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Geographical Distribution and Ecotypic Differentiation of Wild Rice in Thailand

by

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The origin of cultivated rice (*Oryza sativa* L.) has hitherto been studied by many researchers, mainly in two approaches. One is the genome analysis based on cytogenetics (MORINAGA *et al.*, 1943, HU, 1960, RICHHARIA, 1960, YEH, 1961, and LI *et al.*, 1964) and the other is the comparison of characters between wild and cultivated rices based on population genetics (MORISHIMA *et al.*, 1960, and OKA, 1964).

The present paper deals with the geographical distribution of wild rices in Thailand and the process of their ecotypic differentiation, by making comparisons of various characters between the wild and cultivated rices.

I Materials and Methods

The samples of wild rice were collected at the locations listed in Table 1 and shown in Fig. 1. Collection numbers from 1 to 15 are samples from northern Thailand, 16 to 26 are from northeast and 27 to 30 are from southern Thailand. A few panicles were usually taken as a sample at each site and these sampling sites were carefully plotted on a map to draw a geographical distribution of the wild rice samples.

All the samples were carried back to Japan and their characteristics were studied with the plants grown in a glass isolation house at the National Institute of Agricultural Sciences, Hiratsuka. Of the thirty samples of wild rice twenty that headed within 150 days were chosen for the principal component analysis together with one cultivated rice and ten samples of supposed-to-be natural hybrids. Numerical data of the nineteen characters responsible for ecotypic differentiation were taken in the present study. (Table 3)

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Table 1 Sampling Sites of Wild Rices in Thailand

Collection No.	Date	Places
1	Nov. 13	Muang, Chachoengsao
2	Nov. 16	Song Phi Nong, Suphan Buri
3	Nov. 18	Nong Khae, Saraburi
4	Nov. 18	Muang, Saraburi
5	Nov. 19	Takhli, Nakhon Sawan
6	Nov. 19	Khok Samrong, Lop Buri
7	Nov. 20	Khanu Woralaksaburi, Kamphaeng Phet
8	Nov. 11	Ko Kha, Lampang
9	Nov. 12	Hang Dong, Chiang Mai
10	Nov. 24	Muang, Mae Hong Son
11	Nov. 28	Muang, Chiang Rai
12	Nov. 29	Chiang Dao, Chiang Mai
13	Nov. 30	Fang, Chiang Mai
14	Dec. 3	Si Satchanalai, Sukhothai
15	Dec. 5	Muang, Sukhothai
16	Dec. 13	Muang, Nakhon Ratchasima
17	Dec. 14	Nang Rong, Buri Ram
18	Dec. 14	Prakhon Chai, Buri Ram
19	Dec. 16	Muang, Roi Et
20	Dec. 17	Yang Talat, Kalasin
21	Dec. 19	Nong Rua, Khon Kaen
22	Dec. 23	That Phanom, Nakhon Phanom
23	Dec. 22	Nong Han, Udon Thani
24	Dec. 26	Non Sung, Nakhon Ratchasima
25	Dec. 27	Muang, Nakhon Nayok
26	Jan. 4	Tha Muang, Kanchanaburi
27	Jan. 6	Thalang, Phuket
28	Jan. 7	Huai Yot, Trang
29	Jan. 11	Muang, Surat Thani
30	Jan. 13	Muang, Ratchaburi
Sampling Sites of Natural Hybrids between Cultivated and Wild Rices		
31～33	Jan. 7	Huai Yot, Trang
34～41	Dec. 27	Muang, Nakhon Nayok

