8. RECNET PROBLEMS IN RICE BREEDING FOR BLAST RESISTANCE IN JAPAN

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The rice blast is by far the most serious disease in rice culture in Japan, causing a great damage each year. In the recent 5 years annual loss in rice yield was estimated to be about 340,000 tons in brown rice. Thus, a major effort of Japanese rice breeders is directed toward the breeding of highly resistant varieties to rice blast.

Brief History of Breeding of Blast Resistant Varieties

It is known there are fiive series of blast resistant varieties derived from the different resistant genes as follows[4) 5)]:

1. Blast Resistant Varieties Derived from Formosan Varieties.

Using Formosan upland variety " Sensho " Iwatsuki attempted to introduce the resistant genes into various kinds of lowland rice varieties. First cross was made with "Kinai-Ban 33" in 1922, and fifteen to twenty years later, resistant varieties "Shinju" and "Futaba" were bred out.

2. Blast Resistant Varieties Derived from Chinese Varieties.

Chinese rice varieties " Rei-shi-ko " and " To-to " were used as parents to breed risistant varieties by Matsuo and Kōyama. Matsuo investigated the incidence of leaf blast of many foreign varieties collected from various countries, and clarified that two Chinese varieties "Rei-she-ko" and " To-to " were highly resistant. Kōyama attempted to introduce their resistant genes into various Japonica varieties, and succeeded in breeding the highiy blast resistant varieties "Kanto 51–55". Many varieties recommended were derived from the hibridization of Japanese varieties and "Kanto 51" or "Kanto 53".

Iwatsuki and Ujihara attempted to introduce resistant genes of Chinese variety "Hokushi-Tahmi" into Japonica varieties such as "Shuho" etc., and bred out the highly resistant varieties "Kongo" and "Minehikari". The lineage of them is shown in Fig. 1.

In Chugoku Agricultural Experiment Station, Formosan upland veriety " Okaine " was crossed with Japonica variety "Asahi ". Then in Shimane Agricultural Experiment Station $B_3 F_4$ line of this combination was crossed with Japonica variety " Wase-Sakura-mochi ", and succeeded in breeding of highly resistant variety " Yashiro-mochi".

3. Blast Resistant Varieties Derived from Indica Varieties.

Shigemura and Kitamura have bred out " Pi No. 1 " and " Pi No. 2 " as intermediate parents by double back-crossing of a Philippine variety " Tadukan " with Japonica variety " Sembon-Asahi ". They also continued to breed out " Pi No. 3 " and " Pi No. 4 " from the hybridization between " Norin 8 " and " Tadukan " with continual crossing for five times and four times with "Norin 8", respectively. They also bred out " Pi No. 5 " by introducing the highly resistant gene of " Tadukan ". The lineage of " Pi No. 3 " is shown in Fig. 1. The resistant varieties "Shimokita" and " Tosa-Sembon " were derived from the crossing between " Pi No. 1 " or " Tadukan " and Japonica variety " Norin 29 ".

4. Blast Resistant Variety Derived from the U. S. Variety " Zenith ".

Kariya bred " BC–68 " as intermediate parent by back-crossing between American variety

