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Rice Cultivation under the Different Irrigation Systems in Nong Wai Pioneer Agriculture Project Area of Khon Kaen, Thailand

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Field surveys of rice cultivation and hearing investigation of the farm managements were conducted in 1985 at the three villages of Khon Kaen in North-Eastern Thailand, for clarifying the effectiveness of the irrigation projects conducted and also for comparing the superiority of two different irrigation systems adopted at the areas from agronomical and economical viewpoints. The irrigation systems, both intensive (accompanied by land consolidation) and extensive (with only irrigation canal), have made rice cultivation possible throughout the year and have brought stability in the lives of the farmers as well as the farm managements based on rice cultivation. The intensive irrigation system has made the new method of rice cultivation of direct sowing by pregerminated seeds of non-glutinous varieties possible and enhanced rice yield to more than 6.0 tons/ha in brown rice (estimated) due to a high density of seeding (500 hills/m^2) and proper water control. One of the most serious problems in the area was the uneven distribution of water in the fields due to the shortage of water flow from the diversion dam. Rice cultivation in the extensive irrigation area has been successfully conducted by using proper devices of gravity irrigation system. The only problem in this area may be the irregular shapes and small size of the fields, which will be a handicap for mechanization of rice cultivation in the future. Rice cultivation in the rainfed area has almost not been conducted due to severe drought, with the exception of some restricted places, where it was possible to reserve water from the rainfall.

INTRODUCTION

This report is one part of the collective report of the survey research conducted by Thai and Japanese experts two times in 1984 and 1985 in Khon Kaen province of North-Eastern Thailand, supported by a grant from the Ministry of Education, Science and Culture of Japan.

The title of the research program submitted to the Japanese government was 'Studies on the effect of irrigation development on the agricultural progress in Thailand'. The members were five agri-economists, K. Tsuchiya, S. Kai, H. Moriyama (Kyushu Univ.), K. Adulavidhaya (Kasetsart Univ.), P. Prapertchob (Khon Kaen Univ.), an agri-engineering scientist, M. Kuroda (Kyushu Univ.) and an agronomist, K. Wasano (Saga Univ.). One of authors, P. Thanutong is a pathologist of Khon Kaen University who joined our research work at the area.

Many reports concerning rice production in Thailand have so far been published

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as summed up by Hamamura and Motomura (1980), but almost all of them were restricted to analytic ones about the productivity of rice in the fields and soil conditions or descriptive informations about the indigenous rice cultivation in the country. This survey research is a synthetic one which was conducted from three different fields in order to find out some programs for stabilization and mordernization of rice cultivation under different irrigation systems in the North-Eastern region of Thailand and to provide some suggestions for future project planning in the area.

STATISTICAL REVIEWS ON RICE PRODUCTION IN THAILAND

1. Rice production during the last 20 years in Thailand

As shown in Table 1, both total amount and regional contributions of rice production in Thailand have amazingly changed during the last 20 years. From the late 1960's major irrigation projects in Thailand (Nakashima, 1981) had commenced in the Northern region. As a result, the paddy fields cultivated in the whole country has increased to nearly 10 million hectares, i. e. an increase of more than 50 % in comparison to the early 1960's. An increase of three million hectares in the whole country has been largely contributed to an increase of five times in the Northern region and also an increase of nearly two times in the North-Eastern region. On the contrary, in the Central Plains, there is a little decrease in the acreage planted during the last 20 years. At present nearly half (46 %) of the acreage in the country is distributed in the North-Eastern region and another quarter of the total, each for the Central Plains and Northern regions, respectively.

In the early 1960's almost 90 % of the total rice production was shared by the Central Plains and the North-Eastern regions, which is now shared by three regions, Northern, North-Eastern and Central Plains regions. At present all the regions are producing more than five million tons of rice, but with an increase of only 0.5 tons/ha for the last 20 years. An increment of 0.85 tons/ha (largest) and 0.22 tons/ha (smallest), has been attained in the Central Plains and the North-Eastern region, respectively.

Table 1. Planted area, production and yield of paddy, averaged by three years' statistics of 1961 – '63 and 1981 – '83, in Thailand.

Region	Area (1000ha)		Production (1000t)		Yield (ton/ha)	
	'61 – '63	'81 – '83	'61 – '63	'81 – '83	'61 – '63	'81 – '83
Whole Country	6,253.0	9,611.3	8,430.7	17,340.3	1.34	1.80
Northern	414.2 (6.6)*	2,108.6 (21.9)	837.0 (9.9)	5.030.0 (29.0)	2.02	2.39
North-Eastern	2,548.5 (40.8)	4,442.5 (46.2)	2,566.0 (30.4)	5,427.7 (31.3)	1.00	1.22
Central Plain	2,812.7 (45.0)	2,390.1 (24.9)	4,330.7 (51.4)	5,717.0 (33.0)	1.54	2.39
Southern	477.5 (7.6)	670.2 (7.0)	696.3 (8.3)	1,166.0 (6.7)	1.46	1.74

* Figure in parenthesis shows the percentage.

Table 2. Planted acreages, productions and yields of rice (unhulled), averaged by three year statistics of 1981—'83, seperated into the major and second season cultivations in each of the 16 provinces (grouped into five different agro-economic zones) in North-East Thailand.

Agro-Economic Zone and Province	Area (1000ha)		Production(1000t)		Yield (t/ha)	
	Major'	Second	Major	Second	Major	Second
Whole Country	9,037.1	574.29	15,312.4	2,028.32	1.69	3.53
Northern	2,048.3 (22.7)*	60.37 (10.5)	4,833.7 (31.5)	196.33 (9.7)	2.36	3.25
North--Eastern	4,417.7 (48.9)	24.75 (4.3)	5,369.0 (35.1)	58.66 (2.9)	1.22	2.38
Central Plain	1,918.3 (21.2)	471.78 (82.2)	3,990.7 (26.1)	1,726.33 (85.1)	2.08	3.66
Southern	652.8 (7.2)	17.38 (3.0)	1,119.0 (7.3)	47.00 (2.3)	1.71	2.70
North-Eastern Region						
Zone I						
1 Nakhon Phanom	167.1	1.67	188.2	3.22	1.13	1.93
2 Sakhon Nakhon	248.7	0.34	288.6	0.67	1.16	1.97
3 Nong Khai	172.8	2.33	235.9	5.64	1.37	2.42
4 Udon Thani	379.6	0.85	501.6	1.81	1.32	2.14
5 Loei	49.0	0.29	114.9	0.50	2.34	1.69
Zone II						
6 Yasothon	142.4	1.09	156.7	2.32	1.10	2.13
7 Ubon Ratchathani	554.8	3.72	490.5	8.07	0.88	2.17
Zone III						
8 Kalasin	152.0	1.09	237.5	2.76	1.56	2.53
9 Khon Kaen	297.0	7.01	387.1	18.48	1.30	2.63
10 Maha Sarakham	259.4	1.98	285.1	3.89	1.10	1.97
11 Roi Et	367.2	2.00	382.0	4.98	1.04	2.49
Zone IV						
12 Buri Ram	386.9	0.26	517.7	0.66	1.34	2.50
13 Si Sa Ket	324.5	0.32	367.4	0.63	1.13	1.96
14 Surin	429.2	0.09	572.9	0.15	1.34	1.74
Zone V						
15 Chaiyaphum	160.7	0.52	237.6	1.41	1.48	2.69
16 Nakhon Ratchasima	314.2	1.15	389.5	3.28	1.24	2.85

* Figure in parenthesis shows the percentage.
' Major means major season or rainy season and Second, second or dry season

2. Rice production in the North-Eastern region of Thailand

Statistics of the present rice production in the region is separated into two, i. e. the rainy (major crop) and the dry (second crop) season crops, and are as shown in Table 2. These data are based on the data of three consecutive years beginning from 1981. In the dry season, almost all of the acreage (82 % of the total) is restricted to the Central Plains region and only 4.3 % of the total acreage (about 2,500 ha) or 2.9 % of the total production (nearly 60,000 tons) has been contributed by the North-Eastern region. The rice yield in the dry season was 1.0-1.5 tons per hectare higher than in the rainy season.