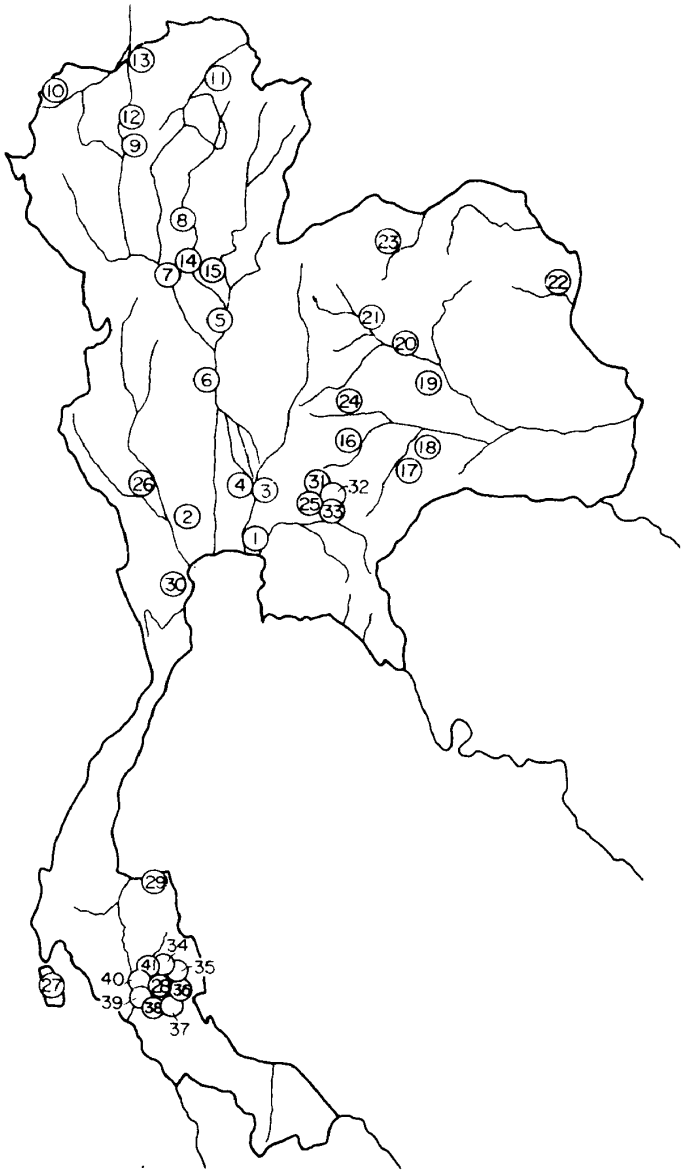

Fig. 1 Sampling Sites of Wild Rices (*O. f. spontanea and O. Perennis*)

II Results of Field Surveys and Experiments

1) Geographical distribution of wild rices

Fig. 2 shows a geographical distribution of wild rices in Thailand. Most of the wild rices are found to be either *Oryza sativa f. spontanea* or *O. perennis*. *O. granulata* reported in Burma and India is seen in a limited area of north Thailand, bordering Burma.

The wild rices are seen covering quite a large area in places provided with ample water during the rice growing season, such as many parts of the Chao Phraya basin, extending from northern to central Thailand. But in the Central part of the Bangkok

