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Expansion of an Improved Variety into Rain-fed Rice Cultivation in Northeast Thailand

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Abstract

Indigenous glutinous rice varieties have recently been replaced with an improved variety, RD6, in Northeast Thailand. The good cooking quality and high yielding ability of RD6 have induced many farmers to plant it in their paddy fields. Productivity per planted field in the surveyed village has increased due to the planting of RD6 as well as the adoption of power tillers, subsidiary irrigation and fertilizers. This variety, a panicle-number type, tends to increase yields more easily than the old varieties when planted densely in the appropriate season with judicious fertilizer management under conditions of no drought and no inundation. Nevertheless, the instability of rice production caused by flood and drought is yet to be resolved in rain-fed cultivation. Planting RD6 in an unsuitable area normally fails to produce a good harvest. More improved varieties for rain-fed cultivation should be released in this region.

I Introduction

Since the release of the semi-dwarf high-yielding rice variety IR8 by the International Rice Research Institute in 1965, modern improved rice varieties have expanded to cover 74% of the rice-growing area in South and Southeast Asia [International Rice Research Institute 1993]. Most of these varieties have short culms and are non-photosensitive, which result in a high yield response to appropriate fertilizers in irrigated paddy fields. Despite the success of the improved varieties in irrigated areas, however, these characteristics of the rice plant are said to hinder the spread of these varieties in rain-fed rice-cultivation areas. Because there is no regulation of water in paddy fields, such short rice plants are damaged by deep waterlogging ; and at times of water shortage, fertilizer dressing enhances drought damage. For these reasons, the fear of crop failure has discouraged farmers from investment in seed and chemical fertilizers for semi-dwarf high-yielding varieties in rain-fed rice-cultivation areas.

Although the area of irrigable paddy land in South and Southeast Asia is estimated as 20% of the total paddy area, modern varieties now cover more than this proportion. This means that modern varieties are planted in the adverse areas for rice growing, like rain-fed paddy fields. This is the situation in rice-growing areas in Northeast Thailand.

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Rice cultivation there is characterized by lower yields and greater instability than in the rest of Thailand.

Rain-fed rice cultivation in Don Daeng village of Northeast Thailand was studied by the author and his colleagues in 1981 and 1983. They reported that the general situation had shown no remarkable changes since the 1960s, when K. Mizuno carried out an anthropological survey in the area [Mizuno 1981], although some farmers had begun to use power tillers or chemical fertilizers. A further survey was carried out from June 1991 to June 1992. The major change recognized was acreage expansion of the modern improved glutinous rice variety RD6, which was released in 1977 for the Northern and Northeastern regions by the Rice Division of Thailand. Peasant farmers prefer planting glutinous rice to the non-glutinous type there. In the Northeast, especially in northern part of the Mun River basin, glutinous rice is the main staple food. For example, approximately 90% of the paddy fields in Don Daeng were planted to many glutinous rice varieties in 1981 and 1983.

RD6 was improved from *Khao Dawk Mali* 105 (KDML105) by active radiation breeding. It is photosensitive, as is KDML105, but taller [Bunduang and Uchin 1990: 13–14].

It is hoped that the elucidation of the process and the cause of extension of the improved rice variety in rain-fed paddy fields in Northeast Thailand in this article will contribute to the improvement of rain-fed rice cultivation worldwide.

II Research Sites

Two villages, Don Daeng in Muang district of Khon Kaen province and Na Hom in Kham Khuan Kaeo district of Yasothon province, were selected for this intensive survey (Fig. 1). Don Daeng is a typical, small village in the commercial sphere of Khon Kaen City, which has recently seen rapid growth as the core city in the midwestern part of the Northeast. Villagers have many opportunities for off-farm jobs there, and a ready market for their vegetables and other products. Most of the paddy land of Don Daeng lies in the floodplain between the Chi River to the north of the village and the low hills to the south, where cassava is grown as a commertial upland crop. Paddy soils belong to the Alluvial Complex Soil series.

Na Hom is a typical small village on the outskirts of Yasothon, a small city in the southeastern part of the Northeast, which is too small to provide many employment opportunities for villagers in the suburbs. Most of the paddy land of Na Hom lies on a large isolated hill. The soils belong to the Ubon series and have lower water retentivity and less nutrients than paddy soils in Don Daeng. Villagers have no land to grow upland crops and vegetables as commercial products.

Villagers who are Thai-Laos depend for their livelihood on rain-fed cultivation of glutinous rice. Mean rainfall for the period from 1980 to 1991 was 1,169 mm/year in Don Daeng (measured at Tha Phla, 5 km west of Don Daeng) and 1,354 mm/year in Na Hom

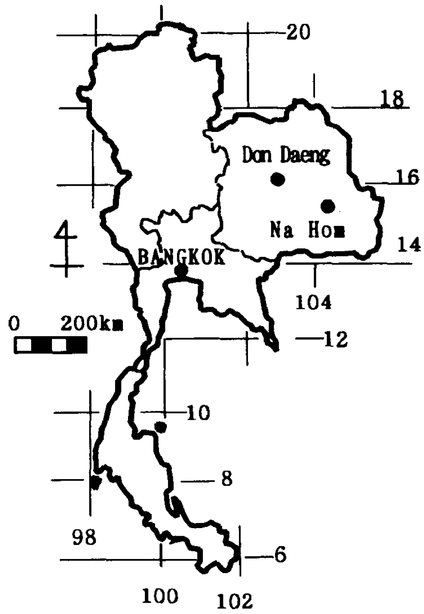

Fig. 1 Villages of Research Sites

(measured at Lumphuk, 9 km northwest of Na Hom). Rainfall distribution during the rice growing season in the surveyed years was as shown in Fig. 2. Don Daeng is in the "rain shadow" area of the Northeast, where crops frequently suffer from alternate drought and flooding stress. Hence, its rice production level is considerably less stable than that of Na Hom [Kaida *et al.* 1985 : 252–254 ; Konchan *et al.* 1990 : 20].

