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Recent occurrences of long-distance migratory planthoppers and factors causing outbreaks in Japan

Tomonari Watanabe, Masaya Matsumura, and Akira Otuka

Serious outbreaks of *Nilaparvata lugens* were reported in 2005 on Kyushu Island, in the southern part of Japan. In order to improve planthopper management, we analyze the factors causing recent planthopper outbreaks: (1) fluctuations in the immigrant density and timing, and (2) the growth rate from the immigrant generation to the reproductive generation. It is considered that the increase in immigrant density was caused by the high planthopper density in the migration source and the development of suitable weather conditions, which can cause planthoppers to be displaced in early to mid-July. High temperature during summer to early autumn, high brachypterous ratio of females, and low *Sogatella furcifera*/*N. lugens* ratio may affect the growth rate from the immigrant to reproductive generation of *N. lugens*. Recent chemical control measures and their problems are described.

Population growth patterns of rice planthoppers, the brown planthopper (*Nilaparvata lugens*) and the whitebacked planthopper (*Sogatella furcifera*), have been studied in both tropical and temperate rice-growing areas since the 1960s (e.g., Cook and Perfect 1989, Kenmore 1980. Kisimoto 1965, Kuno 1968, Kuno and Dyck 1985, Sawada et al 1993, Wada and Nick 1992). Kuno (1968) and Kisimoto (1965) revealed the basic population dynamics of planthoppers in Japan.

In the late 1980s, the low population growth rate of *N. lugens* between successive generations occurred in some areas when the immigrant density was remarkably high (Noda 1988, Sogawa et al 1988). Watanabe et al (1994) analyzed a 40-year light trap record and found three different types of growth pattern for planthoppers: (1) low immigrant density and high population growth rate, (2) low immigrant density and low population growth rate, and (3) high immigrant density and low population growth rate. In the 1980s, immigrant density varied and population growth rates were lower than those in the other decades (Watanabe et al 1994). After the mid-1990s to early 2000, the immigrant densities of both planthopper species were lower than those in the 1980s (Matsumura 2000). Not only changes in population dynamics but also changes in genetic character were observed in the 1980s and 1990s. Major changes

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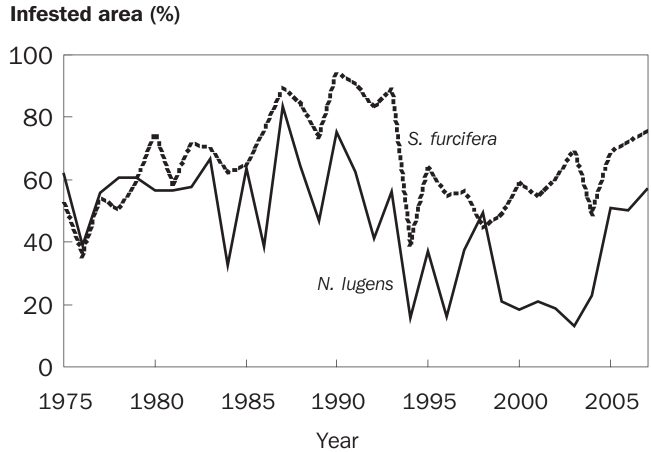

Fig. 1. Changes in the percentages of planthopper-infested area in Kyushu, southern part of Japan.

in the influence of *N. lugens* on resistant varieties occurred around 1988-90 (Sogawa 1992) and 1997 (Tanaka and Matsumura 2000).

In 2005, serious outbreaks of *N. lugens* were reported mainly on Kyushu Island, in the southern part of Japan (Fig. 1). That had not happened in 20 years. Similar outbreaks were reported in China and Korea. Immigration densities in 2006 and 2007 were also higher than those in the previous 10 years, and *N. lugens* outbreaks were again reported in 2007. In order to improve the management strategy for planthoppers, analysis of the factors causing yearly fluctuations in the occurrences of immigrant and reproductive generations is essential. In this paper, we describe the recent occurrences of planthoppers, especially *N. lugens* in Kyushu, and discuss the possible factors causing *N. lugens* outbreaks.