Among the 16 provinces in the North-Eastern region, Udon Thani lying on the Mekong river basin to the western part of the region, Ubon Ratchathani with the largest acreage located along the Mekong to the south-western part of the region and two other provinces of Surin and Buri Ram which are on the Mun river basin to the southern part of the region, all of which are producing more than 500,000 tons of rice, belong to the largest production ones in the rainy season cultivation, followed by Khon Kaen, Roi Et on the Chi river basin in the central part of the region, and Si Sa Ket, Nakhon Ratchasima on the Mun river basin, with a production of more than 300,000 tons of rice.

Rice yield in the rainy season varied from 1.0 to 1.3 tons per hectare among the 16 provinces. Ubon Ratchathani with the largest acreage registered less than 1.0 ton/ha, which was the smallest productivity throughout the region.

In the dry season, Khon Kaen producing 18,000 tons of rice, the largest production in the region, has 7,000 hectares of the fields planted, followed by Ubon Ratchathani with 4,000 hectares of acreage of 8,000 tons of rice production. These two provinces are producing almost half of the production of the region in the dry season, followed by Nong Khai, Nakhon Phanom along the Mekong, and Maha Sarakhan, Roi Et on the Chi river basin with a production of more than 3,000 tons of rice.

Rice yield in the dry season was nearly two times of the rainy season and a yield of about 3.0 tons/ha of Nakhon Ratchasima, which is situated in the south-eastern part of the region, was the highest one throughout the region.

3. Physiographic and Climatic Aspects of North-Eastern Thailand

Fig. 1 shows the regional division of Thailand delineated by Pendleton (1962), which was based on the aspects of internal landform, climate, mineral resources, agricultural land use and so on. Although Thailand was physiographically divided into five regions with some sub-regions as shown in the figure, the one made by Ministry of Agriculture of Thailand, which was adopted in the agricultural statistics of Thailand in 1964, had been different from that of Pendleton's as follows: Northern, North-Eastern, Central and Southern zones. Sub-region Western Mountains (IIB) of Continental Highlands and Southeast Coast region (IV) by Pendleton (see Fig. 1) were incorporated into the Central zone in the latter one.

North-Eastern region is located on the high and undulating hills with the elevations varying from about 250 metre (mean sea level) to the northwest to about 100 metre to the southeast and extends over some 170,000 km^2 including three river basins ; i. e. the Mekong (33,344 km^2), the Chi (55,211 km^2) and the Mun (81,671 km'). This region is called Khorat, forming a saucer-shaped plateau, and is, as shown in Fig. 2, separated from the Central Plains or Cambodia by the mountain ranges, the Phetchaboon to the west and the Phonom Damreck to the south, and also bordered by the Mekong to the north and east of the region.

Furthermore, the region is characterized by poor soil ; i. e. light and sandy, low moisture holding capacity and low fertility, and also by erratic rainfall of nearly 1000 mm a year. Details of the characteristics concerning the paddy soils in Thailand were described by Kawaguchi and Kyuma (1964).

Some parts of the descriptions about the Khorat Plateau by Kawaguchi and

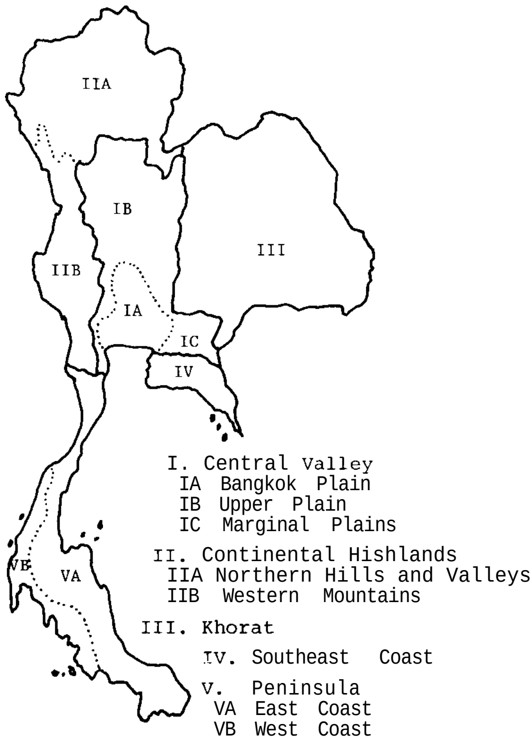

Fig. 1 Physiographic regions of Thailand after R.L. Pendleton, 1962.

Kyuma (1964) are as follows : Main parts of the Khorat are drained by the Mun and the Chi systems, along which rather narrow width of alluvial plains are distributed. Low level terraced lands with near flat to slightly undulating topography are widely distributed from the south-central to the south-eastern parts of the plateau, and some of them are further divided into the lower ones with clayey soil and the higher ones with sandy soil, respectively. On the other hand, middle level of the terraces, which consists of two species of sediments, the upper homogeneously sandy stratum and the lower one with clayey materials which often has laterite gravels and/or soft plinthites, are seen on the northern part of the plateau. The major great soil groups occurring in the Khorat are : alluvial soils, low humic gley soils, gray podzolic soils, and red-yellow podzolic soils. Gray podzolic soils and low humic gley soils are widely distributed in the central and southern parts of the region, mainly on the low and middle terraces. Red-yellow podzolic soils and regosolic gray podzolic soils occur on terrace formations in the northern Khorat. Red-yellow latosols are found on the high terraces.

Some of the data showing poor fertility of paddy fields in the North-Eastern region by Motomura (1973) are as follows : The contents of some elements in the fresh water alluvial soils (the figures in the parenthesis are those of the Central Plains region for

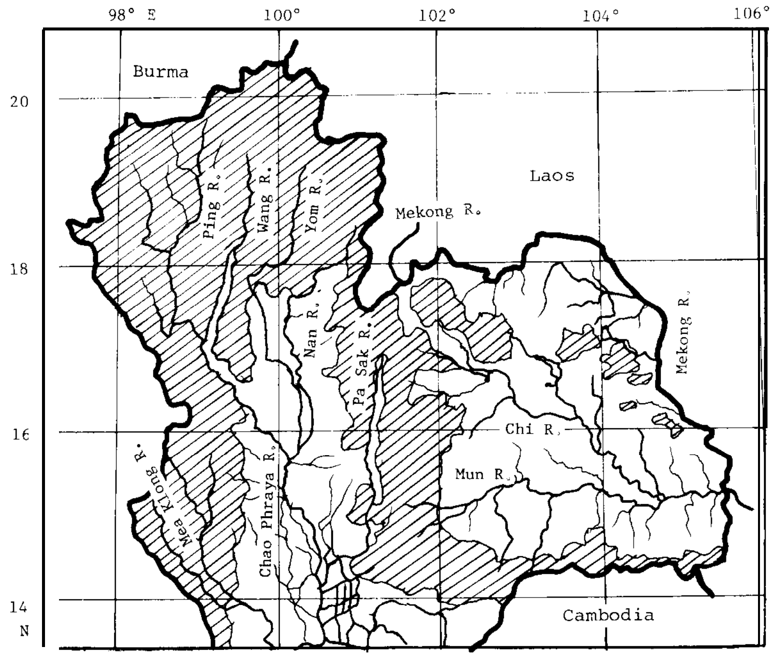

Fig. 2 Topographic map of a part of Thailand roughly traced from the Britannica International Atlas.
Shadowed parts : altitude more than 200 metre.

the comparison) are 0.056 (0.127) % in total N, 0.533 (1.406) % in total C, 23.7 (35.6) ppm in available N, 31 (115) mg/100 g in total P_2O_5, 9 (26) ppm in available P_2O_5, 453 (1100) mg/100 g in total K_2O, and 93 (116) ppm in available K_2O.