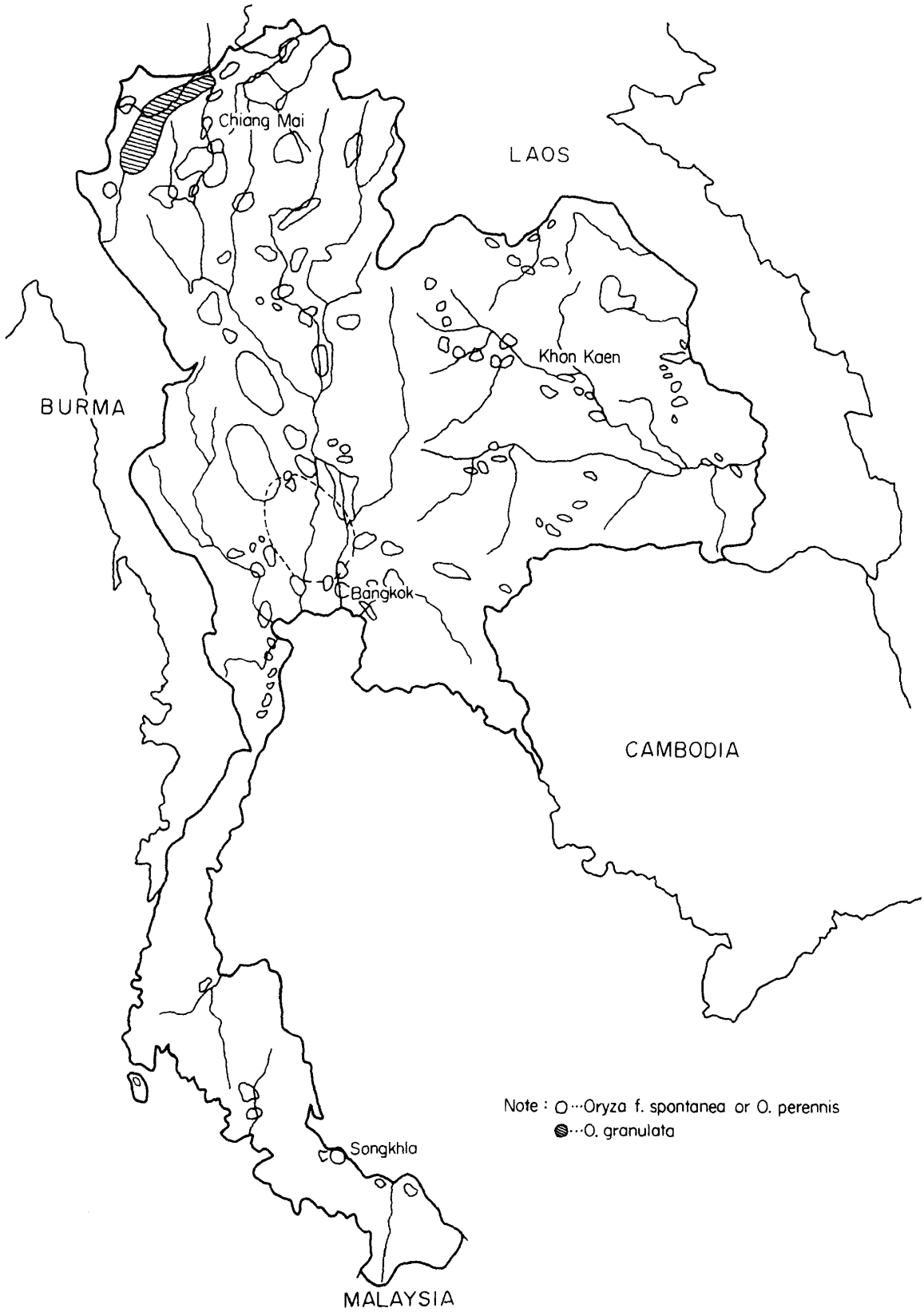

Fig. 2 Geographical Distribution of Wild Rices in Thailand

plain no wild rice is found other than those of floating type, presumably because of an extremely high level of water during the rice growing season.

In northeast Thailand the wild rices have only been found in scattered swamps which are suspected to be remnants of old artificial reservoir for irrigation. The extent of the growing area is, therefore, smaller than that of northern and central Thailand. It is to be noted, in this connection, that our sampling sites coincide with the high yielding area of cultivated rice.

In southern Thailand the wild rice is very rare and only four or five places of small area are plotted (Fig. 1 and Fig. 2). This southern part of peninsular Thailand is blessed with much rain even during the dry season of the continental part of Thailand. So flourishing woods are formed. But paddy fields are rare despite a noticeable cultivation of rubber and sugarcane. The wild rices of southern Thailand appear to grow in the environment completely different from that of central or northern Thailand.

2) Ecotypic differentiation of wild rices

The dimensions of the collected spikelets of wild rice are given in Table 2.