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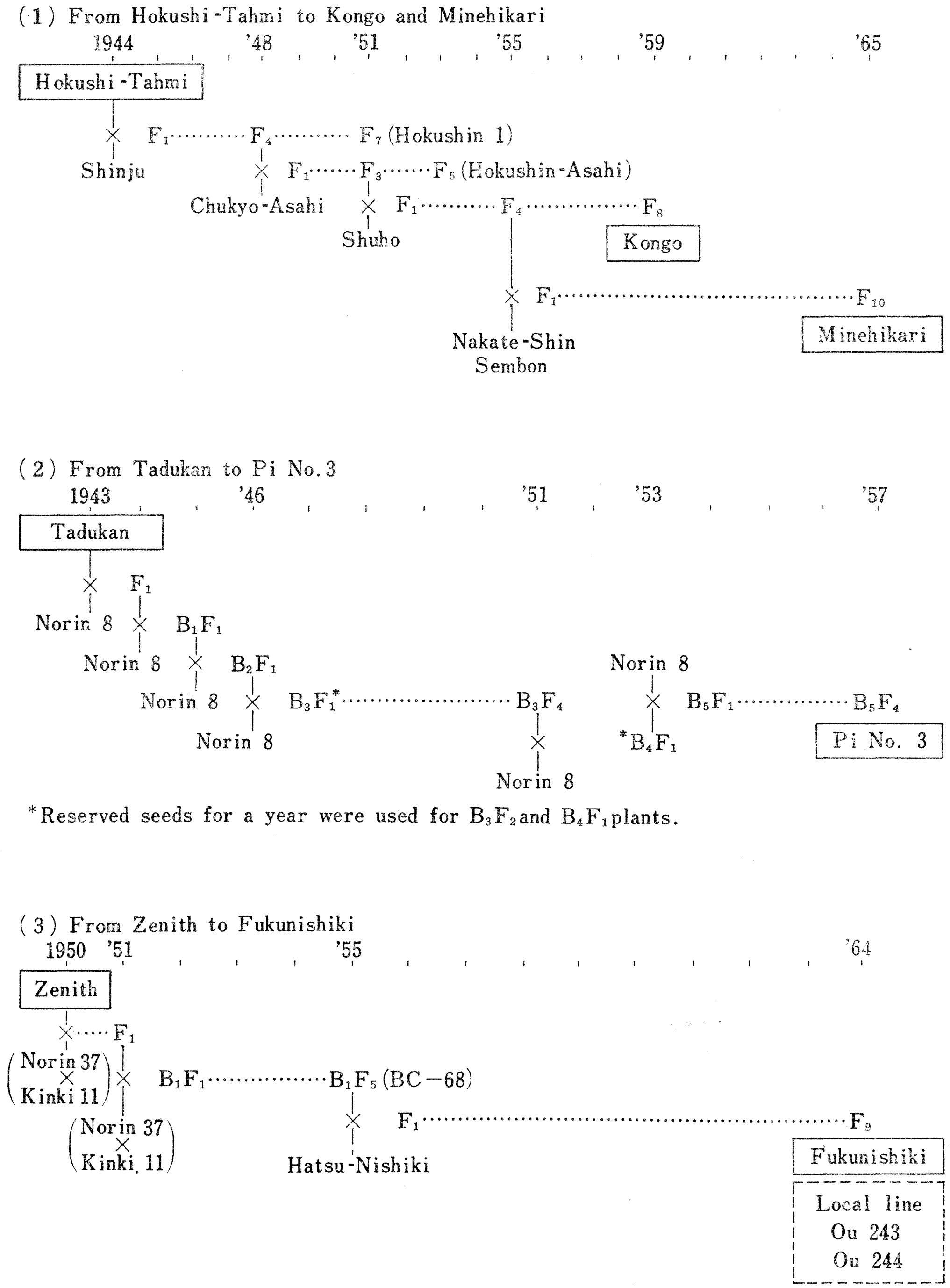

Fig. 1. Lineage of high resistant varieties derived from foreign varieties.

" Zenith " and F_1 Hybrid of Japonica varieties " Norin 37 " × " Kinki 11 ".

The resistant variety "Fukunishiki" was bred by the hybridization between "BC-68" and "Hatsunishiki". The lineage of "Fukunishiki" is also shown in Fig. 1. Recommended varieties derived from "Tadukan" and "Zenith" were shown in Table 2.

5. Blast Resistant Varieties by Hybridization between Japonica Varieties.

In Japan systematic rice breeding has been launched in 1927 and "Norin 6" and "Norin 8" have been bred out in Hyogo Agricultural Experiment Station in 1937. Both varieties manifested characteristics of unique blast resistance, in that "Norin 6" was resistant to neck blast, but susceptible to leaf blast, whereas "Norin 8" was resistant to leaf blast, but not to neck blast.