Fig. 3 shows the distribution of isophytes of annual rainfall based on the 30 year averages and locality of the 16 provinces (recently Mukdahan province was divided from Nakhon Phanom) in the North-Eastern region. As shown in the figure, the area with the heaviest rainfall of nearly 2000 mm a year is restricted to the small area of the north-eastern part of the region along the Mekong. The western half of the region which includes Khon Kaen has an annual rainfall of 1200 mm. Around 1500 mm annual rainfall can be found only along the Mekong basin to the eastern part of the region.

METHODS

In 1985, three villages, Song Pleuy, Bung Kae and Ton, near Khon Kaen city were selected for the investigation and 15 rice farmers from each of the villages were randomly sampled for the survey of farming managements. Each of the villages selected has its own irrigation system different from the other ; i. e. intensive (Song Pleuy), extensive (Bung Kae) and rainfed (Ton) ones. The locality of the villages and distribution of the irrigation systems are as shown in Fig. 4. The Nong Wai Irrigation Project in Khon Kaen province was started in 1970 and the land consolidation program

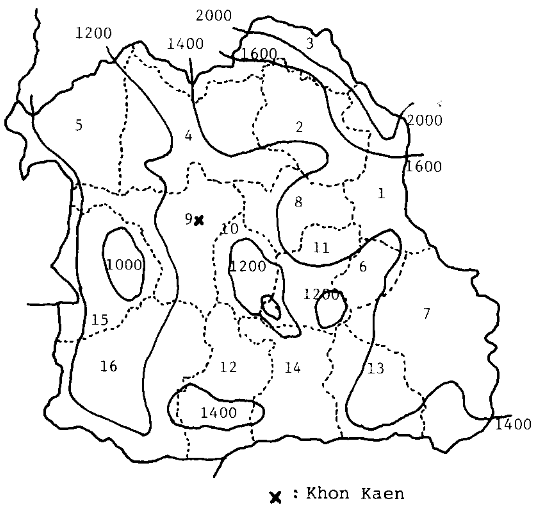

Fig. 3 Distribution in isohyets of annual rainfall due to the 30 year (1931-'60) averages and the names of provinces in North-Eastern Thailand.
Source: Hydrometerology Div. of Meteological Dep. of Thailand and the AICAF report No. 1 (1983).

of about 80,000 hectares had been carried out until 1980 as a pilot farm with irrigation system. Irrigation water at the area is reserved in the Ubol Ratana Reservoir which was constructed by damming the Nam Pong river, a tributary of the Chi river. At the Non Wai Diversion Dam as shown in Fig. 4, the water flow from the reservoir is separated into the two canals, i. e. the Left and Right Bank Canals, and irrigated to the A, B and C areas as plotted in the figure.

The field allocations in the intensive irrigation area (Song Pleuy) as shown in Fig. 9-7 are as follows : About 1.5 metre wide irrigation ditches which become the branches from the lateral irrigation canal (about 3 metre wide) are running through the central half of the area toward east and west. The lateral irrigation canal branched from the main canal (Fig. 9-6) are distributed on the east and west sides of the area toward north and south. The irrigation water can be supplied to the fields through the irrigation ditches and drained into the drainage canal (about 5 metre wide) which is running through the central area toward north and south. The water for irrigation can individually be controlled by a farmer in each of the fields. The paddy fields which were completely leveled had been consolidated into about 25 pieces of rectangular fields with the sizes of 10 to 50 ares on each side of the irrigation ditches along the farm road (about 5 metre wide).

On the other hand, an irrigation ditch in the extensive irrigation area (Bung Kae) as shown in Fig. 9-3 was constructed on the highest level of land in the area so as to make the gravity irrigation over the border of the fields possible. Paddy fields

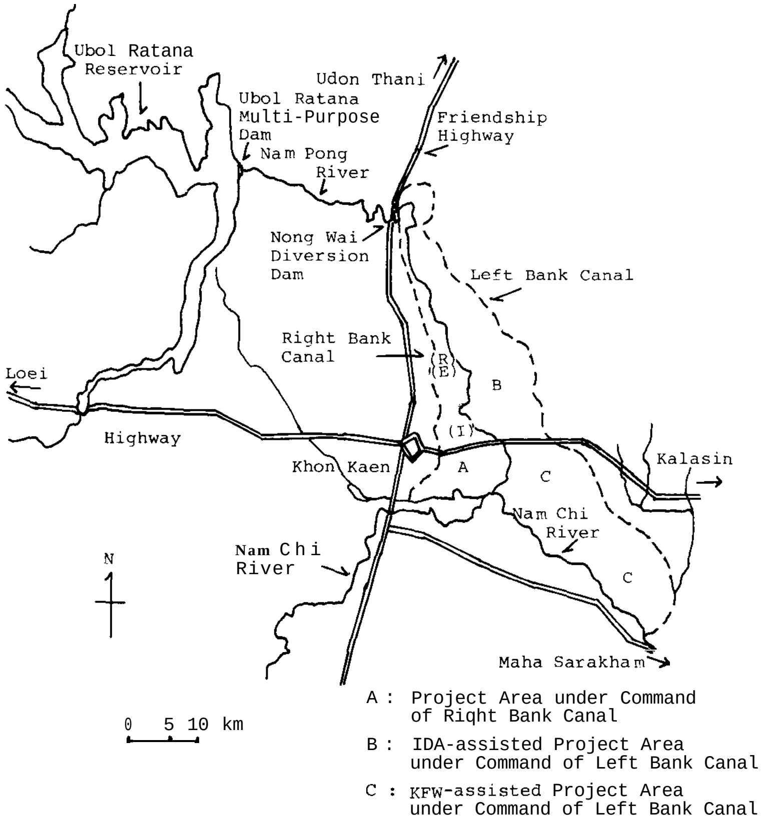

Fig. 4 Locality of the villages surveyed, Song Pleuy (I), Bung Kae (E) and Ton (R), and also Nong Wai Irrigation Project Area in Khon Kaen.

distributed on both sides of the irrigation ditch (about 3 metre wide) along the farm road were extremely different in their sizes and shapes because of no land consolidation conducted.

Paddy fields surveyed in the rainfed area (Ton) were widely different in their soil conditions, i. e. completely dried or deeply flooded, depending on the land level or the topography. Relatively higher places in the area had completely dried up and no rice cultivation had been conducted. As a result, field surveys were conducted at two places, i. e. relatively lower and the lowest level of land in the area, where rice was growing.

All of the fields sampled for the survey were those located near the villages investigated. The plots surveyed were selected so as to represent the whole situations of the fields or rice cultivation in the area. The data of 20 plants per plot, with the exception of 10 plants per plot for counting the spikelet number per panicle from the longest culm of a plant, were collected for studying the agronomic characters and cultivation practices of rice. Number of hills per square metre in the case of transplanting method was obtained by averaging the values of those calculated from the average distences between hills measured from 20 plants per plot and of the number of hills counted in one square metre plot. In the case of direct sowing method number of hills planted in a unit area was estimated from the one counted in a quater of a square metre. Grain sizes and shapes were measured from ten kernels per variety and the weight of 1000 kernels of brown rice with 14 % of moisture content was estimated from the weights of 10 to 50 kernels. The weight of unhulled rice grains was roughly weighed in Thailand by using the balance for weighing a postcard.