To survey the prevalence of RD6, headmen of 237 villages were interviewed. They consisted of 13 in Nakhon Ratchashima, 8 in Buriram, 8 in Surin, 11 in Sisaket, 21 in Ubon Ratchathani, 26 in Yasothon, 22 in Roi Et, 12 in Kalasin, 21 in Maha Sarakham, 33 in Khon Kaen, 6 in Chayaphum, 6 in Loei, 18 in Udon Thani, 9 in Non Khai, 9 in Sakhon Nakhon, 9 in Nakhon Phanom and 2 in Mukudahan province. Although villages were selected in the vicinity of highways or local major roads, the results were thought to give a fair indication of the general situation of RD6 expansion in the Northeast.

III The Prevalence of RD6

III–1 *Don Daeng Village*

Various rice varieties were identified in the 6,008 plots of 207 farmers' paddy fields, covering an area of 403 ha, in 1981, and in the 4,768 plots of 157 farmers' paddy fields, with an area of 343 ha, in 1983. In 1991, the author interviewed 178 farmers on rice varieties planted and their acreage.

The results showed that 27 and 24 varieties were planted in 1981 and 1983 respectively. The most popular variety was *Khao Kasetyai*, a late-maturing glutinous variety. It occupied 46% of the total paddy area in 1981 and 42% in 1983. RD6 was scarcely planted

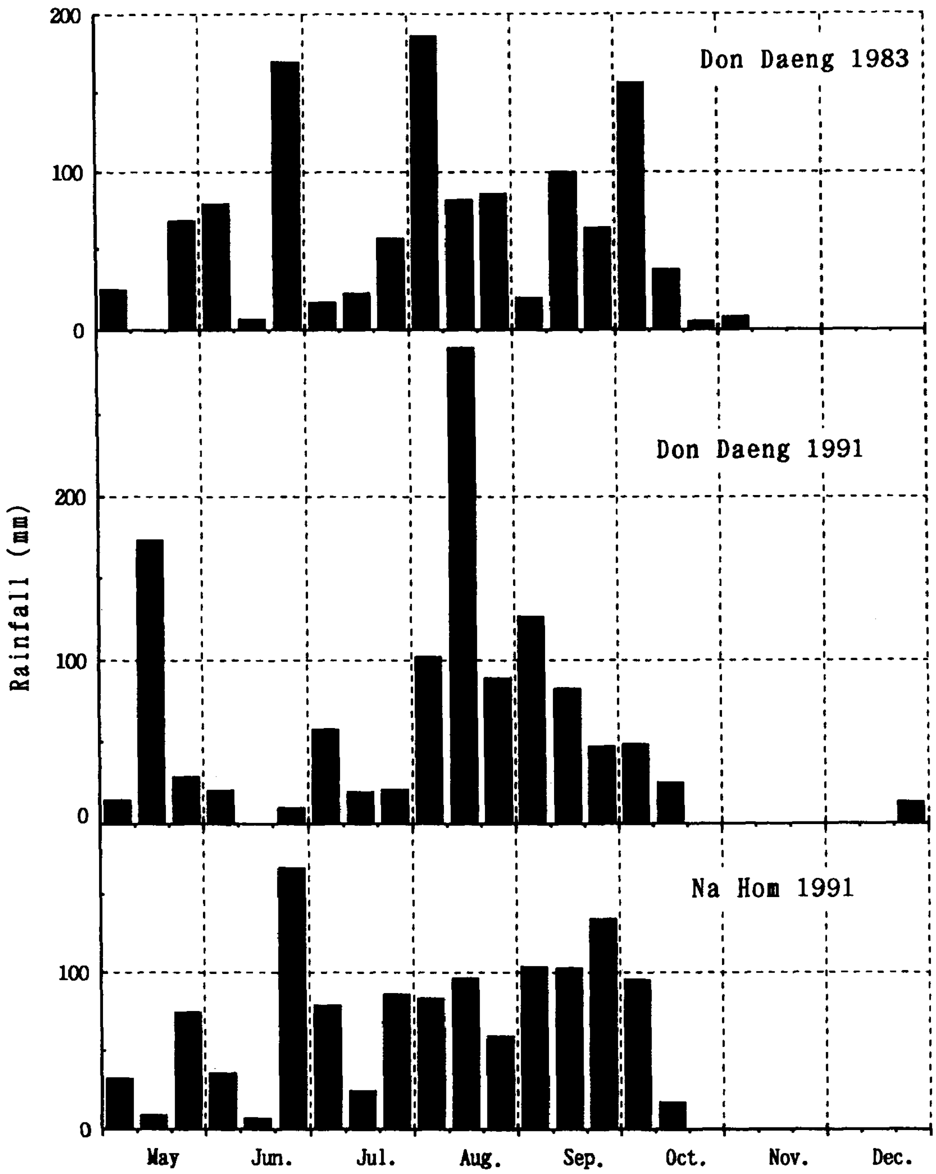

Fig. 2 Rainfall Distribution during the Rice-growing Season

at that time (Table 1).

In 1991, the number of varieties planted had fallen to 11, consisting of 7 glutinous and 4 non-glutinous varieties. RD6 occupied the largest planted area among them. The percent of the area planted to RD6 was much larger than that of *Khao Kasetyai* in the 1980s. Currently, the number of farmers planting RD6 has increased tremendously. The total area planted to RD6 and its parent variety, KDML105, has reached 88.4%.

III-2 *Na Hom Village*

One hundred and fifty-one farmers were interviewed about the rice varieties used and the area they planted. RD6 was planted by almost the same percentage of farmers as in Don

Table 1 RD6 Cultivation in Don Daeng and Na Hom

Village	Year	% Farmers		% Area Planted		% Area Planted to Glutinous Rice	
		KKY*	RD6	KKY	RD6	KKY	RD6
Don Daeng	1981	86.9	0.4	45.7	0.2	48.9	0.2
	1983	89.0	0.9	42.1	0.3	47.6	0.3
	1991	1.7	91.5	0.2	73.9	0.3	89.5
Na Hom	1991	0.0	87.6	0.0	44.8	0.0	94.9

* *Khao Kasetyai*

Daeng (Table 1). A total of four varieties was counted at that time, although in the past many varieties had been planted, as in Don Daeng. The percentage area allocated to RD 6 was less than in Don Daeng because of the large area planted to non-glutinous rice varieties for sale. However, 97.2% of the total area planted was occupied by RD6 and KDML105 in this village.