Oka (1964) reported that *Oryza perennis* has a wider length-breadth ratio (L/B ratio) than *O. sativa f. spontanea*. Among the samples investigated the collection number 8, 9, 11, 12, 17, 23, 24, and 27 have spikelets with L/B ratios wider than 3.50. The collection No. 23 is a wild rice of floating type collected from a pond in a ravine of northeast Thailand. These samples with wider L/B ratios are supposed to be *O. perennis*.

Two mixed populations of wild and cultivated types were discovered. Many plants with wide range of genetic variations were sampled (collection numbers 31 through 41) from these mixed populations. These natural hybrids(?) were formed probably because the genes of the cultivated population had flowed into wild populations. The samples had, as shown in Table 2, longer spikelets with wider L/B ratios. They also had slightly less shattering character than pure wild type, and their spikelet colours were not always black. The cultivated rice in these areas has been grown under the protection of mankind, whereas the wild rice has been neglected as weed and left untouched on lanes of paddy field.

The wild rice grown next to the paddy field might have been pollinated with the pollens of cultivated rice and the introgressive hybridization has occurred in the wild rice populations. As a result of this, the wild rices became similar to the cultivated ones.

Table 3 shows the mean value of each character analyzed in the principal component analysis. Fig. 3 shows a scatter diagram of local wild ecotypes with the first and the second principal components. Component score in the first component was negative for the cultivated type and positive for the wild type, whereas the signes were reversed for re-

spective types in the second component. It is also observed in Fig. 3 that the natural hybrids and the wild rices of central Thailand make up one group, while the wild rices of northern and northeast Thailand are scattered widely in the graph, suggesting that they contain various kinds of ecotypes.

Another evidence to show a wide range of variation in ecotypes of wild rice is demon-

Table 2 Geographical Variation in Characters of Wild Rices

Collection No.		Awn Length (mm)	Spikelet length (mm)	Spikelet width (mm)	Length/Breadth ratio
1		67.4	8.36	2.59	3.22
2		74.2	9.40	2.88	3.26
3		55.8	8.25	2.56	3.22
4		49.4	7.71	2.58	2.99
5		79.2	8.52	2.46	3.46
6		58.6	8.31	2.58	3.23
7		67.0	8.02	2.58	3.11
⑧		58.8	8.66	2.30	3.77
⑨		31.4	8.39	2.23	3.76
10		84.8	8.03	2.44	3.29
⑪		53.5	8.69	2.33	3.73
⑫		52.4	8.59	2.10	4.09
13		45.6	9.24	2.98	3.10
14		70.4	9.24	2.64	3.49
15		62.0	7.24	2.49	2.90
16		81.0	9.62	3.14	3.06
⑰		45.8	7.86	2.23	3.52
18		64.6	8.10	2.48	3.27
19		56.2	7.48	2.28	3.29
20		51.0	7.22	2.33	3.10
21		46.8	7.44	2.51	2.96
22		41.4	7.40	2.27	3.26
㉓	(floating habit)	33.5	8.20	2.31	3.54
㉔		38.6	7.66	2.03	3.77
25		62.0	9.08	2.64	3.44
26		48.8	8.54	2.59	3.29
㉗		45.0	9.39	1.91	4.93
28		38.4	8.15	2.59	3.14
29		40.3	8.00	2.41	3.31
30		64.8	7.75	2.37	3.27
	Natural Hybrid				
31		50.6	8.69	2.32	3.71
32		40.1	8.70	2.51	3.47
33	(Cultivated)	—	7.82	3.09	2.53
34		84.0	8.80	2.51	3.51
35		53.5	8.75	2.57	3.40
36		40.5	9.57	2.37	4.05
㊲		44.0	8.88	2.71	3.27
38		31.7	9.07	2.54	3.57
39		44.3	10.11	2.72	3.71
40		51.3	9.37	2.99	3.13
41		33.0	9.72	2.53	3.86

Note : Collection Nos. encircled have L/B ratios wider than 3.50.

