A Rice (Oryza sativa L.) Breeding for Field Resistance to Blast Disease (Pyricularia oryzae) in Mountainous Region Agricultural Research Institute, Aichi Agricultural Research Center of Japan

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Abstract: Mountainous Region Agricultural Research Institute (MARI), Aichi Agricultural Research Center (AARC) was established in Inabu town (later Toyota city), Aichi Prefecture, in 1933. MARI is situated in latitude 35 degrees 13 minutes north and longitude 137 degrees east and located 505 m above the sea level. The mean yearly temperature is 11.8°C, it has about 1,500 sunshine hours a year, and rainfall in a year is about 2,100 mm. These environmental conditions are suitable for blast. We have been breeding rice with blast resistance in these areas where outbreak of rice blast often occurs. MARI has contributed to rice cultivation in Japan by breeding scores of rice blast resistant cultivars. In particular, the rice cultivars bred by introducing blast field resistance of the upland rice cultivar, Sensho, are being cultivated not only in mountainous regions of a temperate district where outbreak of rice blast often occurs, but also at rice breeding laboratories all over Japan as mother plants for breeding. Since 1967, MARI was assigned by the Ministry of Agriculture and Fisheries as the experimental station for breeding superior cultivars for mountainous regions in the temperate district in Japan. The main cultivars bred by this project are Mine-asahi which have good kernel quality and good eating quality, Chiyonishiki and Mine-hibiki, which are resistant to rice blast, and others. At present, we are introducing the chromosomal region of field resistance to blast from Sensho by QTL (Quantitative trait loci) analysis and various genes from Yunnan cultivars and native gene sources into the cultivars with good eating quality, and breeding highly rice blast resistant lines.

Key words: Blast, Breeding, Field resistance, Gene sources, Rice.

Rice blast is the most important and damaging fungal disease of rice worldwide. Control methods are often based on the use of fungicide and of rice resistance, but developing resistant cultivars is the most desirable means for preventing rice blast. Rice has two types of resistance to blast, complete resistance and durable. Complete blast resistance has been associated with spectacular 'breakdown' of cultivar resistance. In Korea, the complete resistance of the Tongil cultivars was effective for only 5 years, fungus races able to overcome that resistance, appeared in 1978, and the pathogen had spread all over the country; resulting in a devastating blast epidemic (Crill et al., 1981). In Egypt, Japanese cultivar Reiho possessing the gene Pita-2 for complete resistance, was released in 1984. However, the resistance was lost within the first year after production, resulting in a serious epidemic (Reddy and Bonman, 1987).

Bonman (1992) described when the cultivar allowed the pathogen to reproduce that cultivars had various types of resistance included in field resistance (Ezuka, 1979), such as slow blasting (Villareal et al., 1981), quantitative resistance (Ahn and Ou, 1982), dilatory resistance (Marchetti, 1983), and partial resistance (Yeh and Bonman, 1986). In this report, we regarded the resistance without race specificity. Rice cultivars with field resistance to blast have been observed under several production systems, but were not fully analyzed in tropics because of field resistance of each cultivars can be evaluated only when the information on the complete resistance gene are known. Recently, Kato et al. (2004) indicated clearly distinguished field resistance from complete gene resistance to blast in the tropics. Therefore, breeding of cultivars with field resistance has become a major method of crop improvement, but the genetic basis and mechanism of the field resistance is still not fully understood.

Another topic is the recent progress of rice...
genomics has a great impact in rice breeding. Breeders searching for rice cultivars resistant to blast, use DNA markers such as \( P_{bi} \) (Fuji et al., 2000), \( P_{i21} \) (Fukuoka and Okuno, 2001; Saka and Fukuoka, 2005), \( P_{i34} \) (Zenbayashi et al., 2002).

In this report, to recognize the blast field resistance in Japan, we analyzed the history for 70 years, and discuss the present situation and the future of the breeding of rice blast resistance in Mountainous Region Agricultural Research Institute (MARI), Aichi Agricultural Research Center (AARC), is the core of rice blast resistance research in Japan.

1. The contribution of the MARI for the breeding of Japanese rice cultivars.

MARI was established in Inabu town (later Toyota city), Aichi Prefecture, Japan in 1933. The main aim of this institute has been the breeding of rice cultivars resistant to rice blast, and it has contributed to rice cultivation in Japan by breeding scores of rice blast resistant cultivars. In particular, the rice cultivars bred by introducing blast field resistance of the upland rice cultivar, Sensho, are being cultivated not only in mountainous regions of a temperate district where outbreak of rice blast often occurs, but also at rice breeding laboratories all over Japan as mother plants for breeding. MARI has contributed to the breeding of superior cultivars such as Fujisaka 5 and Nipponbare. In 1970, rice cultivars in 70% of the cropping area in Japan had the genes of cultivars bred at this institute (Kushibuchi, 1992), and even in the year of 1998, the cultivars in 43% of cropping area in Japan have the cultivars bred at this institute as an ancestor.