RESULTS AND DISCUSSION

1. Climatic conditions of Khon Kaen in Thailand

Fig. 5 shows the maximum and minimum air temperatures based on 10 days average and monthly rainfall in 1985 (data of Khon Kaen Univ.). Monthly rainfall due to the last 30 years average in the figure was adopted from the Meteological Department. As seen in the data of the past 30 years, September usually receives the heaviest rainfall of more than 250 mm per month. The average rainfall of one month from May to September registers at least 170 mm. This is the monsoon period and major crop,

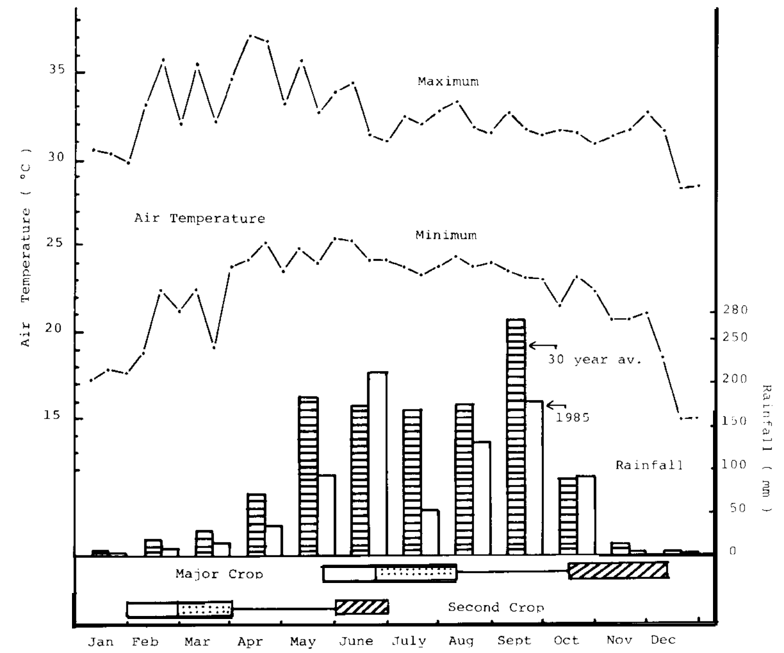

Fig. 5 Maximum and minimum air temperatures and monthly rainfall in a year, and rice calendar in Khon Kaen, North-East Thailand.
Seeding, Transplanting, Harvesting
Source : 30 years average rainfall ; from Hydrometeorology Div. of Meteological Department, 1985 rainfall and air temperature; from Fac. of Agr. of Khon Kaen University, Thailand.

as shown in the cultivation calendar in Fig. 5, is cultivated in this season throughout the country. The month of October which registers 80 mm of rainfall is the most important time for flowering and maturing of rice. The five months from November to next March are referred to as the dry season, during which rice cultivation can be conducted only in the irrigated areas as the rainfall is not sufficient for plant growth in the non-irrigated areas.

In 1985, there was extremely poor rainfall, with the exception of the months of

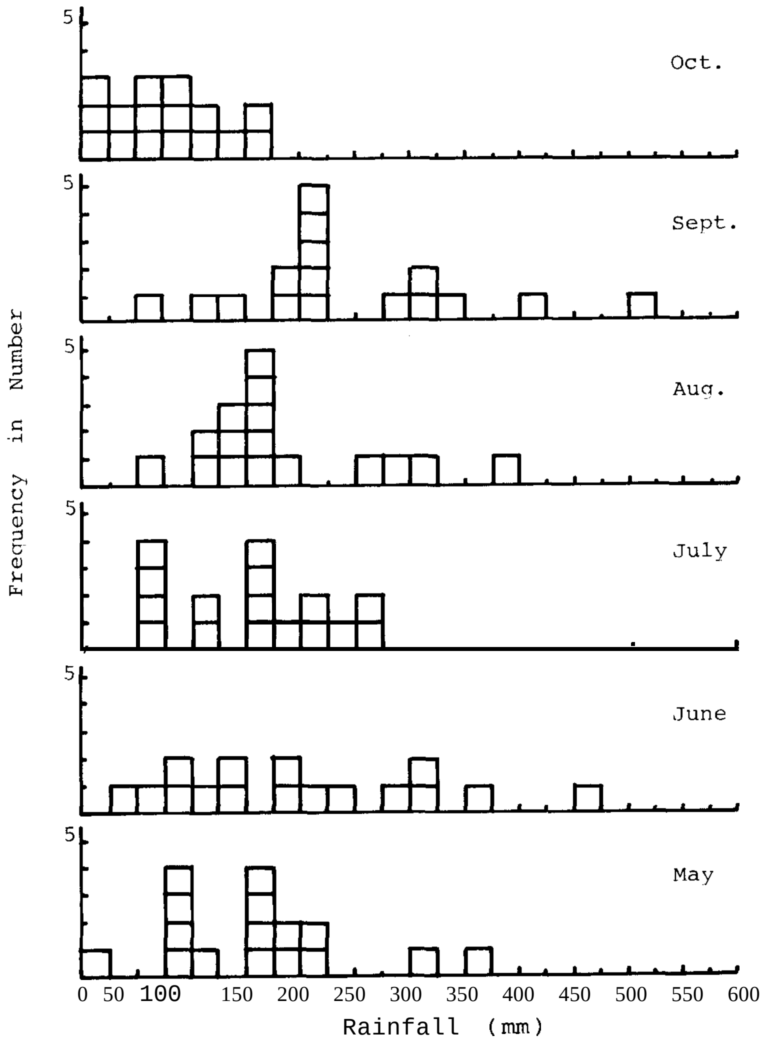

Fig. 6 Variations in monthly rainfall during the rainy season for the past 16 years from 1970 to '85 at Khon Kaen University.
Source of Data : Faculty of Agriculture, Khon Kaen Univ.

Table 3. Mean values and its variations among years of monthly rainfall and pan evaporation at Khon Kaen University, Thailand.

	Rainfall (1970−'85) (mm)			Pan Evaporation (1977 −'85) (mm)		
	Monthly	S.D.	Daily	Monthly	S. D.	Daily
May	161	(± 85)	5.20	172	(±18)	5.54
June	202	(±120)	6.73	145	(±32)	4.81
July	156	(± 73)	5.02	141	(±27)	4.56
Aug.	181	(± 81)	5.83	126	(i-16)	4.08
Sept.	245	(±115)	8.18	114	(±25)	3.80
Oct.	77	(± 51)	2.49	134	(±25)	4.34
Mean	170		5.58	139		4.52

S. D. : Standard Deviation   Source of Data : Fac. of Agr., Khon Kaen Univ.

June and October. The lowest level of rainfall in July in 1985 has made rice cultivation almost throughout the rainfed areas impracticable. Rice growing has been possible only in low level areas, where it was possible to gather water from the surface run-off of rainfall. At some low level spots, staggered rice planting might have been enforced after having sufficient rainfall in September.

Daily air temperature at Khon Kaen in 1985 ranged from 10.9°C (Dec. 24) to 28.1°C (Apr. 14) in the minimum, and 23.7°C (Dec. 16) to 406°C (Apr. 11) in the maximum. The monthly air temperature in the year ranged from 16.1°C (Dec.) to 24.7°C (May) in the minimum and 29.4°C (Dec.) to 35.7°C (Apr.) in the maximum. March to May were the hottest months with a temperature of more than 34°C in the maximum, and December to January were the coolest months with a temperature of less than 20°C in the minimum.

As presented in Fig. 6 and Table 3, monthly rainfall in the rainy season at Khon Kaen shows a wide range of variations among years during the last 16 years. Although some differences in these variations are found due to the season, some years with critically small rainfall a month are seen in any of the months of the rainy season during the 16 years. Even in the month of September which registers the highest rainfall in a year, recorded a rainfall of less than 150 mm per month for 3 years out of the 16 years. During the four months from May to August, six to seven years of the 16 years period, also recorded a rainfall of less than 150 mm per month. These data indicate that Khon Kaen is situated in the region with severe climatic conditions for rice cultivation even in the rainy season, without irrigation facilities.

Kung (1965) showed the water requirements of about 1240 mm during the rice cultivation in Thailand, of which 40 mm for the nursery, 200 mm for land preparation and 1000 mm for irrigation during plant growth were estimated, respectively. He (1966) concluded that the average water requirement from transplanting to harvesting in Asia is about 800 to 1200 mm (6 to 10 mm daily consumption), which is consumed by transpiration (200 to 500 mm), evaporation (180 to 380 mm) and percolation (200 to 700 mm).