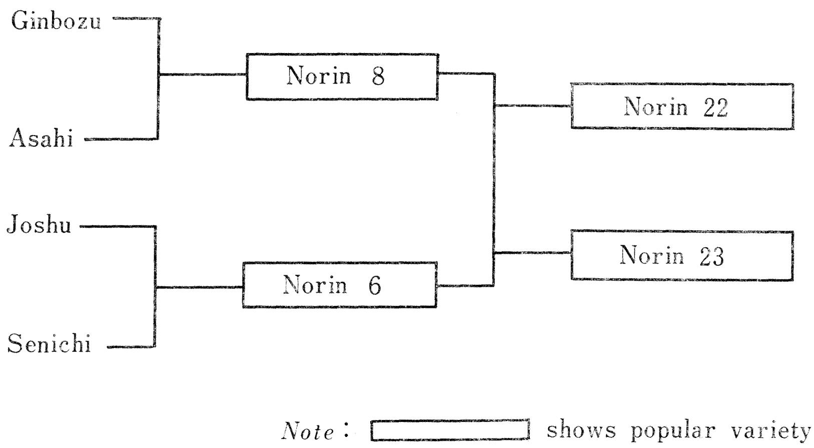

Fig. 1. Breeding processes of blast resistant varieties Norin 22 and Norin 23.

Seko *et al.* produced two varieties "Norin 22" and " Norin 23 " with both leaf and neck blast resistance from the offspring of the hybridization of " Norin 8 ". The breeding process is as shown in Fig. 2. And those varieties had been dominant in western Japan for a long time. "Norin 22" was hybridized with many other Japanese varieties, characterized by resistance to blast accompanied with high yield and superior qualily. Many recommended varieties such as "Honen-Wase", "Chokai" and "Yamabiko" were bred from "Norin 22". Especially "Yamabiko" is a popular parent in the breeding for blast resistance in Japan, together with a good parent, "Norin 22".

Loss of Blast Resistance of the Varieties Registered as the Highly Resistant

As mentioned above, the various kinds of highly resistant varieties were bred out in Japan, by introducing resistant genes from Chinese varieties and indica varieties (Table 1, 2 and 3). These highly resistant varieties showed excellent resistance for few years after they had been registered as new varieties. However, some of these highly resistant varieties such as "Kusabue", "Yukara" and "Pi No. 5" lost their resistance after few years of continuous culturing. For example "Kusabue" had severely been affected by rice blast three years after being released, and the prevalence of the disease could not be controlled in spite of several times' application of fungicides. In case of "Pi No. 5", rice blast severely outbreaked in the fields of wastern Japan, where rice seedlings were transplanted in mid-summer after havesting of rush crop (*Juncus effusus* L.) and heavily fertilized; that is, under the conditions favorable for the outbreak of rice blast. The races of the rice blast fungus in these fields were iden-

Table 1. Blast resistant varieties derived from Chinese variety "Kanto 51", "Kanto 53" and "Hokusi-Tahmi".

Varieties	Female Parent	Male Parent	Origin of Blast Resistant Gene	Field Resistance to Race
Kusabue	Kanto 53*	Norin 29	Rei-shiko	VS
Tatsumi-mochi	Imochi-shirazu**	Fukei 35	〃	M
Yukara	Kanto 53	Eiko	〃	VS
Teine	〃	〃	〃	S
Oyodo	Takara × Zensho 26	Kanto 53	〃	VS
Mangetsu-mochi	F_3 249****	Norin 45	To-to	MS
Tsukimi-mochi	〃	〃	〃	MS
Kaguya-mochi	〃	Heiroku-mochi	〃	MS
Ugonishiki	Kanto 51***	Hatsu-nishiki	〃	S
Tsuyuake	Hokushin 1	Norin 23	Hokushi-Tahmi	S
Sampuku	Hokushin 1 × Norin 23	Tozan 41	〃	MS
Kongo	Hokushin-Asahi	Shuho	〃	M
Minehikari	Kongo	Nakate-Shin-Sembon	〃	M

Note: * Kanto 53: Norin 10 × Reishiko
** Imochi-shirazu: Reishiko × Rikuu 132
*** Kanto 51: To-to × Ginbozu-chusei
**** F_3 249: Norin 25 ⎤
Toto (Chinese variety) ⎦—F-F_2-F_3 ⎤
Norin 36 ⎦—F_1 ⎤
Norin 36 ⎦—F_1-F_2-F_3 249

Table 2. Blast resistant varieties derived from "Tadukan" and "Zenith".