Insects and weather data

Data on daily catches from light traps, total infestation area, and total area of chemical control in paddy fields were downloaded from the database on JPP-NET, the Japan Plant Protection general information NETwork system, which accumulates nationwide statistical data on insect pests and diseases. Monthly mean temperature was downloaded from the climatic statistics of the Japan Meteorological Agency (www.jma.go.jp/jma/index.html). NCEP/NCAR re-analysis data were used for the analysis of upper-air currents.

Immigrant generation

Kuno (1968) revealed that, for both species, *N. lugens* and *S. furcifera*, more than 50% of the variance in the peak density of reproductive generations was due to that in the density of the immigrant generation. Therefore, we first analyzed

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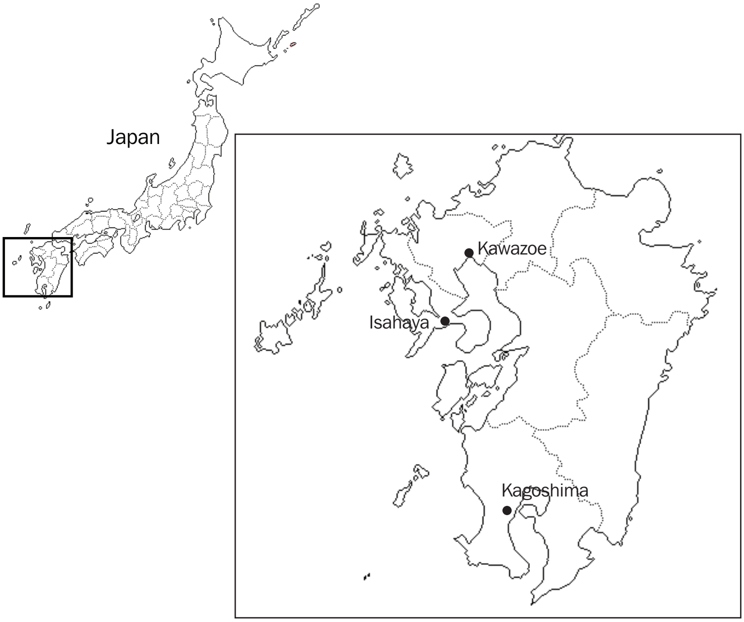

Fig. 2. Location of the monitoring sites.

the fluctuations in the immigrant density and period. Three locations of light trap monitoring sites on Kyushu Island, Isahaya (130.01′E, 32.49′N), Kawazoe (130.20′E, 33.10′N), and Kagoshima (130.47′E, 32.75′N), were selected for the analysis (Fig. 2). Total light trap catches in June and July were calculated.

Annual fluctuations in light trap catches during June and July (Fig. 3) are similar among the three monitoring sites and are also correlated with the annual trend of infested area in Kyushu (Fig. 1). Those relationships show the importance of immigrant density in the population dynamics of reproductive generations of rice planthoppers in Japan.

Fluctuations in the immigrant density of planthoppers are mainly dependent on two factors: planthopper density in the migration source area and weather factors that assist planthopper long-distance migration. The planthopper immigration is highly correlated with the development of the low-level jet stream (LLJ), which is the strong southwesterly upper-air current in the warm sector of a depression moving along the Bai-u (rainy season, June to July) front extending from continental China to Japan (Seino et al 1987, Watanabe et al 1991, Watanabe and Seino 1991). The total number of catches of planthoppers during June and July was also correlated with the cumulative days of the development of LLJ suitable for migration from China and Japan (Figs. 3 and 4).

Fluctuation in the cumulative days of LLJ was mainly due to the changes in the days of LLJ development during July (see annual changes in the June/June + July ratio in Fig. 4). During 1994 to 2004, when planthopper immigrant densities were low, few