Sugimoto (1971) has presented similar values of water requirements of 935 mm (daily 6.7 mm) for 139 days of rice growing duration from August 20 to January 15 in

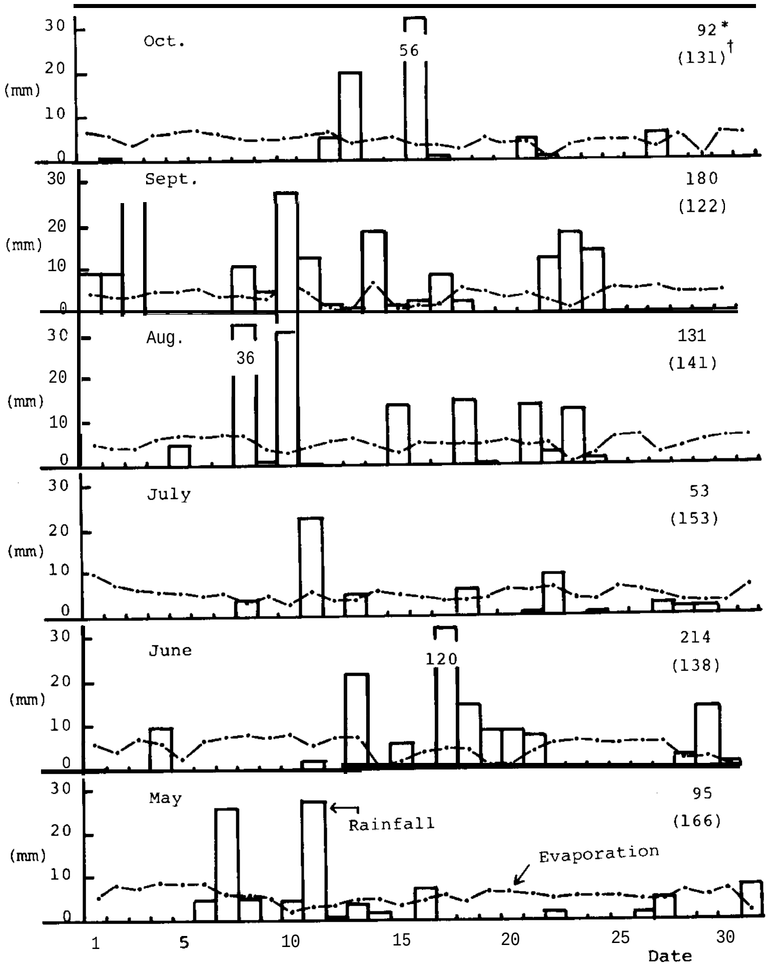

Fig. 7 Rainfall and pan evaporation during the rainy season (major crop season) in Khon Kaen, Thailand, in 1985.
* Total amount to rainfall per month
† Total amount of pan evaporation per month
Source of Data : Faculty of Agriculture, Khon Kaen Univ.

Malaysia (at Kedah), of which 347 mm by evaporation, 387 mm by transpiration and 201 mm by percolation were estimated, respectively.

Monthly pan evaporation within the rainy season at Khon Kaen as shown in Table 3 were relatively stable among the years and had some variations due to the season, with the highest of 172 mm a month (daily 5.54 mm) in May and the lowest of 114 mm a month (daily 3.80 mm) in September.

Fig. 7 shows the distributions of daily rainfall and pan evaporation during the rainy season at Khon Kaen in 1985. Daily mean pan evaporation was about 4.5 mm,

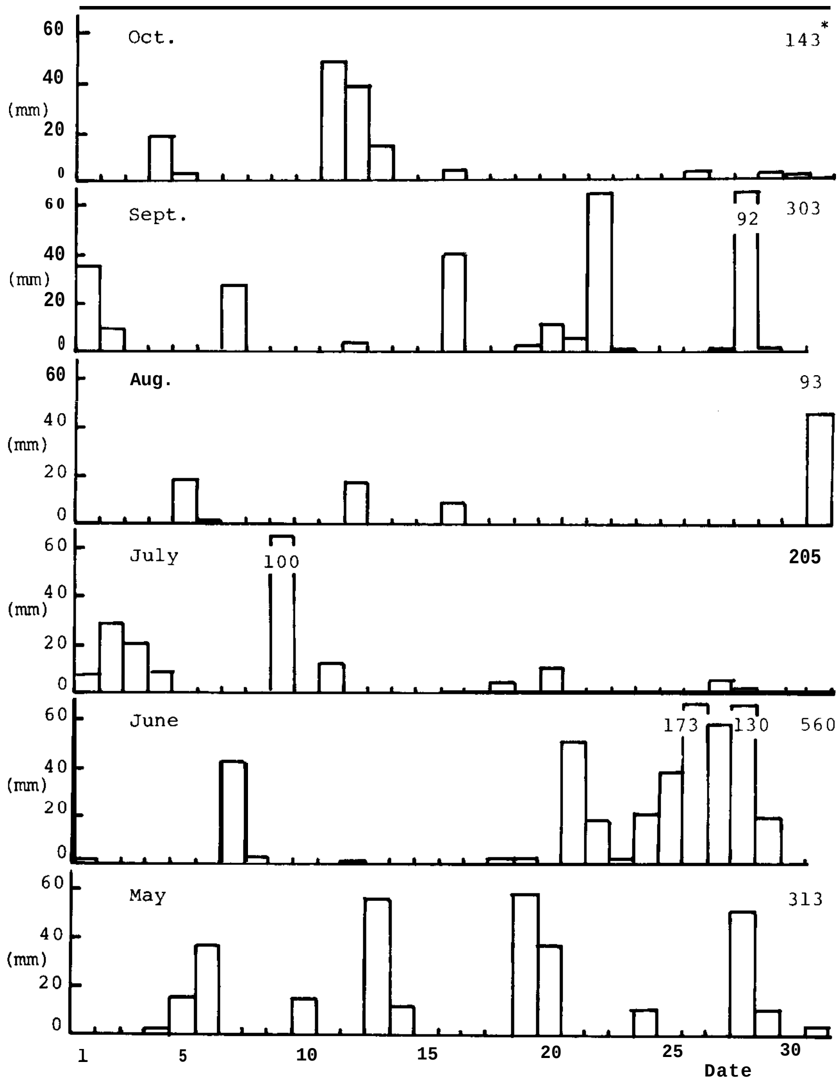

Fig. 8 Daily changes in rainfall during the crop season in Saga, Japan, in 1985.
* Total amount of rainfall per month
Source of Data : Saga Meteorological Station, Japan.

ranging from 0.4 mm to 9.9 mm within the rainy season. The months with monthly rainfall exceeding the pan evaporation were only two, i. e. June and September. Especially during the two months from late June to early August there were only two days which recorded a rainfall of more than 10 mm a day. Such severe climatic condition as seen at Khon Kaen in 1985 could not provide any environmental conditions for rice to live in the fields without irrigation facilities.

Fig. 8 shows the rainfall at Saga city in Japan in 1985 for comparison with those of Khon Kaen. Saga had about three times rainfall in Khon Kaen during the two months from May (land preparation and sowing time in Saga) to late June (transplanting time), but almost no rainfall was seen during one and half months from mid-July (ending time of the rainy season in Saga) to the end of August. Rice cultivation during the period from tillering to panicle formation stages of rice in Saga is also not possible without irrigation systems. From late August to the beginning of September when rice plants start flowering, at least 50 mm of rainfall per day can be expected every week untill mid-October, i. e. just before harvest in Saga.

2. **Rice cultivation under different irrigation systems in Khon Kaen**

2. 1 In the intensive irrigation area (Song Pleuy)

Although the irrigation system in the area as mentioned above might be perfect, some serious problems were found in the some places of the area. Insufficient water distribution due to the lack of water supply from the main canal, large heterogeneity

Table 4-1. Some agronomic characters of rice varieties cultivated in the rainy season in 1985 under different irrigation systems, intensive, extensive and natural (rainfed) The surveys were conducted late October in 1985.