III–3 *Northeast Region*

Of 221 villages where glutinous rice was grown, 199 (90.3%) were planting RD6 as the main variety. In addition, 66 (29.9%) of the glutinous rice-growing villages were planting only RD6 as a glutinous variety. Two villages were planting only RD6 without any other variety. These results show that RD6 was dominant not only in Don Daeng and Na Hom but in all the glutinous rice-growing villages of Northeast Thailand.

IV Process of RD6 Expansion and Its Reputation among Farmers

Fifty-one farmers in Don Daeng and 42 farmers in Na Hom who were planting RD6 widely in their paddy fields were interviewed on the extent of RD6 expansion among villagers. Table 2 shows the planting history of RD6 before 1991 in the two villages. In Don Daeng, the number of years of planting was less than in Na Hom. Almost all farmers in Don Daeng had begun planting RD6 within the past 6 years, whereas in Na Hom many farmers had been planting it for more than 10 years.

Early RD6 adoption is related to the use of chemical fertilizer in Na Hom from the 1970s. As stated in Chapter II, soil fertility of paddy fields is lower in Na Hom, therefore, even a light fertilizer dressing is clearly effective in raising yields [Konchan *et al.* 1990 : 20–22]. The more stable rainfall there has also contributed to effective fertilizer dressing. In contrast, the effects of fertilizer dressing are often masked by higher soil fertility and

Table 2 Number of Years of Planting RD6

Village	1–3	4–6	7–9	10–12	13–
Don Daeng	41.3%	33.3%	9.8%	15.7%	0.0%
Na Hom	9.6	28.5	2.4	47.6	12.0

drought damage in Don Daeng, as mentioned in V–3. RD6 shows a better yield response to fertilizer application than indigenous varieties. Farmers in Don Daeng started to use chemical fertilizers in paddy fields from the 1980s as described in Chapter V.

In sum, the results presented in Table 1 indicate a rapid expansion of RD6 planting during the latter half of the 1980s in Don Daeng.

RD6 adoption in Don Daeng was through farmer-farmer contact (Table 3). Adoption at Na Hom, in contrast, was through recommendation by extension workers and other villagers. Seeds was supplied to the farmers of Don Daeng by villagers in the same village and by relatives in other villages, whereas in Na Hom, it was mostly supplied by extension workers.

These findings indicate that, the rapid spread of information on RD6 in the Don Daeng community was the result of communication among villagers. The agricultural center near Don Daeng seems to have played little part in the spread of RD6 in the beginning, except for its role as seed supplier. In Na Hom, however, the spread of RD6 was the result of the activity of extension workers over 10 or more years. In conclusion, RD6 expansion in the Northeast region might be attributed not only to government agencies' efforts but also to broad communication among farmers.

In the farmers' opinions of RD6, its merits lay in two points: (1) grain quality and taste, and (2) productivity. Its good quality and taste were recognized by 55% of farmers in Don Daeng and 36% of farmers in Na Hom. They appreciated that RD6 rice that had been steamed in the morning maintained its soft quality till evening. The higher yielding ability of the crop was praised by 45% of farmers in Don Daeng and 61% of farmers in Na Hom. Farmers recognized its higher productivity of tillers and panicles. Only one farmer in Na Hom mentioned its higher selling price than other glutinous varieties, though no significant price difference was revealed by the interview survey on production in 1991. In general, farmers in Na Hom tended to evaluate RD6 in terms of productivity, while farmers in Don Daeng were more concerned with its cooking and taste qualities.

As described above, farmers recognized that RD6 produces more tillers and panicles than the previous varieties. This property could be linked to its higher yield response to appropriate fertilizer use and the high genetic productivity potential of the rice variety. RD6 inherited this higher panicle productivity characteristic from KDML105, as reported in the former survey in Don Daeng [Miyagawa and Kuroda 1988b].

Concerning the demerits of RD6, 48% of farmers in Don Daeng and 77% of farmers in

Table 3 Process of RD6 Adoption

	Village	Other Villager	Relative in Other Village	Village Headman	Extension Worker	Agricultural Center
Recom-mender	Don Daeng	70.6%	9.8%	13.7%	3.9%	2.0%
	Na Hom	37.5	2.5	22.5	37.5	0.0
Seed supplier	Don Daeng	45.1	13.7	0.0	7.8	33.3
	Na Hom	7.2	4.8	0.0	83.3	4.8

Na Hom pointed out its susceptibility to diseases. Also, 13% of farmers in Na Hom but only 3 % of farmers in Don Daeng pointed out its susceptibility to insect attack (stem borers). On the other hand, 38% of farmers in Don Daeng, but only 3 % in Na Hom, complained of its short culm. Farmers in Na Hom were more concerned about RD6's susceptibility to both diseases and insect pests than farmers in Don Daeng. This might be related to the earlier noted differences in evaluation of yielding ability between the villages. From my field observations during the heading stage, white panicle initiation showing stem borer attack was more widely recognized in 1991 than in the 1980s in Don Daeng.

RD6 was regarded as resistant to drought by 2 % of farmers in each village. The same number of farmers, on the other hand, considered RD6 not to be a drought-resistant variety. Such results provide no evidence that RD6 introduction into the rain-fed paddy fields has contributed to stable rice production in these areas.

As a demerit, the short culm of RD6 might result in reduced yields due to submergence of rice plants when this variety is planted in low-lying paddy fields in Don Daeng. Before the introduction of RD6, farmers avoided this problem by planting indigenous late-maturing varieties with longer culms. And they avoided the drought hazard in the higher paddy fields by planting indigenous early-maturing varieties. Now these varieties have completely vanished, being replaced in all locations by RD6, which is medium-maturing. If farmers planted RD6 only under appropriate water conditions in their fields, such problems could be averted. There were few submergence problems in Na Hom because of the natural surroundings, as described in Chapter II.

