield and its components of all 31 samples are tabulated in Table 11. As for the transplanted fields, the greatest variation is found in the density of planting and the total dry matter or grain weight per hill. If one visits the various sampling sites at harvest-time the most striking difference one observes is the intervals between the hills and the vigor of the plant.

Fig. 2 was drawn by plotting the twenty-three transplanted fields on a graph with the density of planting on the horizontal and the total dry weight per hill on the

Table 11 Yield and yield components of the rice plant samples from the 31 different places in the Central Plain of Thailand, 1966

group	location number	weight of grain		number of panicles		number of hills/m^2
		gr/m^2	gr/hill	/m^2	/hill	
A	T- 5*	145	23.3	68	11.0	6.2
A	T- 7	228	23.8	86	9.0	9.6
A	T- 8	325	40.1	70	8.7	8.1
A	T-15	513	34.9	157	10.7	14.7
A	T-18	334	30.4	107	9.7	11.0
A	T-22	260	30.2	152	17.7	8.6
A	T-23	245	20.9	105	9.0	11.7
B	T- 1	169	14.3	74	6.3	11.8
B	T- 2	156	18.3	96	11.3	8.5
B	T- 4	99	8.8	71	6.3	11.2
B	T- 9	173	12.0	101	7.0	14.4
B	T-11	148	13.2	123	11.0	11.2
B	T-16	127	10.6	76	6.3	12.0
B	T-17	265	19.9	116	8.7	13.3
B	T-19	287	23.3	90	7.3	12.3
B	T-24	206	18.6	81	7.3	11.1
B	T-25	194	12.9	86	5.7	15.0
B	T-26	192	15.6	87	7.1	12.3
C	T-10	237	9.6	124	5.0	24.7
C	T-12	309	12.6	154	6.3	24.5
C	T-13	185	7.7	144	6.0	24.0
C	T-14	384	12.0	192	6.0	32.0
C	T-21	186	7.9	125	5.3	23.5
	DS- 1**	230	—	57	—	—
	DS- 2	137	—	106	—	—
	DS- 3	146	—	103	—	—
	DS- 4	96	—	111	—	—
	DS- 5	108	—	155	—	—
	DS- 6	121	—	62	—	—
	DS- 7	135	—	38	—	—
	DS- 8	249	—	197	—	—

T* and DS** of location number mean transplanted and directly sown field, respectively.

Table 11 (continued 1)

location number	number of spikelets /panicle	number of spikelets /hill	fertile grain %	1,000 grain weight gr	plant height cm
T- 5	88	968	81.8	29.5	163
T- 7	114	1,026	83.6	27.9	191
T- 8	244	2,123	79.5	23.8	187
T-15	129	1,380	85.0	29.7	153
T-18	117	1,135	87.4	30.7	208
T-22	86	1,522	77.2	25.7	154
T-23	90	810	90.1	28.5	200
T- 1	170	1,071	64.3	20.9	142
T- 2	76	859	76.2	28.1	143
T- 4	75	473	70.6	26.4	138
T- 9	40	280	85.5	35.1	144
T-11	75	825	69.0	23.2	103
T-16	83	523	77.8	26.2	115
T-17	114	992	72.4	27.7	134
T-19	130	949	78.7	31.3	161
T-24	130	949	72.6	27.0	152
T-25	96	547	84.1	27.9	139
T-26	105	746	82.5	25.3	142
T-10	73	365	80.3	33.1	137
T-12	136	857	61.3	23.9	148
T-13	58	348	75.2	29.4	123
T-14	90	540	76.6	28.9	141
T-21	79	419	72.9	26.0	139
DS- 1	165	—	87.6	27.9	145***
DS- 2	51	—	82.6	30.8	100
DS- 3	53	—	89.6	30.1	125
DS- 4	46	—	76.9	24.3	100
DS- 5	52	—	53.5	25.4	110
DS -6	83	—	80.8	29.2	120
DS- 7	152	—	84.0	27.8	260
DS- 8	52	—	79.8	30.7	230