Irrigation system	No. of fields surveyed	No. 0f Items	Name of Variety	Grain Texture	Length of Culm cm(S.D)	Length of Panicle cm(S.D)	Number of Panicles /'hill	Number of Spikelets /panicle
Intensive (I)†	No. 1 (N)	1	RD 8	glu.	110(8.6)	27.2(2.7)	4.9(1.5)	209(40)
	No. 2 (S)	2	RD 23	non-glu.	62(6.7)	21.5(2.2)	1.0(0.0)	76(20)
	No5 (S)	3	RD 21	non-glu.	69(9.8)	20.7(2.3)	1.0(0.0)	82(20)
	No.15 (N)	4	RD 8	glu.	44(5.8)	20.8(2.0)	8.7(1.6)	71(12)
	No.16 (S)	5	?	?	*31(6.0)	—	—	—
Extensive (E)†	No 1	6	RD 6	glu.	102 7.7)	31.1(2.3)	5.7(1.2)	199(34)
	No 2	7	RD 8	glu.	105 6.2)	25.8(1.9)	6.0(0.9)	181(41)
	No. 3	8	RD 8	glu.	132 3.7)	27.1(1.3)	5.6(0.9)	172(55)
	No. 4	9	RD 8		12.5 4.6)	24.1(1.3)	6.0(0.8)	178(28)
	No. 5	10	KaoKaoYai	glu.	*145 8.9)	—	8.2(1.4)	—
	No. 6	11	?	glu.	103 5.4)	24.0(2.0)	6.8(0.9)	174(31)
Rainfed (R)†	Nul (H)	12	?	?	*49 6.6)	—	4.6(1.0)	—
	No. 2 (H)	13	?	?	*61 6.8)	—	6.5(1.5)	—
	No. 3 (II)	14	?	?	*59 11.3)	20.5(1.5)	6.2(1.2)	64(12)
	No4 (H)	15	KaoDoor	glu.	64 5.1)	19.4(1.3)	5.4(1.3)	66(7)
	No. 5 (H)	16	?	?	*74 4.7)	—	9.5(1.3)	—
	No. 1 (L)	17	RD 8	glu.	105 13.3)	24.0(1.7)	5.8(0.9)	121(18)
	No. 2 (L)	18	RD 8	glu.	85 12.4)	21.7(1.7)	4.9(1.3)	113(25)
	No3 (L)	19	RD 8	glu.	95 5.2)	23.8(1.7)	5.1(0.6)	133(24)
	No4 (L)	20	RD 8	glu.	97 11.7)	24.3(1.1)	7.4(1.1)	136(10)

*: Plant height (from the earth level to the uppermost portion of a plant) was measured about the plants in the stages before heading.

—: Data were not available.

†: (I) Song Pleuy, (E) Bung Kae, (R) Ton.

in the soil environments of the fields resulting from the removal of surface soil at the time of land leveling, and inadequate water control for irrigation or drainage have been seen there. Some fields (Fig. 9-8) distant from the source of the irrigation water received less water than those (Fig. 9-10) situated nearer to the source of supply. The fields distributed on the west side of the area were irrigated by scanty water (completely dried in some of them), which was resulted from the absolute difference in water supply between the two lateral irrigation canal distributed on the west and east sides of the area. It is naturally imperative that irrigation systems be devised to supply water throughout the customary rice growth period of the area. Due to lack of pumping schemes in the area, many fields have dried or received severe drought during the growing duration (large soil cracks were observed in the fields), even though they are situated very near to the canal.

Table 4 shows some data of the agronomic characters of rice, cultivation

Table 4-2. (Continued) Some agronomic characters of rice and short descriptions about the situations of a paddy field, rice growing, cultivation practices and some damages caused by pests, diseases and drought (No. of items is same as that of Table 4 1.).

No. of Items	Number of Panicles /m²	Number of Spikelets /m²	Number of Hills/m²‡ (Spacing)	Short Descriptions
1	130	27,100	26.5 (19.2x19.7)	transplanting, fully headed, ill-drained, no weeds, slightly injured by sheath blight (*Rhizoctonia solani*)
2	508	38,700	508	direct sowing, hard dough- ripe stage, well-drained, slightly damaged by stem borers, some sterile spikelets, no weeds
3	512	42,000	512	direct sowing, hard dough-ripe stage, well-drained, no weeds
4	268	18,900	31.0 (–)	transplanting,heading stage,well-drained,no weeds, slight drought damages during tillering stage, some pest damages on panicles
5	–	–	–	replanted after later rainfall, tillering stage, well-drained, no weeds
6	100	19,900	17.5 (21.4X26.0)	transplanting, beginning of the flowering stage, ill-drained, 15cm deep water submerged, slightly injured by brown spot (*Cochliobolus miyabeanus*), no weeds
7	104	18.800	17.3 (25.2X25.4)	transplanting, heading stage, well drained, 5 cm deep water submerged, no weeds, slightly damaged by stem borers
8	123	21,100	21.9 (21.7x21.1)	transplanting, heading stage, ill-drained, no weeds, slight infection of brown spot
9	146	26.000	24.3 (18.8x20.9)	transplanting, heading stage, ill-drained, 10cm deep water submerged, no weeds, slight infection of brown spot
10	123	–	15.0 (27.1x28.4)	transplanting, booting stage, ill-drained, 10cm deep water submerged, slight infection of brown spot, located at near pond, lowest place in the area
11	128	22.300	18.8	transplanting, fully headed, well-drained, 2 cm deep water submerged, slightly infected by brown spot and bacterial leaf blight (*Xanthomonas campestris*), located beside the canal

practices, some damages due to pests, diseases and drought. Five different spots were selected for conducting field surveys. Two fields in which glutinous variety, RD 8, was cultivated were distinctively different in their water conditions. The No. 1 (N) field which means the first field counted from the east side of the area and located on the north side of the central road was well irrigated. On the contrary, the field No. 15 (N), which is the 15 th field from the east side of the area on the north side of the road, was ill-irrigated. As a result, RD 8 in the field No. 1 (N) was growing in excellent stands with tall and stout culm (no lodging), long panicles with lots of spikelets, and was only slightly infected by sheath blight disease. Management on the fields has been well conducted with no weeds. The soil was soft due to ill-draining. Rice plants were planted in a little dense spacing by the regular transplanting method. In spite of smaller number of panicles per hill, spikelet numbers per square metre had been sufficiently retained due to long panicles. Rice yield estimated from the yield

Table 4-3. (Continued).

No. of Items	Number of Panicles /m²	Number of Spikelets /m²	Number of Hills/m²‡ (Spacing)	Short Descriptions
12	109		23.6 (21.2X21.2)	transplanting, booting stage, growth retardation due to severe drought, size of the field(15×20m), dried soil, some weeds, some infection of brown spot
13	157		24.2 (20.1x22.3)	transplanting, heading stage (flowering was seen one fifth of plants in the field and one or two panicles per plant), dried soil, some weeds, slight infection of brown spot
14	156	9,900	25.2 (18.4 × 19.2)	transplanting, heading stage (flowered about 70% of plants in the field), some weeds, slight infection of brown spot, drought damages
13	118	7,800	21.9 (20.8X24.3)	transplanting, matured, ill-drained, not weeded well, bird damages, some infection of false smut (*Ustilaginoidea virens*)
16	198		20.8 (22.1X23.2)	replanted after later rainfall, tillering stage, ill-drained, 15cm deep water submerged
17	124	15,000	21.6 (22.1X22.4)	transplanting, fully headed, ill-drained, 40cm deep water submerged, no weeds, slightly injured by brown spot
18	102	11,500	21.1 (22.6X24.5)	transplanting, headingstage, well-drained, 2 cmdeep water submerged, no weeds, bright green color of plant due to fertilizer deficiency, slight drought damage, slight infection of brown spot
19	121	16,100	23.7 (21.4X21.0)	transplanting, heading stage, ill drained, 13cm deep water submerged, fertilizer deficiency, no weeds, some pest damages on panicles, slight infection of brown spot
20	158	21,500	21.4 (20.9X23.1)	transplanting, heading stage, ill-drained, 26cm deep water submerged, some infection of brown spot

‡ Number of hills per square meter was obtained from averaging the values of those calculated from the average distances among plants planted(10 plants measured) and the number of hills counted in a square meter plot.