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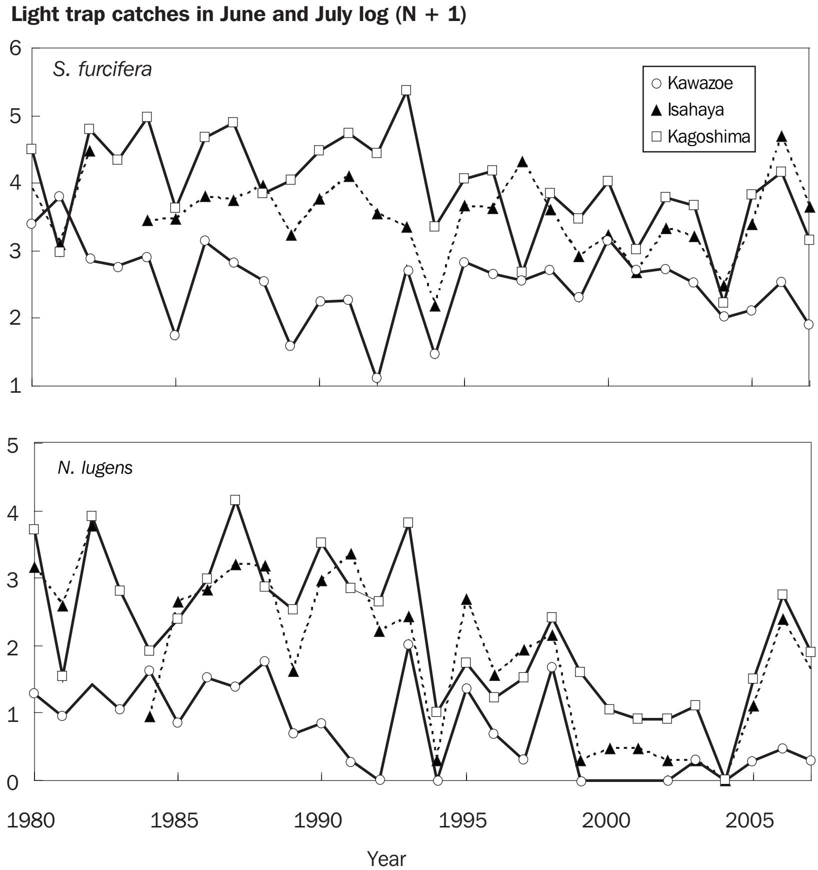

Fig. 3. Changes in the number of light trap catches of *S. furcifera* and *N. lugens* at three monitoring sites in Kyushu, Japan.

LLJ developments were observed during July. The cumulative days of LLJ in July have been increasing since 2005, but not to a high value compared with those during the mid-1980s to early 1990s (Fig. 4). Main immigration periods were observed in mid-July 2005 and early July in 2006 and 2007. Otuka et al (2007) reported planthopper outbreaks in Vietnam and southern China, the suspected migration source areas of the planthoppers. Therefore, the increases in the immigrant density of *N. lugens* in 2005, 2006, and 2007 were caused by the high planthopper density in the migration source area and the development of suitable weather conditions that can cause those planthoppers to be displaced in July.

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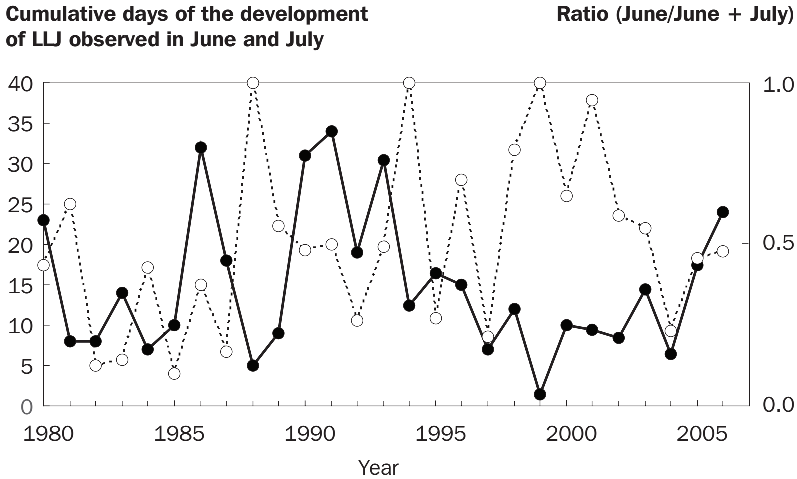

Fig. 4. Changes in the cumulative days of the development of low-level jet stream (LLJ, ●) observed in June and July, and the June ratio (June/July + July, ○). Analysis results in 1980 to 1990 and 1996 to 1998 were obtained from Seino et al (1987), Sogawa (1995), and Syobu and Mikuriya (2000). LLJ development period in 1991 to 1995 and 1999 to 2006 was analyzed using NCEP/NCAR re-analysis data and JPP-NET information, respectively.