2. Meteorological conditions and the test of resistance to rice blast at MARI

MARI is located east of Aichi Prefecture, 505 m above the sea level and on the riverside of Nagura River in the terraced paddy field area (Fig. 1). The test field is covered with humic sandy loam. The mean yearly temperature is 11.8°C, which is 3°C lower than that in the flat area in Aichi Prefecture. It has about 1,500 sunshine hours a year, and rainfall in a year is about 2,100 mm. Characteristically, it has few sunshine hours and abundant rainfall during the rice cultivation period. By using such environmental conditions, we established a method to test the resistance to rice blast caused by natural infection. At the time of establishment of this institute, Iwatsuki (1942), who contributed greatly to the breeding of cultivars resistant to rice blast, announced that for the breeding of cultivars resistant to rice blast, it is necessary to establish a reliable test method and to find the area where rice blast occurs frequently and the disease can be controlled. MARI is situated in an appropriate area in this respect. The resistance to leaf blast has been tested with the plants transplanted in the paddy field until 1963, but after 1964, with the seedlings raised in the nursery upland (Fig. 2). In this test method, however, disease symptoms develop rapidly, and the cultivar difference among the plants infected at the seedling stage is obscure. Therefore, rice was seeded late in May or early in June and fertilized to grow the plants to the four-leaf stage or later stages before the symptoms appear. In recent years, symptoms are judged accurately by spreading the infected rice straw even in the cultivars with \( Pik \) or \( Pik-m \) (resistance gene), in which appearance of disease outbreak was unstable hitherto. Hitherto, the resistance to panicle blast has been tested using the plants transplanted in the paddy field since the establishment of this institute.

Fig. 1. MARI and the field for rice blast test.
MARI has few sunshine hours because it is surrounded by mountains, and is not aired well. In addition, the area is shrouded in fog in the morning of clear days, and the condition is suitable for the occurrence of rice blast.

Fig. 2. Screening field for leaf blast resistance. Lower right inset photograph shows sowing of rice for screening for leaf blast in May or early June.
(Fig. 3). Even in our institute, day temperature just after the end of the rainy season, late June to early August, is considerably high, and to avoid heading at this season, we delayed the transplanting time to stabilize symptom development. Formerly, top dressing during the growth period was limited to a moderate level to avoid the difficulty of judgement due to outbreak of leaf blast during the growth. Recently, however, atmospheric temperature tends to be high, and sometimes symptom development is delayed and fertilizer shortage appears. Thus the growing plants are fertilized so as to develop the slight symptoms of leaf blast during the growth period, and the resistances to panicle blast are being judged by comparing with those of standard cultivars (Hayashi et al., 1993; Saka, 1996; Sugiura et al., 2002).

3. Breeding of rice blast resistant cultivars derived from upland rice Sensho

(1) Poor characteristics associated with resistance to rice blast

At the Aichi Agricultural Research Center (AARC), a breeding project to introduce rice blast resistance from F1 plant of the upland rice cultivar Iyo-sensho 1 (Sensho)/Kinai-ban 33 to paddy rice started in 1924. In this project, the field resistance was first tested in the area where rice blast often occurred, and multiple crossing was adopted to eliminate poor characteristics of upland rice. Later, when MARI was established, breeding of rice blast resistant cultivars started at MARI using the F3 seeds of Ta-sensho and Wase-asahi 2, which was derived from upland rice Sensho and were supplied from AARC. From this combination, cultivar Shinju, that was highly resistant to rice blast was first bred in 1936. This cultivar was resistant to rice blast but had poor characteristics specific to upland rice, such as coarseness, burning up character and poor quality. Therefore, it was further improved and cultivar Futaba was bred in 1940. This cultivar was produced by testing all lines of F3 and later generations for the resistance to rice blast, and by eliminating all susceptible lines. This

![Fig. 3. Screening field for panicle blast resistance. Lower right inset photograph shows transplanting for screening for panicle blast in early June.](image)

Table 1. General information on and field resistance to blast of the cultivars developed by the MARI.