Table 5. Grain sizes and shapes of hulled and unhulled rice of some varieties, which were presented by Khon Kaen Rice Experiment Station and Extension Office, in 1985.

Variety		Length (mm) and S. D.	Width (mm) and S. D.	Thickness (mm) and S. D.	Ratio of L./W. and S. D.	Weight(g) of 1000 gr.s	Others
Hulled Rice	RD. 6	7.18(0.36)	2.22(0.08)	1.74(0.06)	3.23(0.12)	22.4	glutinous
	RD. 7	7.13(0.26)	2.19(0.06)	1.76(0.05)	3.26(0.13)	22.6	translucent
	RD. 8	7.34(0.24)	2.69(0.09)	1.94(0.05)	2.73(0.13)	28.0	glutinous
	RD. 9	7.42(0.44)	2.28(0.06)	1.80(0.04)	3.26(0.19)	22.9	translucent
	RD.21	7.24(0.41)	2.29(0.11)	1.72(0.05)	3.17(0.25)	21.7	translucent
	RD. 23	7.22(0.12)	2.04(0.05)	1.77(0.06)	3.53(0.13)	21.0	translucent
Unhulled Rice	RD. 6	10.10(0.33)	2.68(0.12)	2.03(0.07)	3.78(0.23)	30.0	tawny*
	RD. 7	9.66(0.24)	2.50(0.12)	1.95(0.14)	3.88(0.27)	27.0	straw
	RD. 8	9.87(0.32)	3.12(0.19)	2.10(0.09)	3.17(0.20)	31.0	tawny
	RD. 9	9.56(0.23)	2.57(0.13)	1.99(0.06)	3.73(0.15)	25.0	straw
	RD. 21	9.88(0.63)	2.73(0.13)	1.99(0.07)	3.63(0.29)	26.5	straw
	RD. 23	9.62(0.30)	2.33(0.13)	2.04(0.07)	4.14(0.29)	25.5	straw

S. D.: Standard Deviation   * hull color

components as listed in Table 4 and 5 became 4.25 tons/ha in brown rice, provided the average value of the spikelet number per panicle was reduced to 80 % of the value counted from panicles on the longest culm a hill and the percentages of ripened grains was 70 %.

On the other hand, plant height of the variety RD 8 cultivated in the field No. 15 (N) was less than half of the normal one of the variety found in the field No. 1 (N). The reduction was considered to have resulted from the severe drought during the vegetative period. On the contrary, soil drying during the younger stage of rice seemed to have enhanced tillering ability of the plants as shown by higher number of panicles per hill, but all of which were smaller ones on higher nodes of a culm initiated after later soil saturation. Rice plants in the field No. 16 (S), which were replanted after later rainfall, were still in the tillering stage.

Non-glutinous varieties, RD 23 and RD 21, which have been planted in the field No. 2 (S) and No. 5 (S), respectively, by the direct sowing method characterized by seeding with pre-germinated seeds, were showing excellent stands as shown in Fig. 9-10. Both the varieties belong to indica with the large length-width ratios (slender shape) of brown rice, 3.53 and 3.17 as listed in Table 5, respectively. Both varieties were very similar in their plant types as shorter plant height (less than 70 cm) and panicles with smaller number of spikelets a panicle as shown in Table 4-l. No lodging and almost no damages by pests and diseases were seen except for a little incidence of stem borer attack. No weeds were growing there and no drought damages were found throughout the fields as seen in Fig. 9-10. Because of such a high density of seeding as more than 500 hills per square metre, none of the hills had tillers except for one main stem bearing nearly the same length of panicle as shown in Table 4. As a result, rice yields in brown rice estimated from the yield components have registerd high values as 5.69 tons/ha in RD 23 and 6.38 tons/ha in RD 21, in the case of 70 % of the percentage of ripend grains.

2.2 In the extensive irrigation area (Bung Kae)

The irrigation system in the area mentioned above has been devised to take the water from the inlets constructed along the ditch and was efficiently functioned throughout the area by making use of the water through the gravity irrigation. As a result, no drought problems were found in the area as seen in Fig. 9-(3-5). Rice has been planted by the regular transplanting method. All of the varieties grown there were glutinous ones and RD 8 was a leading variety planted. No weeds and no damages by the pests and diseases were found throughout the area except for a slight infection by brown spot (*Cochliobolus miyabeanus)* and/or stem borers. On the other hand, light green color of the plants growing in the area has indicated that little or no fertilizer might have so far been applied in the field. Such sparse planting as less than 20 hills per square metre as shown in Table 4-2, accompanied with little fertilizer application, was considered to make such tall varieties as RD 8 and RD 6 (more than 100 cm of culm length) grow well, with almost no damages due to lodging and attacks by pests and diseases.

The yield estimates in brown rice of the varieties, RD 8 and RD 6, from the yield components as listed in Table 4 and 5, became less than 3.0 tons/ha in the cases of such smaller number of spikelets as less than 20,000 per square metre, which were due to smaller numbers of panicles per hill and sparse planting density. The highest yield in the area was 4.08 tons/ha of RD 8 in the field No. 4 (E) due to denser spacing as 24.3 hills/m^2. The calculations were made with the assumptions of 70 % of the percentage of ripend grains and 20 % reduction of the number of spikelets per panicle counted from a panicle on the longest stem a plant.

Although no serious problems in rice cultivation were found in the area, irregular shapes and small sizes of the fields without any land consolidation will become one of the most handicapped situations to enhance the mechanization of rice cultivation in the area in future.

2. 3 In the rainfed area (Ton)

Because of the extremely scarce rainfall in 1985 as mentioned above, rice cultivation in the rainfed area has completely been impracticable as shown in Fig. 9-l throughout the area except for some places lying on the relatively lower or the lowest level of land, where the rainfall had been gathered from the surface run-off and seepage through the soils and retained it to supply enough water for rice throughout the growth duration in the rainy season.

In the relatively lower level of the fields indicated by No. 1 (H) to No. 5 (H) in Table 4, rice plants were growing in very poor stands ; i. e. extremely retarded growth (Fig. 9-2), irregular tillering and flowering, and was still tillering stage of plants which were replanted after later rainfall. Almost all of the plants planted in this location have received serious drought damages in different levels.

On the other hand, in the lowest fields from No. 1 (L) to No. 4 (L) as shown in Table 4, all of which have been able to hold enough water in different levels as shown in the wide range of depth of standing water in the fields, glutinous variety RD 8 was growing well but was showing a little larger variation in plant height among hills and poorer stands with shorter plant height and smaller number of spikelets a panicle than that of the extensive irrigation area. Some incidence of brown spot disease throughout the area showed shortage of fertilizer application.

Table 6. Rice cultivation at three respective villages practising different irrigation systems; intensive (Song Pleuy), extensive (Bung Kae) and rainfed (Ton) ones, in 1984, in Khon Kaen Province. Data was collected by Tsuchiya et al. in 1985 through the hearing investigations from sampled farmers.