Population growth rate

Many factors that may affect population growth rate were reported: immigration period and density, female brachypterous ratio, summer temperature, etc. Watanabe et al (1994) analyzed a 40-year light trap record and showed that early immigrant period and high temperature in summer may increase the *N. lugens* population growth rate. Here, we analyzed the effect of each factor on the population dynamics of *N. lugens*.

In 2005, the main immigration period, mid-July, was not earlier than that in other years. Summer and autumn temperature, however, were considerably higher than the 30-year mean temperature. Recently, summer and early autumn temperature have usually been higher than the 30-year mean temperature (Fig. 5), and this is one of the possible factors that stimulate the high growth rate of *N. lugen*s during summer to autumn.

Wing dimorphism of planthoppers has been studied (e.g., Kisimoto 1956, Iwanaga et al 1985, Morooka et al 1988, Matsumura 1996). Iwanaga et al (1985) revealed various responses to density in the wing form (brachypterous and macropterous) ratio among the immigrant populations of *N. lugens*. Matsumura (2002 unpublished data) investigated the annual variation of density and wing-form relationship in the immigrant populations and showed a high ratio of brachypterous females in the 2005 population (Fig. 6).

In 2006, the immigrant density of *N. lugens* was higher than that in 2005 (Fig. 2), but the total percentage of *N. lugens* infested area was not higher than that in the

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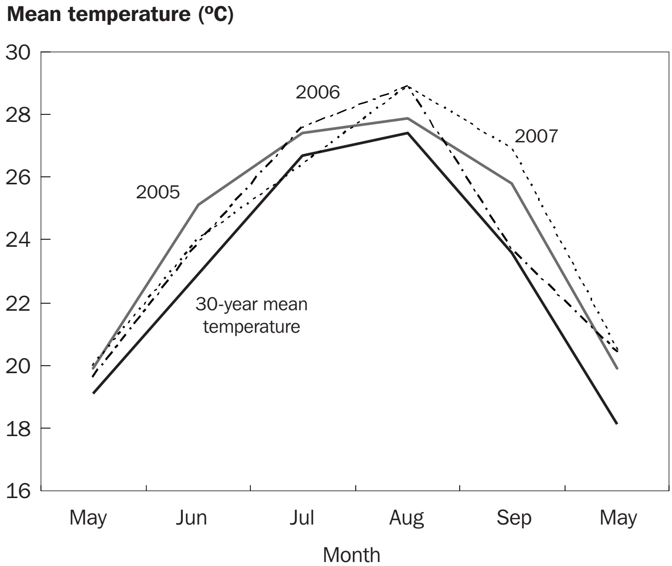

Fig. 5. Monthly mean temperature in Saga, Kyushu, Japan. Data from climatic statistics of the Japan Meteorological Agency.