| Cultivar       | Year of release | Parents                        | Blast ***** field resistance |
|----------------|-----------------|--------------------------------|------------------------------|
| Shinju         | 1936            | Ta-sensho/Wase-asahi 2          | O                            |
| Futaba         | 1940            | Shinju 2/Takane-asahi           | O                            |
| Shu-ho         | 1945            | Norin 6/Futaba                 | O△△△△                       |
| Ayanishiki     | 1947            | Futaba/Kinki 34(Norin 22)       | O△△△△                       |
| Ginga          | 1954            | Shu-ho/Rikuu 132               | O                            |
| Wakaba         | 1950            | Shu-ho/Norin 22                | O△△△△                       |
| Koganenishiki  | 1950            | Shu-ho/Norin 22                | O                            |
| Akihare        | 1962            | Bandai-nishiki/Wakakin         | O○○△△                       |
| Mine-asahi     | 1980            | Kanto 79/40-11(Kiho)            | △△                           |
| Chiyonishiki   | 1985            | Aichi 26(Hathuboshi)/Toyonishiki| △△                           |
| Sachiizumi     | 1986            | Kei 283(Horei)/Oum 295*2       | O○○△△                       |
| Mine-hibiki    | 1999            | Sachiizumi/Mine-asahi           | O○○△△                       |
| Chubu 22 *     | 1974            | Kansai 6/GA-13(Yamato-bare)    | ≠                            |
| Chubu 32 *     | 1976            | Ka 4/Mine-hikari//Chugoku 40   | ≠                            |
| Chubu 111 **   | 2002            | Chubu 100/F8(Chiyonishiki/kumo 1425) | ≠ |
| (Cont.) Sensho **| unknown         | unknown/Taiwanese upland rice  | ≠                            |
| (Cont.) Koshihikari ****| 1956        | Norin 22/Norin 1               | ××                           |

*: Parental line, **: Promising line, ***: Upland rice, ****: Developed by Fukui Agricultural Research Center. *****: Subjective rating ⊗ to × ×, where ⊗ = excellent, × × = poor.
The cultivar was named Futaba after the name of a grand-champion sumo wrestler, Futabayama. The cultivar Futaba still had a burning up character, but had a good plant type and high yielding ability, and cultivated in 1,450 ha as a recommended cultivar in Aichi Prefecture. Futaba was highly resistant to leaf blast but not so much to panicle blast. Therefore, Norin 6 and Norin 22 derived from traditional Japanese cultivars, which are moderately resistant to panicle blast, were crossed with Futaba, and cultivars Shu-ho and Ayanishiki without inferior characteristics were bred in 1945 and 1947, respectively. Shu-ho was cultivated in 8,410 ha and Ayanishiki in 5,230 ha at a maximum. General information on and field resistance to blast of the cultivars are shown in Table 1, and breeding pedigree developed at the MARI in Fig. 4.
(2) Resistance to rice blast superior to that of the parents

In the process of the breeding using Shu-ho as a mother plant, we found cultivars more resistant to rice blast than their parents (Inoue et al., 1983). Cultivar Ginga (Milky Way) bred in 1954 had the highest resistance to leaf and panicle blast among Japanese rice cultivars in those days. Owing to the cultivation of this cultivar, rice production in the mountainous area, where the yield was very unstable, was greatly improved, and in Anan town, Nagano Prefecture, people enjoyed it so much that they decided to hold a Ginga festival. The maximum cropping area of this cultivar was 11,000 ha. Resistance to rice blast of Wakaba and Koganenishiki was higher than that of their parents, and the maximum cropping area of Wakaba and Koganenishiki was 21,000 and about 30,000 ha, respectively. They are cropped even at present. These cultivars were further improved and Akibare was bred in 1962. This cultivar has the blast resistance derived from Wakaba and also has high quality and high yielding ability. Thus in 1969, this cultivar was cropped in 37,504 ha in Japan and in the largest area in Korea at later 70’s (personal communication). How the plants acquired blast resistance higher than that of their parents is unknown, but polygenes for blast resistance in upland rice and traditional Japanese cultivars may have been detected by adequate bioassays and they might have been accumulated by breeding.

(3) Project of breeding superior cultivars for mountainous regions in a temperate district

MARI was assigned by the Ministry of Agriculture and Fisheries as the experimental station for breeding superior cultivars for mountainous regions in the temperate district from 1967. The main cultivars bred by this project are Mine-asahi and Chiyonishiki, which have good kernel quality and good eating quality, and Sachizumi and Mine-hibiki, which are resistant to rice blast, and others. In particular, Mine-asahi has an excellent eating quality and is highly evaluated commercially.