Varieties	Female Parent	Male Parent	Origin of Blast Resistant Gene	Field Resistance to Race T_1
Tadukan	—	—	—	MR
Pi No. 1	Sembon-Asahi × Tadukan	Sembon-Asahi (B_3)	Tadukan	S
Pi No. 3	Norin 8	Tadukan × Norin 8 (B_4)	〃	MS
Shimokita	Hakkoda	Pi No. 1 × Norin 29	〃	S
Zenith	—	—	—	R
BC–68	(Norin 37 × Kinki 11) × Zenith	Norin 37 × Kinki 11	Zenith	M
Fukunishiki (Local line)	BC–68	Hatsu-nishiki	〃	MS
Ou 243	〃	〃	〃	S
Ou 244	〃	〃	〃	M

Table 3. List of new varieties derived from the hybrids with foreign varieties.

Original foreign materials	Basic varieties for breeding	New recommended varieties obtained
1. Sensho	Futaba(1941)	Ayanishiki('48), Fujisaka 5('49) Wakaba, Kotobuki-mochi('50), Akibae('53), Akikogane('59), Setohonami('60).
2. Taiwan Okaine	(B_3F_4)	Yashiro-mochi('61).
3. To-to	($F_3$249)	Mangetsu-mochi, Kagura-mochi('63) Tsukimi-mochi('64).
	Kanto 51-53(50)	Ugonishiki('63).
4. Rei-shi-ko	Kanto 53-55('50)	Kusabue, Senshuraku('60), Teine, Yukara, Oyodo('62).
	Imochi-shirazu('51)	Tatsumi-mochi('65).
5. Hokushi-Tahmi	Hokushin 1('51)	Sampuku('64), Tsuyuake('65).
	Hokushin-Asahi('53)	Kongo('62), Minehikari('65)
6. Tadukan	PiNo. 1-2	Shimokita('62), Tosa-sembon('66).
	PiNo. 3-4('57)	(Under trial)
	PiNo. 5 ('61)	
7. Zenith	(54BC-68)	Fukunishiki('64).

Note: ——— Straight cross
━━━ Back cross
========= Multiple cross

tified with C and T races of the classification by Goto *et al.*[2] Thus it was assumed that "Kusabue" and "Pi No. 5" which were originally resistant to N race of causal fungus of rice blast, were probably attacked by such new fungus as C and T races which had unexpectedly developed through mutation or other process.

The races of blast fungus are classified into three major groups for convenience by Goto *et al.* The races which are officially registered in 1967 are shown in Table 4.

True Resistance and Field Resistance

Blast resistance of rice variety is considered to consist of two elements, true resistance and field resistance. True resistance which is roughly classified into resistant and susceptible, is determined by a few major genes. The different resistant gene is respectively required for each race of blast fungus, and the resistant gene to some race of blast fungus is not resistant to other races. Such true resistance can be examined by inoculation of each race of blast fungus on rice seedling in the stage of 3 to 4 leaves.

On the other side, field resistance is considered to be determined by the accumulation of many minor genes. The grades of field resistance, quite differing from the resistance due to major genes mentioned above, vary in a wide range from none to fully diseased and it also fluctuates under the influence of environmental conditions. In other words, the blast resistance of rice variety is indicated as the sum of true resistance and field resistance, and field resisstance can approximately be regarded as the whole blast resistance minus true resistance.

Therefore, it is necessary to previously check true resistance of them according to Goto's method, for the determination of field resistance of some varieties. Then, field resistance can be examined in blast nursery by inoculation of the race of blast fungus which is already known to infest the varieties.

Table 4. Races of blast fungus in Japan.