Thus it was concluded that differences in the reputation of RD6 between villages depend on differences not only in planting history but also in the landform around the paddy fields, soil fertility and fertilizer use in general [Miyagawa 1993].

It is also remarkable that farmers attach as much, or, in Don Daeng, more value to the cooking quality of RD6 as to its yielding ability. This cooking quality is unrelated to any commercial value but is important for home consumption. It seems some curious that farmers have been asking for good-tasting rice, though they have suffered from instability of rice production in rain-fed cultivation. In Don Daeng, the village economy was almost entirely dependent upon non-agricultural income in the 1980s and the contribution of the rice-growing sector was very small [Funahashi 1990 : 179]. Rice was seldom sold. There was thus little incentive among farmers to increase production of highly marketable varieties like KDML105.

V Changes of Rice Cultivation as Related to RD6 Acreage Expansion in Don Daeng

V-1 *Irrigation, Machinery and Fertilizer*

In 1983, 42 farmers owned small gasoline-powered pumps and were using them for nursery beds, land preparation before transplanting and coping with severe drought. In 1991, 83% of the farmers in Don Daeng used pumps with gasoline- or diesel-powered engines and/or a electric motor. Irrigation in the area was boosted to cover one third of the total paddy area in 1991, as a result of the construction of a medium-scale pump station in 1983 on the bank of the Chi River in Ban Lao Nokchum village near Don Daeng. Using these facilities, farmers were able to transplant at the appropriate time and cope up with the drought during or after the monsoon.

From 1983 to 1991, the number of farmers owning power tillers increased tremendously from 1 to 20. Currently, 81% of farmers cultivate their paddy fields by machinery. Power tiller usage has many merits for farmers; labor-saving, and quick plowing and harrowing. Through quick plowing and harrowing, farmers can transplant rice seedlings under ideal water conditions in their paddy fields, i.e., 20 cm of water depth, which seldom occurs even during the rainy season. With irrigation, this machinery use allowed earlier planting of healthier young seedlings, and resulted in a higher ratio of planted area to total paddy area than in the past.

Chemical fertilizer application to planted fields also increased among farmers, from 0% in 1981, through 3% in 1983, to 67% in 1991. Paddy fields where water conditions were improved by irrigation became able to accept some fertilizers. Farmers would tend to look for better growth of the rice plant after overcoming the uncertainties of planting. A larger as well as more stable ratio of planted area to total paddy area as a result of irrigation and machinery might induce more widespread fertilizer use. These factors might have encouraged the cultivation of high-yielding varieties such as RD6 in Don Daeng.

V-2 *Correlation between Landforms, Rice Variety and Cropping Season*

Many shallow saucer-shaped landforms called *nong* are located around Don Daeng. The villagers' paddy fields are scattered in about twenty *nong* of various sizes. Water conditions of paddy fields vary according to the topography inside the *nong*. Four types of water conditions were identified: waterlogging, accumulating, intermediate, and draining [Miyagawa *et al.* 1985: 240–242]. The waterlogging zone lies in the lower part, and the draining zone occupies the fringes of the *nong*. Table 4 shows variations in the planting ratio of the different types of rice varieties in the four water zones of a *nong*, which covers 98 ha and has 1,207 plots. In 1983, the waterlogging zone was occupied by late-maturing varieties, whereas medium and early-maturing varieties were chiefly planted in the draining zone. Most of the non-glutinous varieties were medium-maturing and were planted in the draining zone.

In 1991, only four varieties were planted: RD6, a glutinous late-maturing variety, and two other non-glutinous medium-maturing varieties. RD6 was the dominant variety in all water conditions. The planted ratio of RD6 was higher in the lower paddy fields than in the higher paddy fields.

Table 4 Planted Area by Rice Varieties in Various Water Zones of a *Nong*

Year	Varieties	Waterlogging Zone	Accumulating Zone	Intermediate Zone	Draining Zone
1983	Glutinous				
	Late-maturing	84.5%	72.9%	12.9%	0.0%
	Medium-maturing	15.5	19.6	72.3	54.0
	Early-maturing	0.0	0.0	6.0	17.7
	Non-glutinous	0.0	7.5	8.9	28.2
1991	Glutinous				
	Late-maturing	4.4	4.4	0.3	0.0
	RD 6	95.6	79.3	71.4	55.9
	Non-glutinous	0.0	16.3	28.2	44.1