4. Breeding of blast resistant cultivar using specific resistance gene

Introduction of blast resistance from the plants other than upland rice has been attempted in cooperation with AARC using foreign rice cultivars. However, we were troubled with hybrid sterility, poor quality and others. Among the foreign cultivars, a Chinese cultivar, Hokushi-ta-mi (in Chinese letters, reading Japanese, respectively) was found to be highly compatible with Japanese cultivars, and Hokushin line was produced from the posterity of the cross between Hokushi-ta-mi and Shinju in 1944. In 1948, we built a glasshouse in the paddy field, spread the infected rice straw there, and tested the blast resistance of hybrid populations. Under this condition, disease symptoms that were almost fatal developed in most of the Japanese cultivars, but no symptoms appeared in the Hokushin line. However, in spring of 1951, outbreak of rice blast suddenly occurred in the Hokushin line, and in full of that year, Kanto 51–55 (having the Pik gene) bred by National Agricultural Research Center (NARC) in our field also suddenly suffered from rice blast. Later, in 1964, Kusabue having the Pik gene, which was bred at NARC, also lost the resistance in farmer’s field, and the study on the related race of pathogen started (Yamazaki and Kosaka, 1980). Hokushin line had the Pik-m gene. Thereafter, the resistance was repeatedly tested in the presence of the fungi that attack the Pik-m gene, and Mine-hikari was bred in 1965. This cultivar had not only the Pik-m gene, but also the blast resistance gene derived from upland rice, and cropping area of this cultivar reached 15,122 ha. Thereafter, breeding of the lines with Pik-m is in progress, but the outbreak of the resistance occurred during the test of cultivars or lines having Pik-m, which varied with the year, showing the Vertifolia effect (Saka et al., 1994), and now this is not the main system of breeding.

5. Introduction of new genes to breeding of rice blast resistant cultivars

We are searching for genetic resources other than those in Sensho for rice blast resistance, and trying to introduce them to breed resistant cultivars. Reconsidering the failure of breeding using Hokushi-ta-mi, we selected the resistant lines having no special complete resistance gene by a repeated testing using pathogenic races. As a result, lines highly resistant to rice blast were bred from Chubu 22 and Chubu 32, the posterity of upland rice and foreign rice (Saka et al., 1994), and recently Chubu 111 was bred from Yunnan cultivars. In particular, Chubu 111 is highly resistant to rice blast and has good eating quality. Analysis of its resistance gene is in progress.

6. Combination of rice blast resistance and good eating quality

Combination of rice blast resistance and good eating quality is an important subject of rice breeding in Japan for many years. Many cultivars cultivated in Japan have good eating quality but poor resistance to rice blast. The two characters are controlled by polygenes, and this may be why the number of experimental stations where the blast resistance is exactly tested is limited, and an easy method of testing the eating quality has not been established. At this institute, we showed that the test of rice blast resistance in the field and the measurements of protein content of rice and iodine colorimetry of milled rice are effective to combine these two characters (Saka et al., 1995). However, the scale of the breeding is limited,
and recently we are breeding using DNA markers.

7. Application of genome research to rice breeding

MARI has been participating in the Rice Genome Project since 1994, and analyzing the genes for field resistance to rice blast of Sensho. By QTL analysis, the resistance gene in Sensho was found to be located on four loci (Kato et al., 2002). At present, we are backcrossing the plants having a DNA marker in each chromosomal region with Mine-asahi, and breeding near-isogenic lines (Saka and Fukuoka, 2005; Saka et al., in press). We are planning to narrow the effective regions, and finally to produce a line having all four gene loci. As mentioned above, Mine-asahi has a good eating quality comparable to that of Koshihikari. By using this cultivar as a parent of backcrossing, and using DNA markers, we are planning to combine rice blast resistance comparable to that of upland rice with excellent eating quality, which was hitherto unsuccessful.