Differential Varieties	Group T			Group C									Group N					
	T_1	T_2	T_3	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	N_1	N_2	N_3	N_4	N_5	N_6
Te-tep	M	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tadukan	M	M	M	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Usen	S	S	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Chokotou	S	R	R	S	M	R	S	R	S	R	S	R	R	R	R	R	R	R
Yakeiko	S	R	R	S	M	S	R	S	R	S	S	S	R	R	R	R	R	R
Kanto 51	S	R	R	S	S	S	S	S	S	S	S	S	R	R	R	R	R	R
Ishikari-shiroke	S	R	S	S	S	R	S	S	S	R	R	S	S	R	R	R	S	S
Homarenishi	S	S	S	S	S	R	S	S	R	S	S	R	S	S	R	R	R	R
Ginga	S	S	S	S	S	S	S	S	R	S	S	S	S	S	R	S	S	R
Aichiasai	S	S	S	S	S	R	S	S	S	S	S	R	S	S	S	R	R	S
Norin 20	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Norin 22	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

Note: 1. Readings of reaction are resistant (R), modetate (M) and susceptible (S).
2. Japanese races of blast fungus respectively correspond to international races as follows:

Japanese race	International race
T–1	IC–1
T–2	ID–10
T–3	ID–8
C–1	IF–1
C–2,–4,–5,–6	IE–1
C–3.–7,–8	IF–2
N–1,–5	IG–1
N–2,–3,–4	IH–1

Resistance to New Races of Blast Fungus

As mentioned above, true resistance of rice variety varies due to the change of races of blast fungus. Thus it is safely assumed that, if field resistance of rice variety doesn't vary due to the change of races, the contraction of rice blast in the resistant varieties will be avoidable when field resistance is additionally introduced into a variety which originally has true resistance to some individual races of blast fungus. Fig. 3, 4 and 5 show the degrees of the field resistance of rice varieties to the differnt races of blast fungus. These results have supported the assumption that field resistance of rice variety doesn't vary due to the change of races of blast fungus.

Thus, breeding of highly resistant varieties must be made by two methods. One is the accumulation of resistant genes to all races. Another is the breeding of varieties keeping high field resistance, even when they do not have the genes of true resistance. There is no varieties completely resistant to all or majority of each race of blast fungus. Therefore it is necessary to introduce true resistance and field resistance into one variety.

Even if a highly resistant major genes directly related to resistance covering a broad range of races it is always exposed to instability of high resistance. Therefore, it is desirable to breed out a variety having stable field resistance, so that the damage would not be so great even when attacked by some new races of blast fungus.

Considering those findings as mentioned above, we intend to apply such methods as fol-

Damaged Leaf Area % by C1 race

N1 \ C1 (Damaged Leaf Area % by N1 race)	VS	100	75	50	25	10
VS	Kamenoo Norin 21					
100		Sasashi-gure Norin 17				
75			Norin 41			
50				Hatsu-nishiki		
25				Towada Otori	Fuji-saka 5 Miyoshi	
10						

Fig. 3. Degree of Field Resistance to Race N_1 & C_1.

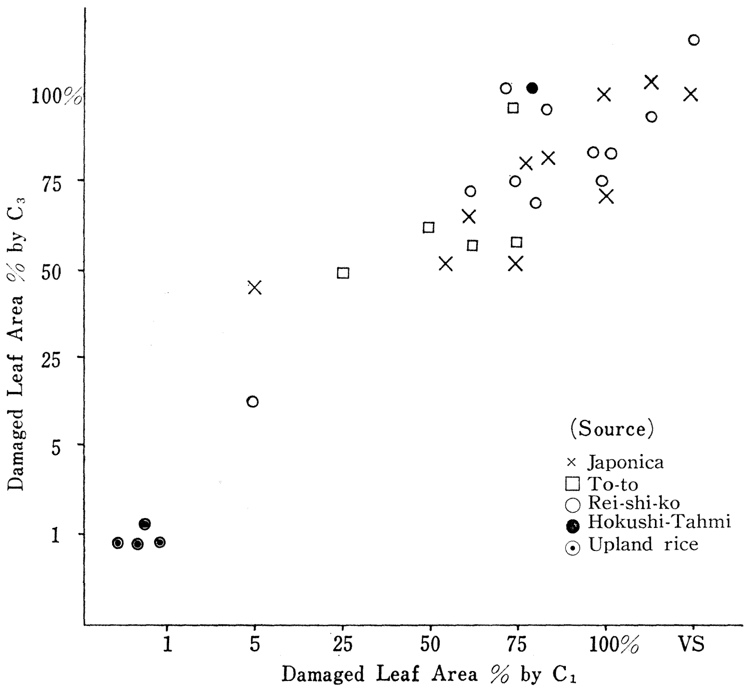

Fig. 4. Degree of Field Resistances to race C_1 and C_3.