Table 3 Characters used in Principal Component Analysis of Wild Rices and Natural Hybrids

Col. no.	*GDH*	*CL*	*PL*	*NE*	*FL*	*TF*	*AF*	*AUL*	*ANF*	*BUN*	*LUI*	*NPR*	*SF*	*AL*	*SL*	*SW*	*ANL*	*AW*	*NSR*	
1	113	52	14	4	22	0.22	12.4	34.6	20	55	4.0	4	93.1	67	8.4	2.6	1.3	0.16	0	Wild Rice
2	91	68	19	4	17	0.24	7.4	30.7	20	50	0.0	7	60.6	74	9.4	2.8	0.7	0.22	3	〃
3	90	57	16	4	17	0.22	9.2	35.1	40	25	2.2	7	94.6	56	8.3	2.6	1.0	0.24	2	〃
5	93	104	18	5	18	0.33	25.5	89.9	100	50	13.0	8	86.5	79	8.5	2.5	1.5	0.22	2	〃
6	80	84	11	4	18	0.24	13.7	73.0	50	37	4.9	10	74.7	59	8.3	2.6	0.9	0.22	9	〃
7	96	76	17	5	15	0.37	9.5	41.8	40	40	1.2	8	85.1	67	8.0	2.6	0.9	0.20	1	〃
12	100	105	27	7	35	0.30	33.0	110.4	40	60	3.5	9	10.1	52	8.6	2.1	1.4	0.30	0	〃
13	86	125	22	6	19	0.35	15.1	64.1	20	33	16.0	9	53.2	46	9.2	3.0	1.4	0.21	5	〃
14	90	135	24	5	24	0.22	17.9	91.4	13	15	9.0	8	31.2	70	9.2	2.6	1.3	0.20	5	〃
18	88	141	20	9	17	0.31	11.5	32.7	30	40	6.3	9	35.9	65	8.1	2.5	0.6	0.22	2	〃
19	103	102	21	5	15	0.23	8.2	45.1	15	35	3.0	8	96.6	56	7.5	2.3	0.9	0.25	2	〃
20	91	82	16	5	13	0.22	4.3	28.1	22	30	6.5	7	93.5	51	7.2	2.3	0.6	0.20	1	〃
21	132	81	17	4	23	0.24	40.0	94.3	23	50	11.2	5	24.0	47	7.4	2.5	1.1	0.31	3	〃
22	91	72	17	4	25	0.28	14.5	48.0	34	140	4.7	6	96.2	41	7.4	2.3	0.7	0.12	5	〃