*** Approximate height for the samples from directly sown fields

Table 11 (continued 2)

location number	total dry weight		panicle /straw ratio	date of harvest	fertilizer applied**** kg/ha
	gr/m^2	gr/hill			
T- 5	585	94.3	0.40	Nov. 29	no
T- 7	856	89.2	0.41	Nov. 30	18
T- 8	944	116.6	0.75	Nov. 30	no
T-15	1,404	95.5	0.49	Dec. 28	78
T-18	1,321	120.1	0.45	Dec. 29	no
T-22	1,038	120.7	0.45	Nov. 18	yes
T-23	1,169	99.9	0.31	Nov. 29	no
T- 1	510	43.2	0.66	Nov. 23	90
T- 2	556	65.4	0.48	Nov. 27	no
T- 4	395	35.3	0.47	Nov. 29	yes
T- 9	514	35.7	0.68	Dec. 1	no
T-11	581	51.9	0.46	Dec. 5	36
T-16	446	37.2	0.50	Dec. 28	no
T-17	588	44.2	0.81	Dec. 29	no
T-19	766	62.3	0.79	Dec. 29	no
T-24	617	55.6	0.62	Nov. 19	no
T-25	572	38.1	0.66	Dec. 30	90
T-26	738	60.0	0.60	Dec. 28	no
T-10	736	29.8	0.52	Dec. 1	no
T-12	835	34.1	0.79	Dec. 5	no
T-13	540	22.5	0.73	Dec. 6	no
T-14	1,030	32.2	0.73	Dec. 6	48
T-21	644	27.4	0.71	Dec. 30	16
DS- 1	524	—	0.93	Dec. 1	no
DS- 2	370	—	0.76	Dec. 1	no
DS- 3	465	—	0.57	Dec. 5	no
DS- 4	306	—	0.74	Dec. 6	no
DS- 5	401	—	0.65	Dec. 6	156
DS- 6	397	—	0.61	Dec. 28	no
DS- 7	508	—	0.47	Dec. 30	no
DS- 8	948	—	0.48	Dec. 30	no

**** Ammo-phos : N : P_2O_5 : K_2O = 16 : 20 : 0, the recommended rate for rice by the Department of Rice is about 90kg Ammo-phos per hectare.

vertical axis. According to the position on this graph, the twenty-three samples can be classified into groups A, B and C. The hill population of groups A and B is less dense than that of group C. The total dry matter of one hill is greatest in group A, followed by those in groups B and C. The mean values of the yield and its components by group and the analysis of their variance are shown in Table 12. The differences of the yield components among the three groups are significant at a 1% or 5% level except the number of spikelets per panicle and one thousand grain weight. Therefore, this classification is considered adequate for the better understanding of the growth types of the twenty-three transplant rice samples.

The total dry weight per hill is greatest in group A, becoming lower in group B and still lower in group C (A>B>C). Although the number of panicles per hill

Table 12 Mean value of yield and yield components by groups A, B and C

group	weight of grain gr/m²	weight of grain gr/hill	no. of panicles /m²	no. of panicles /hill
A (7 plots)	293	29.1	106	10.8
B (11 plots)	183	15.2	91	7.7
C (5 plots)	260	10.0	148	5.7
F value for group	3.98**	25.42*	8.07*	8.58*
LSD (0.05)	92	5.5	29	2.4

group	no. of hills/m²	no. of spikelets /panicle	no. of spikelets /hill	fertile grain %	1,000 grain weight gr
A	10.0	124	1,281	83.5	28.0
B	12.1	99	747	75.8	27.2
C	25.7	87	506	73.3	28.3
F value	6.60*	0.13	9.99*	4.84*	0.22
LSD	2.8	46	347	6.8	3.7

group	height cm	total dry weight gr/m²	total dry weight gr/hill	panicle /straw ratio
A	179	1,045	105.2	0.47
B	138	571	48.1	0.61
C	138	757	29.2	0.70
F value	14.32*	12.97*	83.56*	5.46**
LSD	45	211	121	0.14

* significant at 1 percent level
** significant at 5 percent level

followed this same order, the difference between groups B and C was not significant ($A>B\geqq C$). As there was no significant differences in the number of spikelets per panicle among the three groups ($A\geqq B\geqq C$), the number of spikelets per hill showed the same tendency as the number of panicles per hill ($A>B\geqq C$). Thus the grain weight per hill was greatest in group A, and groups B and C do not differ significantly ($A>B\geqq C$). The grain weight per hill of group B almost equals that of group C on account of the lower number of panicles per hill although the dry weight per hill was higher.