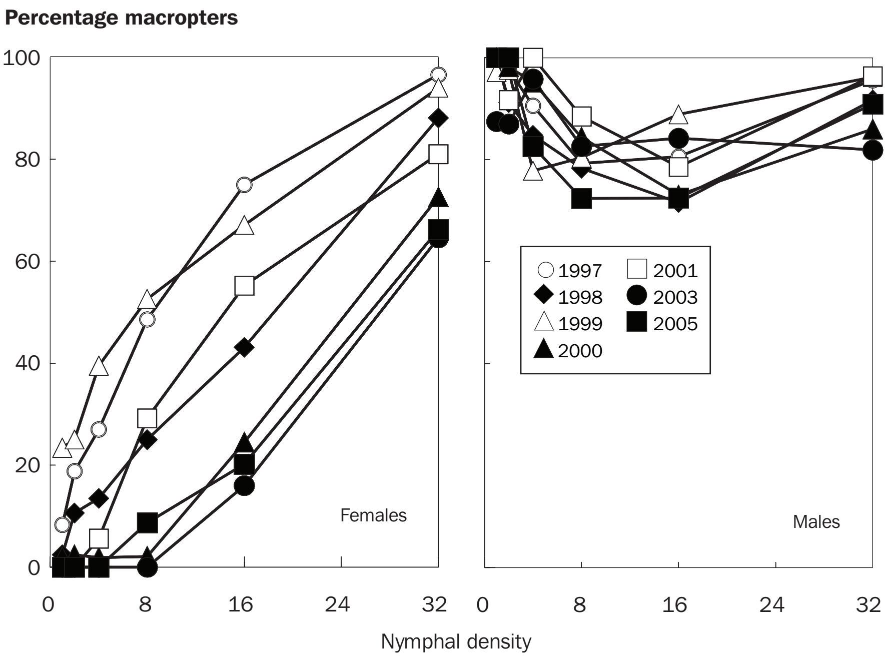

Fig. 6. Density and wing-form relationship in immigrant populations of *Nilaparvata lugens* in Japan (Matsumura 2002, unpublished data).

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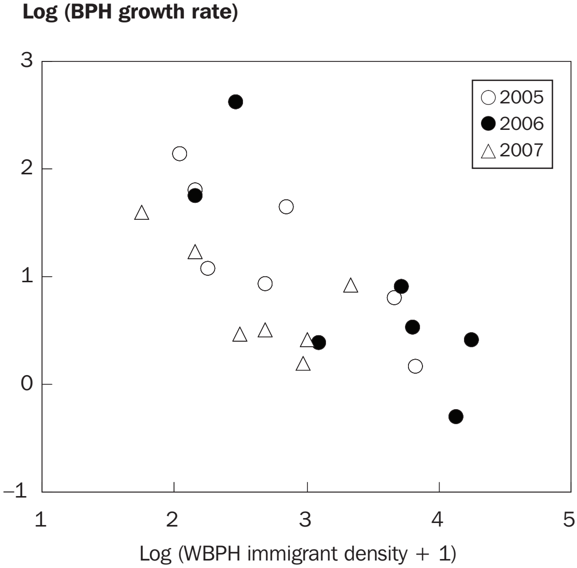

Fig. 7. Correlation between *S. furcifera* immigrant density and *N. lugens* growth rate from the immigrant generation to reproductive generation.

previous year (Fig. 1). The negative effect of *S. furcifera* on the population growth of *N. lugens* was suggested in laboratory experiments (Matsumura and Suzuki 2003). In order to analyze the effect of *S. furcifera* population on *N. lugens* growth in field conditions, population growth rates from the immigrant generation to reproductive generation were calculated using light trap data. Seven locations for light trap monitoring sites on Kyushu Island—Kawazoe, Koshi, Hondo, Miyakonojyo, Nobeoka, Kunitomi, and Kagoshima—were selected. The total number of trap catches from 20 June to 20 July represented population density of the immigrant generation, and from 21 July to 30 September represented population density of the reproductive generation. Negative correlation was observed between *S. furcifera* immigrant density and *N. lugens* growth rate (reproductive/immigrant) (Fig. 7). Average *S. furcifera/N. lugens* ratios of the immigrant generation varied among years: 42, 59, and 24 in 2005, 2006, and 2007, respectively. The high *S. furcifera* ratio in the immigrant generation may have caused the low growth rate of *N. lugens* in 2006.

Changes in insecticide application manner

Insecticide applications are a major control method against planthoppers in Japan. In the 1980s, total insecticide usage was more than 2–3 times per field. However, the total amount of chemical application decreased in the mid-1990s (Fig. 8). One major reason for that reduction in chemical usage was the introduction of persistent

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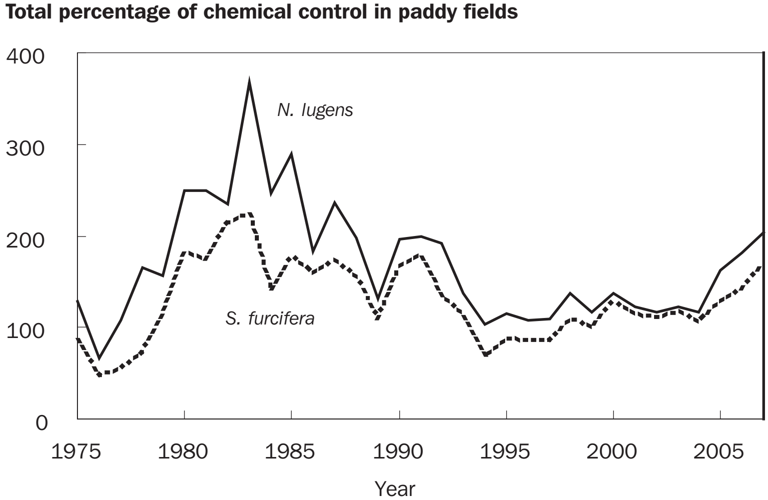