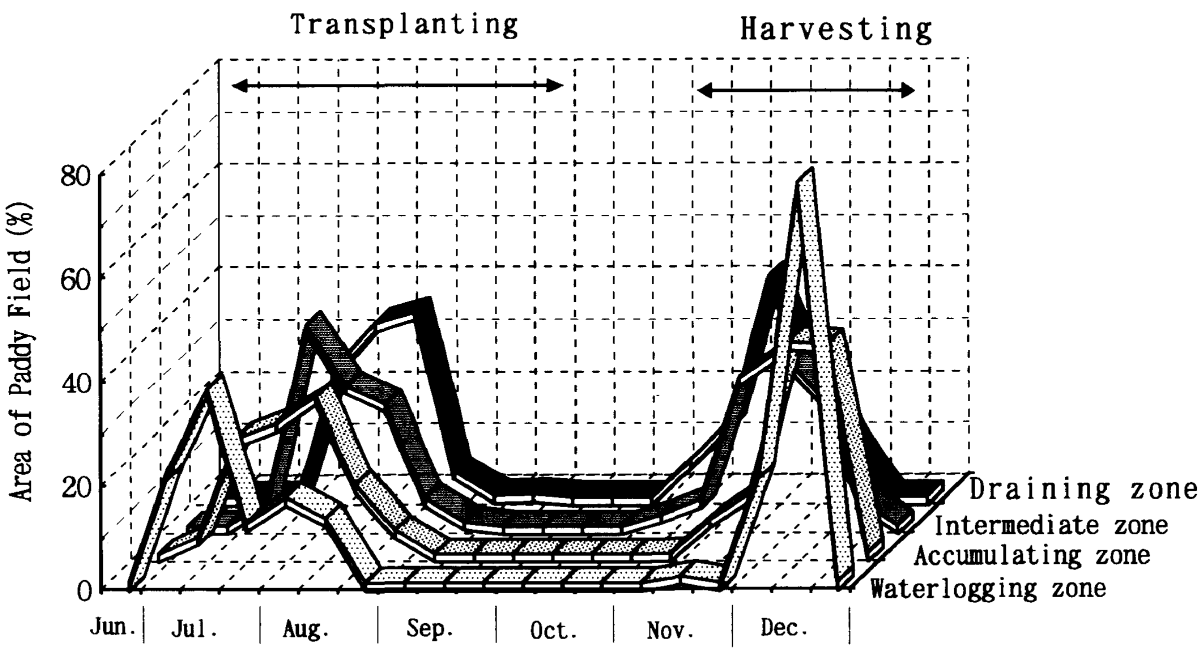

Fig. 3 Progress of Transplanting and Harvesting (1983)

The progress of transplanting and harvesting works in the *nong* in 1983 is shown in Fig. 3. Though the rainy season commenced a little late this year, there was enough rainfall at proper intervals throughout the monsoon season. The proportion of the total area planted was almost 100%. Even the highest plots were not subjected to soil moisture stress. Consequently, there was a bumper harvest in Don Daeng, one of the best ever.

Fig. 3 shows that transplanting proceeded from the waterlogging zone to the draining zone, while harvesting progressed in the opposite direction. This relationship between water conditions in the paddy fields and the working process was the same in other *nong* as in 1983. The low-lying fields were planted with late-maturing varieties only. In the middle and high fields towards the fringes, late-maturing varieties were fewer, but medium- and early-maturing as well as non-glutinous varieties were common. Under these circumstances, the lower fields are planted first and harvested last; and the higher fields are planted later and harvested earlier. This pattern was recognized as a major adaptive technology to the differences in water conditions among paddy fields in rain-fed rice culture.

Fig. 4 shows the transplanting and harvesting times in 1991 in the same *nong* as Fig. 3. Transplanting in all water zones peaked in the same season, although that in the waterlogging zone began earlier than in the other zones. Harvesting in the accumulating, intermediate and draining zones peaked in the same season. Harvesting in the waterlogging zone was a little later. Following the commencement of the monsoon in this year, an unexpectedly long dry spell occurred from June to mid-August, which greatly affected transplanting. Heavy rains brought by a typhoon in late August allowed transplanting in all paddy fields, but subsequent flooding caused by the rain completely submerged the rice plants in most paddy fields other than those in sampled *nong*.

The harvesting time was very short, despite the long transplanting time, which differed from that in 1983. RD6 and KDML105 are strongly photosensitive, medium-maturing varieties. Regardless of when they are planted, as long as it is before the end of August, panicle initiation occurs in the middle of October. This coincides with the end of the monsoon season, which is more or less fixed every year. Therefore, the best harvesting time in all paddy fields is concentrated in a particular season. Farmers might have to provide more labour for harvesting during this short season now than in the past. If rice is harvested later than the appropriate maturing stage, the yield decreases drastically due to loss by overripening. At the same time, this short harvesting season also allows villagers the time to engage in off-farm jobs.

When RD6, as well as KDML105, is planted in September, the heading and flowering stage is delayed beyond the end of rainy season. Rice plants respond to water stress most

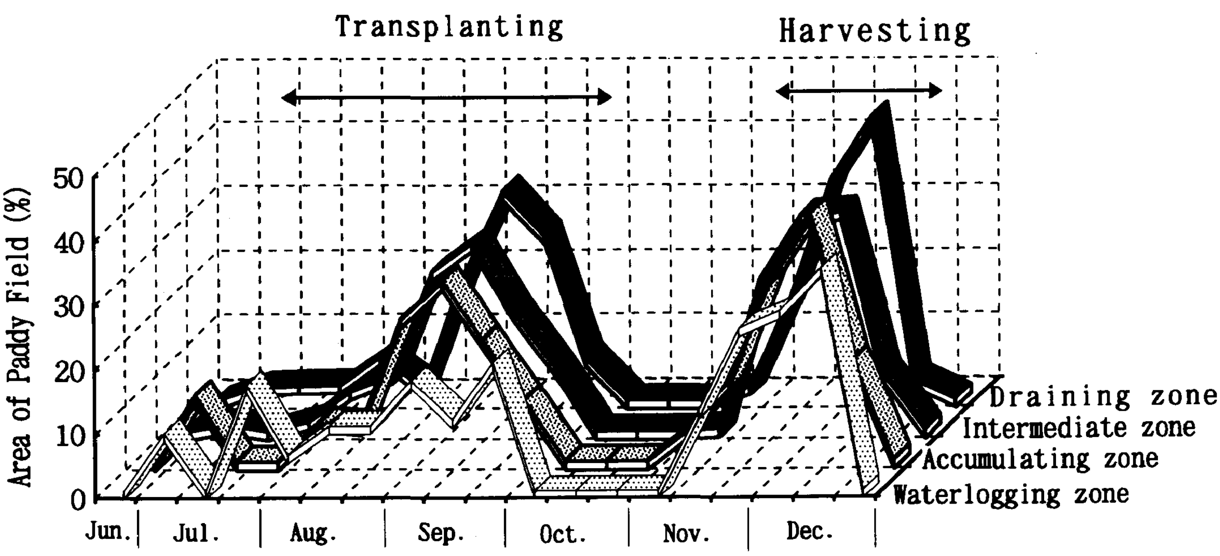

Fig. 4 Progress of Transplanting and Harvesting (1991)

sensitively at this growth stage by producing many empty grains, which consequently reduces yield. In 1991, transplanting peaked in September, and heading was thus delayed until November. Ordinarily, transplanting in the higher paddy fields is later than in lower paddy fields, as mentioned above. This method resulted in later heading of RD6 in the high paddy fields than in the lower paddy fields, and this aggravated the drought damage.