23	90	123	17	6	19	0.24	13.3	42.1	115	5	28.0	6	87.2	34	8.2	2.3	1.3	0.20	1	〃
25	91	98	17	6	19	0.26	14.2	69.7	90	40	18.0	11	69.2	38	7.7	2.0	1.1	0.20	3	〃
26	83	65	18	4	17	0.26	9.4	29.6	17	7	0.0	7	94.6	49	8.5	2.6	1.1	0.21	3	〃
28	96	81	18	6	18	0.19	11.9	54.4	50	10	0.0	8	13.3	38	8.2	2.6	0.9	0.26	1	〃
29	115	113	17	4	36	0.29	16.0	52.0	130	40	21.0	8	3.3	40	8.0	2.4	1.2	0.18	0	〃
30	84	52	14	4	21	0.20	15.0	62.0	30	50	8.0	7	80.4	65	7.8	2.4	1.2	0.26	2	〃
31	98	81	15	6	15	0.27	5.8	30.1	20	35	2.0	4	83.3	70	8.7	2.7	1.5	0.26	1	Natural Hybrid
32	115	93	19	6	23	0.19	12.1	39.3	15	45	5.0	5	35.5	40	8.7	2.5	1.3	0.45	3	〃
33	98	71	18	5	22	0.22	12.2	50.1	10	10	4.0	7	74.1	0	7.2	3.8	0.9	0.32	11	Cultivated Rice
34	100	81	17	4	27	0.13	14.1	45.4	20	40	0.0	5	38.9	50	8.8	2.5	1.1	0.33	2	Natural Hybrid
35	113	104	16	7	19	0.16	11.6	56.8	15	30	8.0	7	87.1	50	8.6	2.4	1.6	0.33	2	〃
36	115	73	15	5	14	0.25	8.8	21.8	15	35	6.0	5	90.3	100	9.7	2.7	0.9	0.26	0	〃
37	99	95	18	6	26	0.20	18.8	73.7	20	10	0.9	7	88.2	100	9.0	3.6	1.3	0.35	2	〃
38	105	58	17	5	22	0.29	13.1	40.8	20	40	4.0	6	69.2	70	9.4	3.4	1.0	0.40	1	〃
39	106	80	24	5	27	0.21	16.3	53.0	50	20	1.5	9	77.1	70	10.5	3.6	1.2	0.25	2	〃
40	96	73	19	4	27	0.38	16.5	53.1	30	35	1.0	8	76.7	60	9.4	3.8	1.1	0.23	2	〃
41	104	56	15	4	28	0.13	8.4	25.5	30	20	0.0	4	50.0	30	9.6	2.3	1.1	0.40	1	〃