The density of planting of group C was significantly higher than the other two groups, between which the difference was not significant ($C>B\geqq A$). Groups A and C change position in the total dry matter production ($A>C\geqq B$) and the number of panicles per unit area ($C>A\geqq B$) while group B is the last in both cases.

As the percentage of fertile grain of group C is significantly lower than that of group A and the number of spikelets per panicle of group C is the lowest of the three (though not significantly so), the difference of the final yield was significant neither between groups A and C nor groups B and C, but significant only between groups A and B, although the number of panicles per unit area was greatest in group C. In other words, group C compensated the fewer panicles per hill by dense planting and obtained a yield as high as group A, while group B scored the lowest yield, if not significantly lower than group C, by the poor tillerings although the interval among hills were as wide as group A.

Brief comments on each type of plant :

It may be interesting to contrast this classification of plant types with the twelve areas described in the previous sections. Unfortunately we shall have to give up the idea because the sampling sites were too few and not well sufficiently random.

Group A : This type of plant is found in the most fertile and well irrigated areas. Startling effects of a plentiful application of nitrogenous fertilizers should not be expected in this tall and loosely planted type if fertilization is not accompanied by improvements in other cultivation techniques.

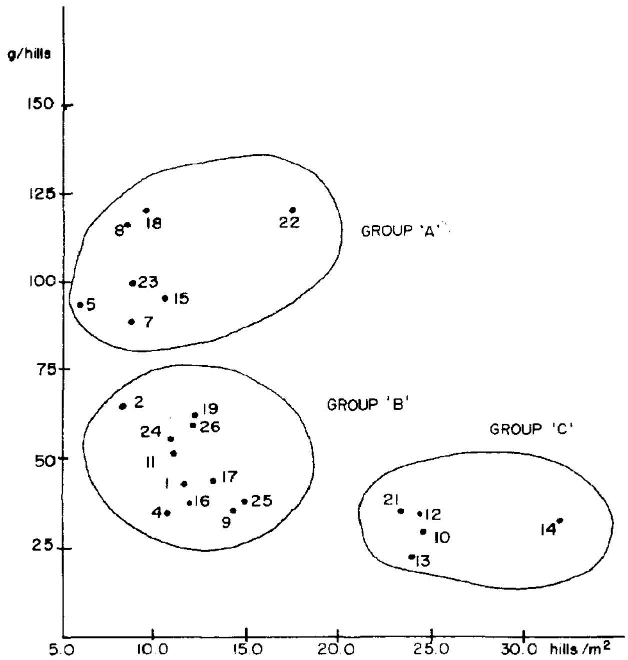


Fig. 2 Relation between number of hills/m^2 and dry weight / hill among 23 samples from transplanted fields

Because this type of plant already yields about eleven relatively big panicles per hill, its dry matter production exceeds ten metric tons per hectare and its panicle/straw ratio is below 0.5. Application of nitrogen is likely to cause lodging or disease. Denser planting and the split application of nitrogen are worth trying. The correlation coefficient between the yield and density of planting was significant at 5% level among the seven samples belonging to group A.

Group B : This type seems to be common in the low to medium yield transplant area in the Central Plain. As stated previously, the dry matter production and the panicles per hill of this group are nearly half those of group A although the density of planting does not differ much. This may be attributed to inferior soil or other environmental conditions rather than varietal differences. The effect of fertilization on this type of plant would be greater than that on group A.

Group C : The five samples of this group were taken from the shallow water fields on the western hillside or on, or close to the river levee in the fresh water alluvial area. Though these places may often sustain damage through drought, the plant nutrients are not necessarily poor. The very dense hill population, the outstanding characteristic of this group, is devised for obtaining the yield during the short period of flooding.

III Summary

Information concerning the regional differences within the Central Plain of Thailand was obtained from various sources published and unpublished, from the viewpoint of the rice cultivation. On this basis a subdivision of it into twelve areas was proposed. Results of the yield and yield components survey in 1966 were reported. The correlations between the yield and its components for twenty-three samples from the transplanted fields were discussed, and the samples classified into three different patterns of yield components.

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