Harvesting of RD6, which is normally done one month after heading, became extremely difficult and time-consuming because of the prevailing soggy conditions in the lower paddy fields, which finally dried up in December. Furthermore, seeding rate, nursery bed area to planted field area, and planting density have increased, as described in V–3, resulting in a heavier work-load for farmers during seeding, transplanting and harvesting than in the 1980s.

V–3 *Changes in Rice Yield*

1) *Rice Production per Household*

Annual rice production since 1978 by each cultivator in the area discussed in III–1 was recorded, and the mean value per household is plotted in Fig. 5. The number of sampled households varied from 199 to 255 over the period studied because of lack of data for some cultivators in some years. The mean values of production per household and grain yield per unit cultivated area were 1,368 kg and 0.86 t/ha, respectively. Annual production varied greatly, however, and tendency was not found for either production or yield to increase, because the trend of potential yield was masked by the year-to-year fluctuation caused by severe flood in 1978, 1980 and 1991, and severe drought in 1979, 1982 and 1986.

Besides the survey on the paddy fields, the author interviewed all farmers of Don

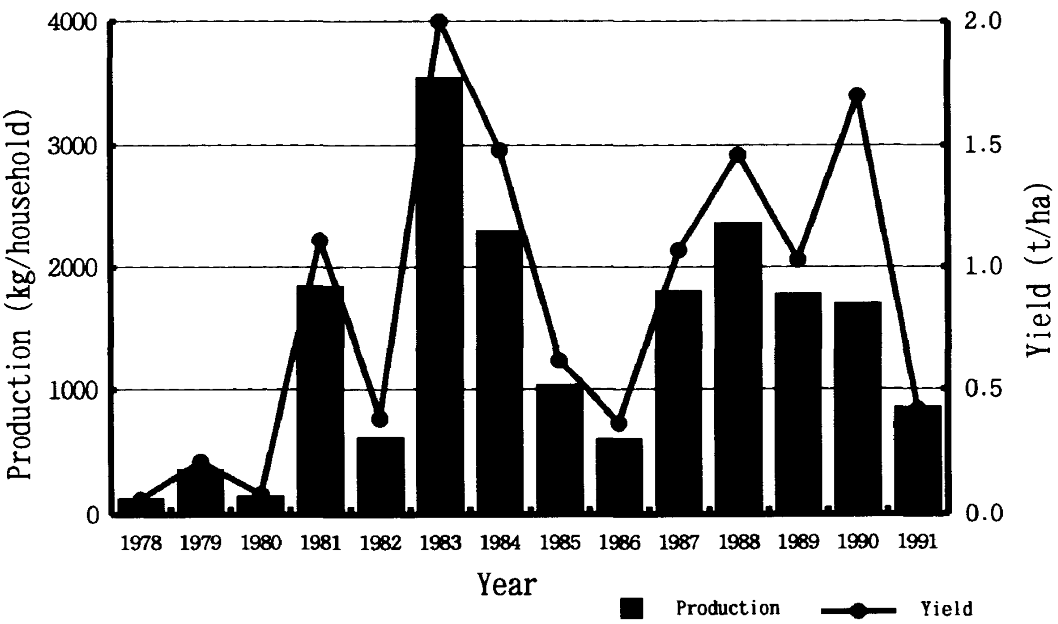

Fig. 5 Changes of Rice Production per Household and Yield per Unit Cultivated Area

Daeng on planted area, harvested area and rice production in 1991. Due to severe flooding, only 35% of the planted area was harvestable; and 60% of the farmers got less than 1 t of rice grain and 39% of them got nothing from their paddy fields. The mean value of production per household was 1,214 kg, and that of yield per unit planted area was 0.67 t/ha. The mean yield per unit cultivable area could not be obtained, but it might be nearly equal to the yield value per unit planted area, because the planting ratio was nearly 100% in this year as mentioned in V-2. Whatever the case above, these values were below the average of the long-term record but those of 1978 and 1980, when Don Daeng suffered extremely severe flooding.

However, when farmers with no harvest are excluded, the mean values of production per household and yield per unit harvested area reached 2,002 kg and 2.04 t/ha, respectively. The yield value was almost the same as that in 1983, when Don Daeng harvested its epoch-making bumper crop, irrespective of the damage caused by the delay of transplanting due to the absence of rainfall and by drought in the higher paddy fields. This fact implies that the potential productivity that can be realized in the absence of flooding and drought has improved recently.

2) *Yield Evaluation by Cutting Survey*

Seventeen plots of sampled paddy fields of average growth were selected from among paddy fields where the rice plants did not suffer from flooding. In each plot, 40 hills of rice plants were harvested and their yields and yield components determined. The 17 plots consisted of 14 plots of RD6 and 3 plots of *Khao Chao Daeng*, a non-glutinous variety. Only 4 of the 17 plots were chemically fertilized.

Table 5 compares the yield and yield components in 1991 with those in 1983

Table 5 Changes of Rice Yield and Yield Components in Don Daeng

	Year	N	Mean	Max.	Min.	CV (%)
Grain weight (g/m²)	1983	174	236	532	66	32
	1991	17	356	621	169	34
Straw weight (g/m²)	1983	173	319	1,511	60	62
	1991	17	447	769	217	38
Number of hills/m²	1983	174	12.4	17.4	5.3	16
	1991	95	17.4	26.0	10.5	17
Number of panicles/hill	1983	174	5.9	13.2	2.9	27
	1991	17	9.2	15.7	6.2	32
Number of spikelets/panicle	1983	174	108	186	34	25
	1991	17	92	136	51	29
Number of spikelets/m²	1983	174	7,731	19,549	2,230	35
	1991	17	15,203	25,498	9,842	26
Percentage of ripened grain	1983	174	74	92	40	11
	1991	17	81	93	45	20
1000-grain weight (g)	1983	174	36.3	48.7	23.1	12
	1991	17	26.1	27.8	23.9	5

measured by the same method [Miyagawa and Kuroda 1988a]. The mean, minimum and maximum values of yield in 1991 were all apparently higher than those in 1983.