8. Learning from history and passing on to the future generations

As mentioned above, studies on the breeding of cultivars resistant to rice blast have been conducted at this institute (Tanabe, 1991) for 70 years and several experimental data reported in the Japanese Society for Crop Science Tokai Branch (Akama et al., 1984; Koide et al., 1985a, 1985b, 1986; Hayashi et al., 1993; Sugiuira et al., 2002). Based on the results obtained in our institute, we would like to give the following message to the breeders of future generations. First, we recommend promoting breeding of blast field resistance further. Japanese rice cultivars have been improved by using very limited genetic resources, and belong to a peculiar cultivar group. Because the genetic background has been clarified, the resistance of the hybrids can be clearly confirmed unless it includes complete resistance. The cultivar bred in our institute by introducing field resistance did not show any breakdown of the resistance in Japan where rice blast often occurs, for scores of years. Such a stable blast resistance should be introduced in further breeding. On the other hand, the breeding using the complete gene is easy, because it is a single dominance, and the gene is easily introduced. In recent years, multilines were bred by introducing the complete resistance gene into Sasanishiki and Koshihikari (Sasahara and Koizumi, 2004; Kojima et al., 2004). The effect of the introduction of such a gene has been confirmed, but at MARI, blast resistance acquired by introducing such a specific gene often broke down within 1–2 years. Furthermore, some cultivars such as Koshihikari have no genetic background for field resistance to rice blast, and if complete gene activity in these cultivars is suppressed, they might be damaged seriously. In addition, the cultivation of the Multiline is questionable because seed collection and examination of pathogen race are troublesome. Next, we recommend breeders to consider the values of genomic research. At present, we are breeding the resistant cultivars from the posterity after 4 or 5-time crossing of Sensho with Mine-asahi, using DNA makers. By eliminating the unnecessary chromosomal region from Sensho by using DNA markers, various characters have been improved considerably, and the breeding process which might have expended about 30 years in our old system seems to have been accomplished within 7–8 years. Breeding using such accurate bioassay and DNA marker may drastically reduce the breeding years. By the use of DNA marker closely linked with rice blast resistance, the process of bioassay can be omitted. In addition, the resistance to rice blast detected only at a limited number of laboratories may be detected at many rice breeding laboratories by using DNA markers. In other words, the resistance that could not be detectable until now becomes detectable. Of course, it is necessary to continue the field research for blast. Among the genome researches related to blast resistance in Japan, the studies on Pb1 (Fujii et al., 2000) and Pb21 (Fukuoka and Okuno, 2001) have been analyzed most in detail, owning to the resistance test in the field of our institute. If these genes are cloned and their function clarified, resistance to rice blast may be detected more clearly.

References

Ahn, S. W. and Ou, S.H. 1982. Quantitative resistance of rice to blast disease. Phytopathology 72 : 279-282.

Akama, Y., Koide, T., Inoue, M. and Fujii, K. 1984. A case study on the breakdown of true resistance to rice blast a rice cultivar ‘Fukuhonami’. Rep. Tokai Br. Crop Sci. Soc. Jpn. 98 : 15-17*.

Bonman, J. M. 1992. Durable resistance to rice blast disease-environmental influences. Euphytica 63 : 115-123.

Crill, P., Ham, Y. S. and Beachell, H. M. 1981. The rice blast disease in Korea and its control with rice production and gene rotation. Korean, J. Breed. 13 : 106-114.

Ezuka, A. 1979. Breeding for and genetics of resistance in Japan. In Proc. Rice Blast Workshop. IRRI. Manila, Philippines. 27-28.

Fujii, K., Hayano-Saito, Y., Saito, K., Sugiuira, N., Hayashi, N., Tsuji, T., Izawa, T. and Iwasaki, M. 2000. Identification of a RFLP maker tightly linked to the panicle blast resistance gene, Pb1, in rice. Breed. Sci. 50 : 183-188.

Fukuoka, S. and Okuno, K. 2001. QTL analysis and mapping of Pb21, a recessive gene for field resistance to rice blast in Japanese upland rice. Theor. Appl. Genet. 103 : 185-190.

Hayashi, M., Inoue, M., Saka, N. and Nakajima, Y. 1993. Selection of rice standard varieties for panicle blast resistance in different heading time group (Pb4, Pb5 gene varieties). Rep. Tokai Br. Crop Sci. Soc. Jpn. 115 : 25-26*.

Inoue, M., Morimoto, T., Tanabe, K., Shumia, A. and Fujii, K. 1983. Breeding of field resistance of rice varieties superior to their parents to blast. Res. Bull. Aichi Agric. Res. Cent. 15 :
Iwatsuki, N. 1942. A story of the breeding process of rice cultivars highly resistant to blast disease. Ikushu kenkyu. 1: 25-41**.

Kato, H., Tsunematsu, H., Ebron, L. A., Yanoria, M. J. T., Mercado, D. M. and Khush, G. S. 2004. Studies on partial resistance to rice blast in the tropics. In S. Kawasaki eds., Rice Blast: Interaction with Rice and Control. Kluwer Academic Publishers, Netherlands. 137-143.