Item	Season	Intensive		Extensive		Kainfed	
		non-glu.	glu.	non-glu.	glu.	non glu.	glu.
1. Average acreage of paddy fields a farmer (ha)							
(1) Acreage owned		2.35		2.49		2.81	
(2) Acreage harvested	Rainy S.	1.01	1.18	0.50	1.86	0.21	2.56
	Dry S.	2.18		1.18	0.27		
2. Average yields (ton/ha)	Rainy S.	2.63	3.02	(2.44)	* 2.73	(1.34)	2.10
	Dry S.	2.78		3.06	(1.56)		—
3. Average labor hours (hrs./10a)	Rainy S.	83	93	(70)	83	(73)	66
	Dry S.	61		98	(88)	—	
4. Expenditures for fertilizer (Baht/10a)	Rainy S.	29.6	42.1	(20.9)	19.1	(8.3)	23.8
	Dry S.	62.7		45.2	(28.4)		
5. Numbers of agricultural machines and implements, and animals for work a farmer							
(1) Buffalo		0.67		2.10		2.40	
(2) Power cultivator		0.53		0.27		0.13	
(3) Plow with steel blade		0.27		1.10		1.13	
(4) Sickle		5.30		4.80		4.30	
(5) Hoe and weeder		2.60		2.90		3.50	
(6) Irrigation pump		0.13		0.13		0.40	
(7) Duster		0.60		0.67		0.40	
6. Names of varieties planted and the numbers of farmers (in parenthesis)	Rainy S.	RD23 (7) RD21 (2)	RD8 (9) S T (1)	LT (3)	RD6 (9) RD8 (7)	L T (1)	RD6 (7) RD8 (3) S T (2)
	Dry S.	RD23 (8) RD21 (4)		RD23 (5) RD21 (2) KD13 (2) RD3, LT (2)			

* LT, Lungtong ; ST, Sanpatong
The data in parenthesis may not completely be available for direct comparisons among the related data because of smaller acreages planted.

3. Outlines of the farm managements at the villages under different irrigation systems in 1984 (Date collected by Tsuchiya *et al.* in 1985)

The acreage of the fields owned by a farmer in the three villages investigated averaged 2.5 hectares and tended to decrease as the efficiency of land use becomes higher as shown in Table 6. The composition of rice varieties, glutinous and non-glutinous, were different due ‘to both the season planted and the irrigation systems adopted. Glutinous varieties were planted in the rainy season except the small acreage in the extensive irrigation area. The rates of acreage planted by glutinous varieties in the rainy season accounted for more than 90 % in the rainfed area in spite of the fact that nearly 50 % of non-glutinous varieties had been planted in the intensive irrigation area. On the other hand, rice cultivation in the dry season, conducted only in the

Table 7. Rice cultivations at Song Pleuy village in Khon Kaen in 1984, under intensive irrigation system due to Nong Wai Pioneer Project. Data was collected by Tsuchiya et al. in October in 1985.

Item	Rainy season Trans.	Rainy season Direct	Dry season Trans.	Dry season Direct
1. Number of farmers	7	4	3	11
2. Total acreages planted (ha)	6.08	9.12	3.72	28.92
3. Average acreage a farmer (ha)	0.87	2.28	1.24	2.63
4. Average yields (ton/ha)	2.61	2.68	3.73	2.52
5. Average labor hours (hs./10a)	95.3	62.4	106.0	48.7

6. Details of labor hours (hs./10a)	Transplanting	Direct sowing
A. Rainy Season		
(1) Transplanting (including nursery work) or direct sowing	42.2	3.3
(2) Replanting or resowing	3.3	1.6
(3) Water management	10.3	9.3
(4) Harvesting	26.6	39.6
(5) Threshing and winnowing	4.7	3.8
(6) Others	8.2	4.8
(7) Total	95.3	62.4
B. Dry Season		
(1) Transplanting (including nursery work) or direct sowing	20.6	2.9
(2) Replanting or resowing	5.1	1.0
(3) Water management	38.6	6.3
(4) Harvesting	34.3	31.1
(5) Threshing and winnowing	0.8	1.6
(6) Others	6.6	5.8
(7) Total	106.0	48.7

irrigated areas, were planted by non-glutinous varieties except for small acreage in the extensive irrigation area planted by non-glutinous ones.

Rice yields (paddy) estimated from the numbers of bags harvested by a farmer were generally ranging from about 2.0 to 3.0 tons/ha except for two cases of small acreage planted.

Especially in the rainy season large difference was observed in the data collected from the farmers through the hearing investigation (about 2.5 tons/ha) and the statistical data (1.30 tons/ha).

Labor hours employed in cultivating rice were greatly different between the rainy and dry seasons or different cultivation practices and among the three villages or different irrigation systems. It ranged from 61 to 98 hours per ten ares (0.1 ha). The largest labor hours needed for rice cultivation was found in the case of the cultivation of non-glutinous varieties in the area under the extensive irrigation system in the dry season, followed by that of glutinous varieties in the area under the intensive irrigation system in the rainy season. On the other hand, the least hours employed in rice cultivation was in the case of non-glutinous varieties for the intensive irrigation area during the dry season, followed by cultivation of glutinous varieties for the rainfed area during the rainy season.

The largest amount of the fertilizer applied or its purchasing cost spent for rice

Fig. 9 Rice cultivations under different irrigation systems, [redacted] (3-5) and intensive [redacted] irrigation systems in Khon Kaen, [redacted]hailand

cultivation was found in the case of non-glutinous varieties for the intensive irrigation area during the dry season. The cost was 40 % more than that spent in the extensive irrigation area for the non-glutinous varieties in the dry season. and nearly three times that in the rainfed area for glutinous varieties in the rainy season. These show that the irrigation system adopted in each of the areas had clearly changed the intensity of rice cultivation practices. The actual amount of the fertilizer applied, estimated from the price of about 250 Bt/50 kg synthetic chemical fertilizer (16 : 20 : 0) purchased by farmers, becomes only 20 kg/ha N in the case of 62.5 Bt/10a (0.1 ha) cost.

Conditions of the agricultural machines, implements and draft buffaloes possessed by the farmers in the intensive irrigation area have been distinctly different from those of the other two areas. As shown in Table 6 smaller number of buffaloes and plows, and slightly larger number of power cultivaters and sickles possessed by a farmer in the intensive irrigation area than those farmers in the other two areas, show the fact that mechanization of rice cultivation has been possible only in the irrigation system accompanied with land consolidation.

Relatively smaller number of varieties of rice had been cultivated throughout the areas investigated except for the dry season when it was cultivated in the extensive irrigation area. The most popular variety planted in the areas were RD 23 in the non-glutinous and RD 8 and RD 6 in the glutinous, all of which were newly bred in Thailand. These simplification in the varieties planted is due to the intensive activity of the extension workers in the areas. On the other hand, the large number of varieties planted in the extensive irrigation area in the dry season may indicate that the large variations in the environmental conditions occur in the fields of the area in the dry season.

As mentioned above, most of rice cultivation in the intensive irrigation area have been conducted by the direct sowing method. According to the information from the staff of the Khon Kaen Rice Experiment Station, the direct sowing method was introduced from the Central Plains region in 1980 and has become prevalent in some irrigated places. In direct sowing culivation about 12 kg/rai (7.5 kg/10a) seeds are directly sown in the field about two days (in the case of sandy soils) or three to five days (in the clayey soils) after germination, followed by weeding by flooding or rare hand weeding.

Table 7 shows the some characteristics of rice cultivation by the direct sowing method comparing with those of the transplanting method. Rice cultivation by direct sowing method has been conducted more prevalently in the dry season than in the rainy season. However rice yield in the dry season was higher in the transplanting cultivation than that of direct sowing method. The reduction of the yield (1.21 tons/ha in paddy) might have resulted from the uneven distribution or shortage of irrigation water as shown in Fig. 9-2.

Labor hours needed for rice cultivation in the area widely ranged from 49 to 106 hours per ten ares (0.1 ha) depending on the planting methods and the seasons planted. It was found that the least hours were required for rice cultivation in the case of direct sowing in the dry season. This has resulted from less hours needed for sowing, water management and harvesting practices. One of the problems found in the direct sowing cultivation may be the longer hours needed for harvesting in the rainy season.

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