The number of hills/m^2 was surveyed in 78 plots besides the 17 sampled plots in 1991. Mean, minimum and maximum values for 1991 were higher than those for 1983, which shows the impact of technical change, such as increased planting density, on rice cultivation in this village. Actually, farmers recognized the relationship between variety change and increasing planting density, as the lower vegetative growth of the present rice plants allows more seedlings to be planted per unit area.

In relation to the planting density, the area of nursery beds and seeding rates were surveyed for an average of 11 farmers. Results showed that the area ratio of nursery beds to planted fields increased from 0.06 in 1983 [Miyagawa 1990] to 0.09 in 1991, while the seeding rate in planted fields increased from 31.3 kg/ha to 40.6 kg/ha and the seeding rate in nursery beds increased from 5.2 kg/a to 5.8 kg/a.

Although a higher planting density was adopted, the number of panicles per hill showed a slight increase, while the number of spikelets per panicle decreased somewhat in 1991. This was caused by the change of plant type from the panicle-weight type of the old indigenous varieties to the panicle-number type of varieties such as RD6, KDML105 and *Khao Chao Daeng*.

The mean value of straw weight generally increased. The maximum value in 1991 was less than that in 1983, since late-maturing varieties were not planted. Nevertheless, poor rice was not found in 1991, which might be the result of the change to the improved varieties and good chemical fertilizer management as described in V–1.

Although spikelet number per panicle decreased, the number of spikelets per unit area in 1991 increased to double that in 1983. This can be attributed to the increased number of panicles per unit area. Generally, an excessive number of spikelets per unit area reduces the percentage of maturing grains. Nevertheless, the percentage maturation in 1991 was higher than that in 1983. The values in plots with higher spikelet numbers were higher than those in plots with lower spikelets numbers.

One-thousand-grain weight in 1991 was about 10 g less than that in 1983. This was also caused by the change from the large-grain type of the indigenous glutinous varieties to the slender grain type of RD6, KDML105 and *Khao Chao Daeng* [Miyagawa 1991 : 28–29].

These results suggest that the increase of potential yield in Don Daeng, which is realized in the absence of severe flooding and drought, was due to higher planting density and plant type improvement by the variety change.

Yield analysis in 1981 and 1983 revealed that enhancement of vegetative growth could result in increasing yield [Miyagawa and Kuroda 1988a]. Fig. 6 shows the relationship between straw weight and the number of spikelets as sink size. When straw weight increased, there was a ceiling number of spikelets in 1983, while the number of spikelets increased lineally in 1991. Therefore, enhancement of vegetative growth might

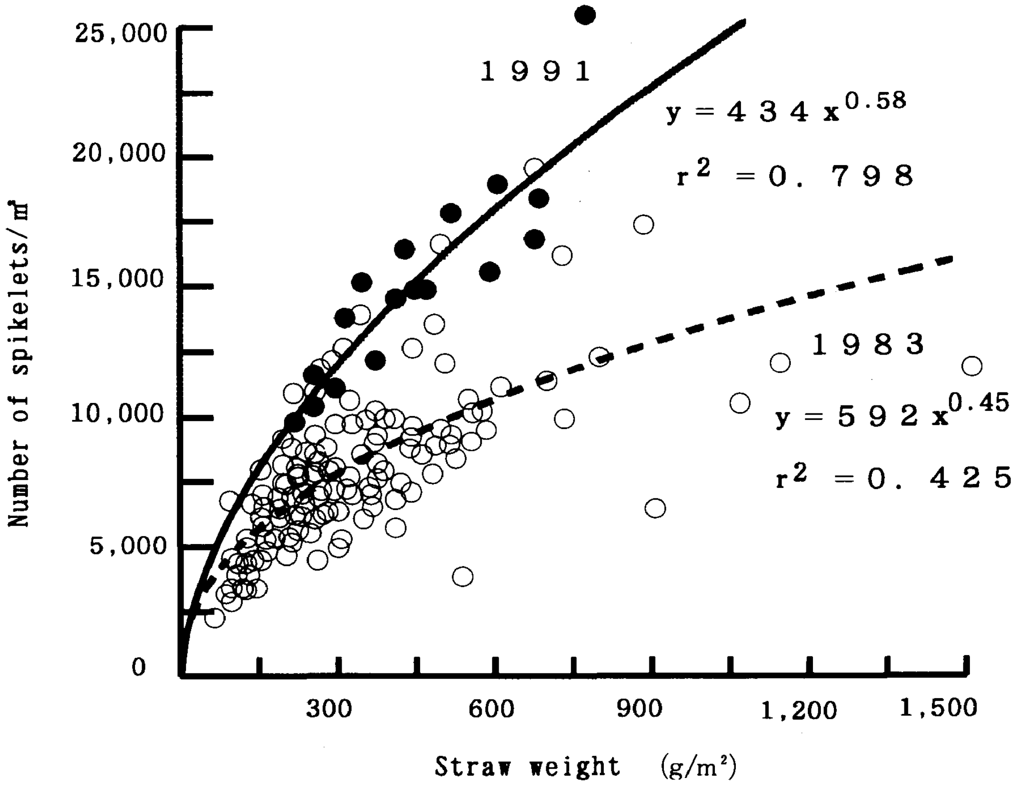

Fig. 6 Relationships between Straw Weight and the Number of Spikelets

result in increased grain yields more readily than in the past. This means fertilizer utilization efficiency has increased in this area. For more efficient fertilizer use in future, however, RD6 will need to be replaced by a more lodging-resistant variety. RD6 is not semi-dwarf and is not able to yield appreciably more than the maximum value of this survey. An alternative will be for farmers to restrict fertilizer use and continue planting RD6 for its superior grain quality.