Note : *GDH*: Growth duration before heading (day), *CL*: Culm length(cm), *PL*: Panicle length(cm), *NE*: Nos. of elongated internode, *FL*: Length of flagleaf (cm), *TF*: Thickness of flagleaf (mm), *AF*: Area of flagleaf (cm^2), *AUL*: Area of upper three leaves (cm^2), *ANF*: Angle of flagleaf, *BUN*: Bending of uppermost node, *LUI*: Length of uppermost internode (cm), *NPR*: Nos. of primary rachis, *SF*: Self-fertility (%), *AL*: Awn length (mm), *SL*: Spikelet length (mm), *SW*: Spikelet width (mm), *ANL*: Anther length (mm), *AW*: Anther width (mm), *NSR*: Nos. of secondary rachis.

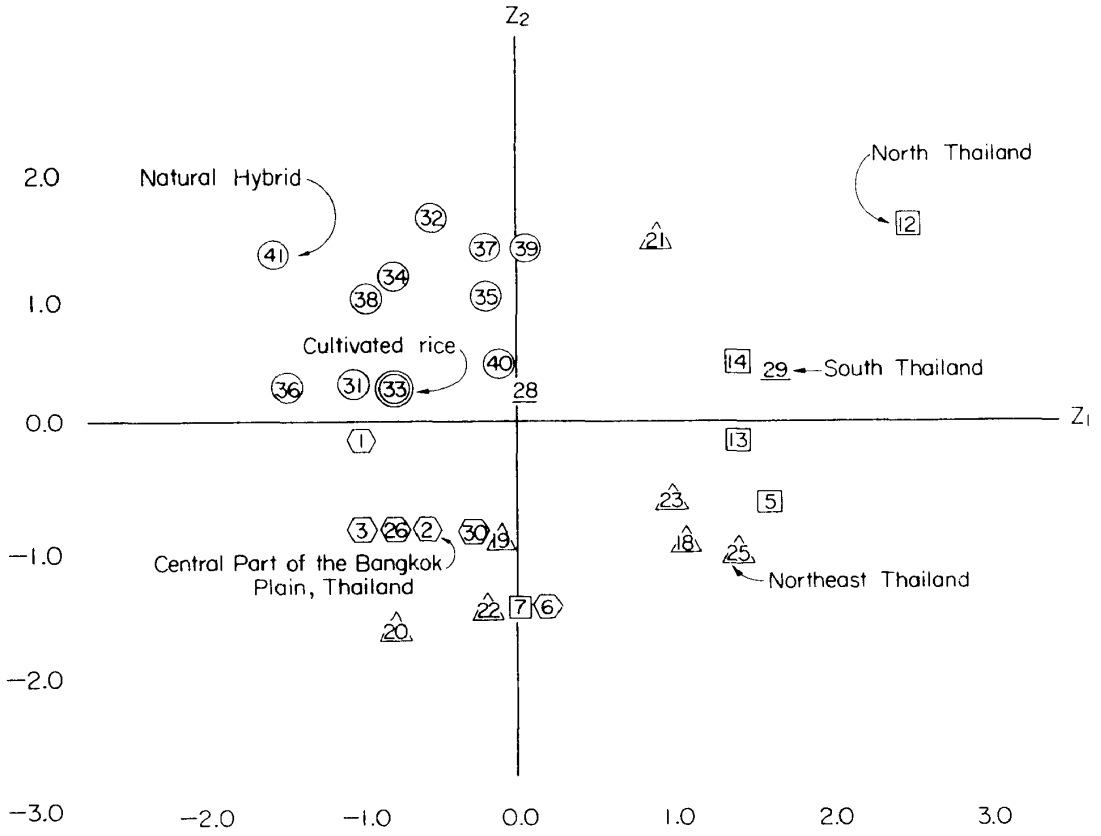

Fig. 3 Scatter Diagram of Local Ecotypes of Wild Rices in Thailand in Four-dimensional Space Projected to the (Z_1–Z_2) Plane
Z_1 : First principal component, Z_2 : Second principal component
Note : ○…Natural hybrid, ◎…Cultivated rice, ⬡…Central part of the Bangkok Plain, Thailand, □…North Thailand, △…Northeast Thailand, —…South Thailand

strated in Fig. 4, which shows a scatter diagram with the fourth and the sixth principal components. Component score of the cultivated type was positive for the fourth component but negative for the sixth component. As the collection No. 18 is located quite opposite to the cultivated collection No. 33, the former is supposed to be a typical example of the wild rice type. This wild collection No. 18 has a longer culm with bending nodes, lower self-fertility, and fewer secondary rachis as compared to the cultivated sample (collection No. 33). Fig. 4 shows that the natural hybrids have a wide range of variation, while the widest diversity was observed in the wild collections of northeast Thailand.

III Discussions

Five kinds of wild rice, *Oryza sativa f. spontanea, O. perennis, O. officinalis, O. granulata,* and *O. ridleyi* have so far been reported to grow in Thailand (Oka, 1958, Tateoka, 1964). But the authors could not collect the samples of *O. officinalis* and *O. ridleyi.*