Kato, T., Endo, I., Yano, M., Sasaki, T., Inoue, M. and Kudo, S. 2002. Mapping of quantitative trait loci for field resistance to rice blast in upland rice, Sensho. Breeding Res. 4: 119-124**.

Koide, T., Akama, Y., Fujii, K. and Kudo, S. 1985a. Leaf blast resistance of F2 population derived from the crosses between upland rice. Rep. Tokai Br. Crop Sci. Jpn. 100 : 51-53*.

Koide, T., Akama, Y., Kudo, S. and Fujii, K. 1985b. Leaf blast resistance of non-glutinous recommended rice varieties. Rep. Tokai Br. Crop Sci. Jpn. 100 : 55-58*.

Koide, T., Akama, Y., Kudo, S. and Tounyama, T. 1986. Comparison with the reactions of Japanese upland rice varieties to rice blast fungus by spray inoculation method and inject inoculation method. Rep. Tokai Br. Crop Sci. Soc. Jpn. 102 : 19-21*.

Kojima, Y., Ebitani, T., Yamamoto, Y. and Nagamine, T. 2004. Development and utilization of isogenic lines Koshihikari Toyama BL. In S. Kawasaki eds., Rice Blast: Interaction with Rice and Control. Kluwer Academic Publishers, Netherlands. 209-214.

Kushibuchi, K. 1992. Breeding of paddy rice before World War II. J. Agric. Soc. Jpn. no. 1300 : 19-24*.

Marchetti, M. A. 1983. Diatory resistance to rice blast in USA rice. Phytopathology 73 : 645-649.

Reddy, A. P. K. and Bonman, J. M. 1987. Recent epidemics of rice blast in India and Egypt. Plant Dis. 71 : 850.

Saka, N., Inoue, M. and Nakajima, Y. 1994. Screening of high field resistance lines to rice blast disease. Res. Bull. Aichi Agric. Res. Ctr. 26: 17-25**.

Saka, N., Inoue, M., Ito, K., Hayashi, M. and Nakajima, Y. 1995. Blast resistance and eating quality in Japanese major rice cultivars and local lines of Aichi agricultural research center moutainous region experiment farm. Res. Bull. Aichi Agric. Res. Ctr. 27: 23-31**.

Saka, N. 1996. Panicle blast resistance: test method using the area where outbreak of rice blast occurred. In R. Yamamoto, N. Horisue and R. Ikeda, eds., Rice breeding manual. Yokendo, Tokyo. Japan:15-19*.

Saka, N. and Fukuoka, S. 2005. Evaluating near-isogenic lines with QTLs for field resistance to rice blast from upland rice cultivar Sensho through marker-aided selection. In K. Toriyama, K.L. Heong and B. Hardy eds., Rice is life: scientific perspectives for the 21st century. IRRI, Manila, Philippines. CD-ROM:487-489.

Sasahara, M. and Koizumi, S. 2004. Rice blast control with Sasanishiki multilines in Miyagi prefecture. In S. Kawasaki eds., Rice Blast: Interaction with Rice and Control. Kluwer Academic Publishers, Netherlands. 201-207.

Sugirya, K., Saka, N., Otake, T. and Kudo, S. 2002. Selection of criterion rice varieties for the evaluation of field resistance to the leaf blast in warm-temperate mountainous region of Japan. Tokai J. Crop Sci. 132 * 133 : 1-6**.

Tanabe, K. 1991. Inahashi experiment station, Inahashi branch, Mountainous region agricultural research center. In Soc. Rice in Aichi (Aichi no ine). Aichi. 699-728*.

Villareal, R. L., Nelson, R. R., MacKenzie, D. R. and Coffman, W. R. 1981. Some components of slow-blasting resistance in rice. Phytopathology 71 : 608-611.

Yamazaki, Y. and Kosaka, T. 1980. Rice blast disease and its resistance breeding (Ine no imochibyo to teikousei ikushu). Hakuyu-sha, Tokyo. 1-607*.

Yeh, W. H. and Bonman, J. M. 1986. Assessment of partial resistance to Pyricularia oryzae in six rice cultivars. Plant Pathol. 35 : 319-323.

Zenbayashi, K., Ashizawa, T., Tani, T. and Koizumi, S. 2002. Mapping of the QTL (quantitative trait locus) conferring partial resistance to leaf blast in rice cultivar Chubu 32. Theor. Appl. Genet. 104 : 547-552.

* In Japanese.
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