There is still a lot to be done to tap fully the high-yielding genetic potential of RD6 in these selected areas. As described in IV, late transplanting in higher paddy fields resulted in poor or no rice yield under drought conditions. The relationship between transplanting time and grain yield in 1991 showed that the best yield was obtained by transplanting between late July and mid-August, while yield decreased rapidly when transplanting was delayed until September (Fig. 7). The interval between transplanting and heading was 70–90 days when rice was transplanted during the optimum period. In the four of the sampled plots where transplanting was delayed, heading occurred 50–60 days after transplanting. Vegetative growth there was poor, the number of spikelets was about 50 and the proportion of ripened grain was about 50%, though the number of panicles per unit area was moderate owing to chemical fertilizer application and dense planting. Four plots planted in late June gave slightly lower yields than those planted in early August because of a small number of panicles, despite the considerably higher

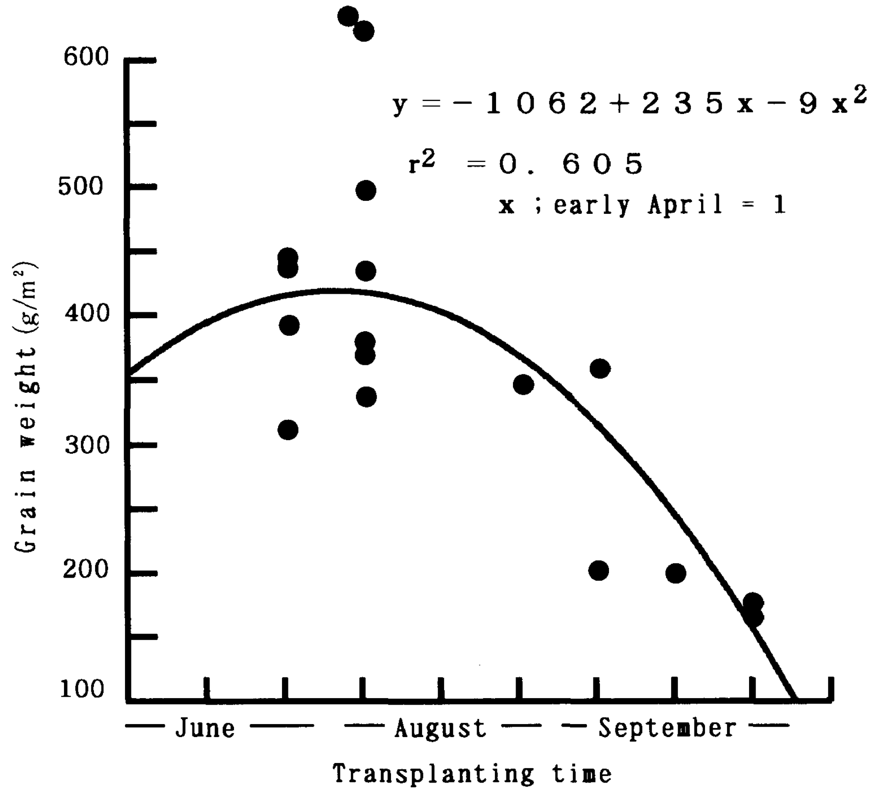

Fig. 7 Relationship between Transplanting Time and Grain Yield in 1991

straw weight.

In 1983, the best transplanting time was less distinct, but transplanting in September resulted in a low yield. This means that anytime before September was best for transplanting, even very early transplanting before the expected rains arrived.

VI Conclusions

The improved variety RD6 that has spread over Northeast Thailand readily offers a higher potential yield through appropriate timing of transplanting and enhanced vegetative growth. It was recognized that the potential yielding capacity has risen gradually in this area. Simultaneously with the variety-related change of yielding ability, a technical change in rice growing has also taken place.

When RD6 was introduced alone without fertilizer application, most farmers did not grow it, as in the early 1980s in Don Daeng, because they were uncertain of its yielding ability. On the other hand, farmers were compelled to try to raise yields on their own paddy fields rather than expanding cultivated area, because little available land remained that could be cleared for new paddy fields in the villages of the Northeast [Fukui 1993 : 296–328].

In the late 1980s, as investment in rice growing increased, RD6 spread rapidly not only to Don Daeng but to innumerable villages in the Northeast. Funds for investment in sample villages were supplied mainly by non-rice growing sectors, such as cash crops and off-farm jobs in urban areas like Khon Kaen or Bangkok. In the first extension stage, the planted area of RD6 expanded with the introduction of modern growing technology to raise yields, as was seen in Na Hom. In Don Daeng, the first stage began later and was of much shorter duration than in Na Hom. In the second stage, the RD6 explosion was aided by its cooking quality. Mutual communication among villagers as well as government agencies' efforts played an important role in these expansion processes.

In practice, there were few villagers who understood the relationship between RD6 extension in their paddy fields and technical innovations such fertilizers, power tillers and irrigation. From interviews with farmers (185 in Don Daeng and 148 in Na Hom), it was not possible to discover any statistically significant relationships between RD6 planted area ratio and productivity or farming input in either village : production and yield per unit planted and harvested area ; expenditure on labor for plowing and transplanting ; expenditures on chemicals, irrigation and consolidation of paddy fields ; and the amount of organic manure and chemical fertilizer used. Variation of RD6 planting among farmers in the village was less than the variation of input into the rice-growing system. In sample villages, it can be said that RD6 has already spread beyond the paddy fields that offer appropriate cultivating conditions for the variety.

This phenomenon of RD6 expansion as a fashion, which occurred in the second stage of extension, resulted in planting of RD6 in paddy fields with various unsuitable conditions, which caused many problems as described. Moreover, there is much anxiety about the severity of diseases and pests which might emerge in the near future due to the broad prevalence of one genotype in the area north of the Mun River. Although past breeders' efforts are admirable [Pushpavesa *et al.* 1986], the author expects them in future to breed and release many different varieties appropriate for the rain-fed paddy fields in Northeast Thailand, with maturity periods suitable to various water conditions, resistance to lodging, disease and insects, and high market qualities.

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