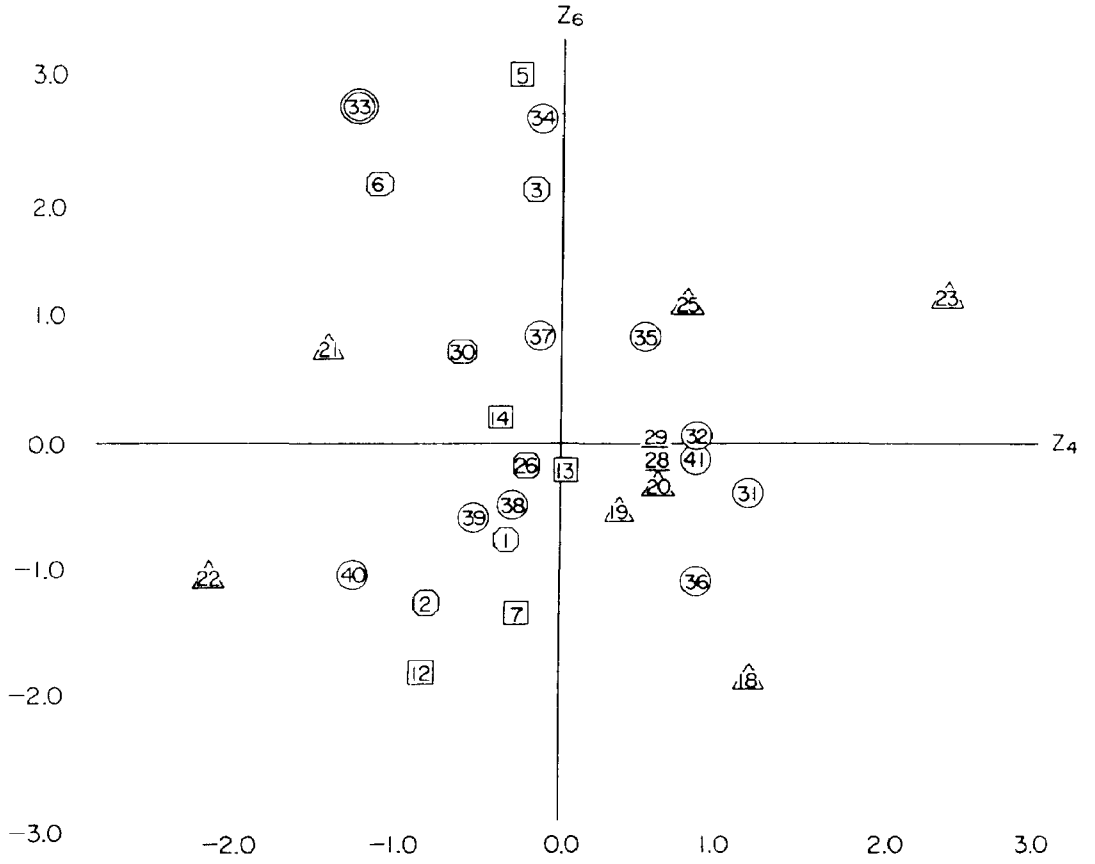

Fig. 4 Scatter Diagram of Local Ecotypes of Wild Rices in Thailand in Four-dimensional Space Projected to the (Z_4–Z_6) Plane
Z_4: Fourth principal component, Z_6 : Sixth principal component

The distribution of *O. sativa f. spontanea* and *O. perennis*, as shown in Fig. 2, indicates that the areas supplied with water in abundance during the rice growing season are prefered by these wild rices and these areas coincide quite well with the productive areas for rice cultivation. Furthermore, these areas are closely associated with human habitats, particularly in the case of northeast Thailand, where the wild rice has survived in the ponds constructed in old days. It is also interesting to note here that the growing areas of wild rices seem to cover old village areas which were disclosed through ethnological studies by Ishii *et al.* (1967).

The results of the present study revealed some facets of ecotypic differentiation of wild rices. The collected samples of wild rices, *Oryza sativa f. spontanea* and *O. perennis* show a considerable differentiation of ecotypes, particularly those from north and northeast Thailand prove to have differentiated into distinct ecotypes. In this connection, the fact that the wild rice coexists always with the cultivated one should not be overlooked. Thus, the introgressive hybrids of the wild rice produced by repeated polinations with the cultivated rice pollens have come to exist, resulting in close resemblance of wild rices to the cultivated ones in such characters as growth duration, area of upper three leaves and self-fertility.

IV Summary

1) Geographical distributions of the wild rices, *Oryza sativa f. spontanea* and *O. perennis* were mapped after an extensive collection covering almost all areas in Thailand.

2) The wild rices are found to distribute in swamp areas in dry season. The cultivated rice grows well also in these areas. So the suitable area for rice cultivation might be judged from the distribution of the wild rices.

3) Collected samples were raised in a green house in order to investigate the nineteen characters in detail by the use of the principal component analysis. The ecotypes of the samples collected from north and northeast Thailand had a wide range of variation.

4) The characters that seem responsible for ecotypic differentiations are self-fertility, length-breadth ratio of grains, bending of nodes, length of uppermost internode, etc.

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