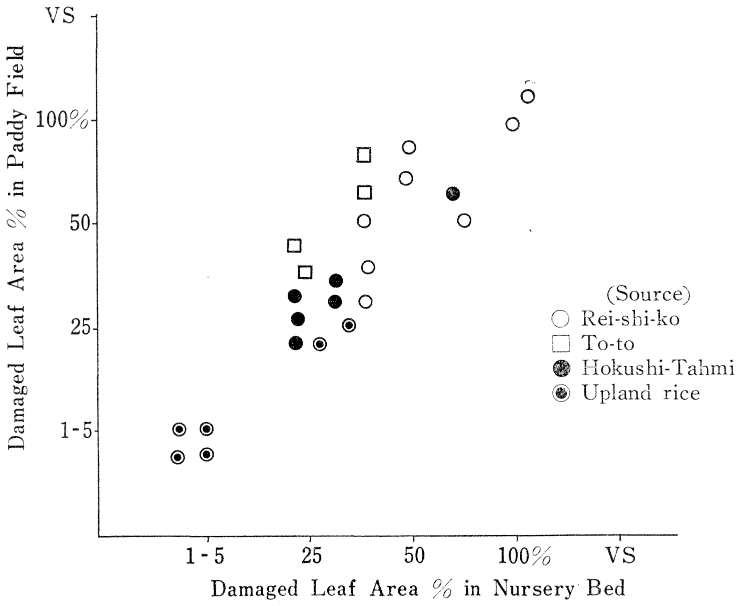

Fig. 5. Degree of Field Resistance to race C_1 in Nursery-bed and Paddy Field.

lows for the breeding of resistant varieties to rice blast:

Selection of early generations is screened in greenhouse inoculation tests for individual resistance to C or T races. Advanced generations — individuals or lines — will be retested in blast nurseries distributed with N race for the screening of field resistance.

Problems of Rice Blast Requiring Further Attention

Field test on rice blast is essential in all breeding programs. It should be complemented in greenhouse tests with typical known races such as C or T races.

Fundamentally it is disirable to breed new rice varieties which possess the resistance to all known races of blast now existing. But it is perhaps a very difficult task. It might be possible to develop new rice varieties which manifest the resistance at least to the typical principal races of blast fungus which are now wide-spread. And if field resistance is introduced into such varieties, the varieties having stable resistance will be bred out. This is because, according to our research findings field resistance doesn't vary even when races of blast fungus change.

At present the question "What is field resistance ?" still remains unclarified. The mechanism of field resistance is not clear. Therefore it must be clarified from the standpoint of genetics, plant pathology and plant physiology to answer the question.

Discussion

D. V. W. Abeygunawardena, Ceylon: May I ask whether you encounter violent fluctuations in the susceptibility of field resistant varieties either in different testing sites or in stations ?

Answer: From the results of investigations on the distribution of races in blast testing station, group N races were found to be most common throughout many stations. But in few stations we could observe the expansion of C races, caused by the extension of varieties derived from Chinese varieties. During the research works on field resistance in C races fields, we could get the same tendency as I observed in my station. In Tohoku district test of leaf blast is possible from May to August. In spite of early or late sowing in the nursery bed we can also observe parallel tendency.

E, C, Cada, Philippines: In the Philippine variety "Tadukan" spelled "Ladukan". In fact I remember that this variety was given to a Japanese delegate during the 3 rd ICA seed improvement conference held in Manila 1963.

Answer by K. Goto, Japan: Thanks for your comment, but I wonder whether our "Tadukan" and Filipino "Ladukan" are the same or not, considering that these two varieties have been grown in different conditions for more than 10 years. Therefore, I should like to correct after examination of the characteristics of these two varieties.

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