Fig. 8. Changes in the total percentages of chemical control in paddy fields against planthoppers in Kyushu, Japan.

systemic insecticides for nursery-box application. This method has been widely used in more than 60% of the rice fields in Japan for control of insect pests of early-stage rice plants. The *N. lugens* population growth rate from the immigrant generation to the first generation is higher than that in other generations (Fig. 9, Kuno 1979, Watanabe ad Tanaka, unpublished). Therefore, reducing the initial population growth rate using insecticide is an effective method for *N. lugens* in the temperate region.

The nursery-box application method can reduce labor and time for chemical treatment, and the total amount of chemical usage. But the chemicals are applied regardless of the pest density at transplanting time, earlier than planthopper immigration. Under such conditions, farmers may lose their concern about insect pest occurrences, and tend to miss a timing of an additional spray even when the forecasting of outbreaks is released. Many agricultural cooperative associations have introduced radio-controlled helicopters to spray additional chemicals in rice fields. The flight schedule of the helicopter is usually fixed before the rice-growing season and does not depend on pest incidence. In 2005, even with the forecasting information on *N. lugens* outbreaks, an additional spray of chemicals with appropriate timing was difficult for such reasons.

The development of insecticide resistance to some chemicals was reported in the planthopper population in 2005 (Matsumura et al 2007, Gyotoku and Kuchiki 2007). Insecticide resistance is one of the important population characteristics, as well as wing-form response to density and virulence to resistant varieties that we should know in more detail to improve the control strategy for planthoppers.

A high-precision and real-time migration prediction model was developed (Otuka et al 2005) and is now available on the Web (http://agri.narc.affrc.go.jp/). The combination of information on planthopper incidence in each area and a real-time

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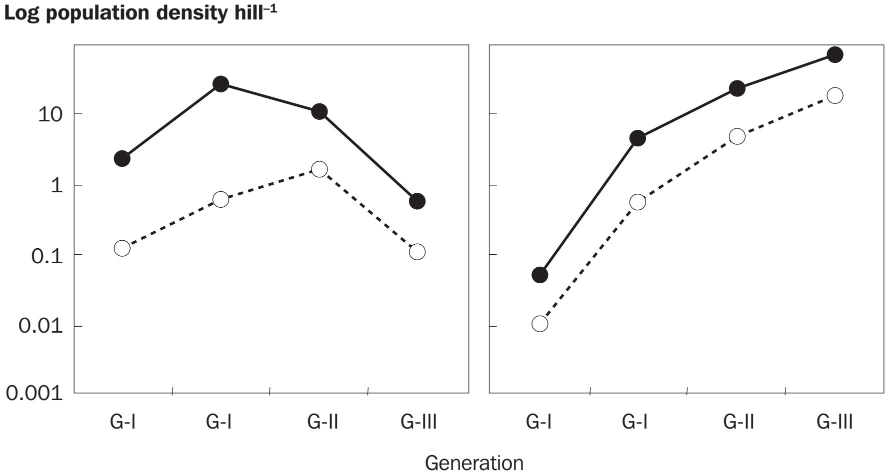

Fig. 9. Population growth of two planthopper species obtained by field census in Kyushu, Japan. 1961-68: Kuno (1979); 1987-91: Watanabe and Tanaka, unpublished.

prediction model makes it possible to improve wide-area planthopper management. Therefore, we should discuss Asia-wide planthopper management strategies.

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Notes

Authors' addresses: Tomonari Watanabe and Akira Otuka, National Agricultural Research Center, Tsukuba, Ibaraki 305-8666, Japan; Masaya Matsumura, National Agricultural Research Center for Kyushu Okinawa Region, Koshi, Kumamoto 861-1192, Japan. Email:tomonari.watanabe@affrc.go.jp.

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