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**Landing Places of Migratory Planthoppers,
Nilaparvata lugens (STÅL) and *Sogatella furcifera*
(HORVÁTH) (Homoptera: Delphacidae) in Japan**

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Migratory planthoppers, *Nilaparvata lugens* (STÅL) and *Sogatella furcifera* (HORVÁTH), both migrate from abroad to Japan every year. *Tsubo* is the term used for lowland paddy fields where the planthoppers usually make their first landing. In order to identify and examine the general features of *Tsubo*, a nationwide questionnaire survey was conducted in 1986 and 1987. Two typical types of *Tsubo* were identified by topographical conditions and wind direction. One type is located on the east side of hills sheltered from westerly winds and is generally found along the coast. The other type is located at the end of valleys facing windward. Migration of planthoppers to Japan takes place during the rainy season (usually early June to mid July) when the prevailing wind is from the southwest. The airborne insects generally land on the side of hills away from the wind or in a protected valley facing windward. Survey of the planthopper population in *Tsubo* early in the season will aid in the assessment of planthopper abundance in any given year.

INTRODUCTION

The brown rice planthopper, *Nilaparvata lugens* (STÅL) and the whitebacked rice planthopper, *Sogatella furcifera* (HORVÁTH) (Homoptera: Delphacidae) are both serious pests of rice plants in Japan. Since they do not diapause, it is hard for them to survive the winter in Japan because of low temperatures and a lack of host plants. ASAHINA and TSURUOKA (1968) reported that *S. furcifera* and *N. lugens* were caught on a weather ship located at the Ocean Weather Station 'Tango', about 500 km south of the Japanese coast, during July and August in 1967. KISIMOTO (1971, 1976) who analyzed the relationship between the synoptic weather patterns of Far East Asia and the migration of rice planthoppers suggested that the planthoppers originating in mainland China are transported by a depression or successive depressions along the Baiu front. Recently, SEINO et al. (1987) proposed the hypothesis that the carrier of these planthoppers is the southwesterly low-level jet streams which occur at altitudes of 1,000–2,000 m. A computer program of this model was developed by WATANABE et al. (1988).

The migration of rice planthoppers includes a series of three stages, i.e. take-off, transportation, and landing. Although the relationship between transportation and weather pattern has been studied by many authors as mentioned above, we know very little about take-off and landing. For landing, it is claimed that there are special places

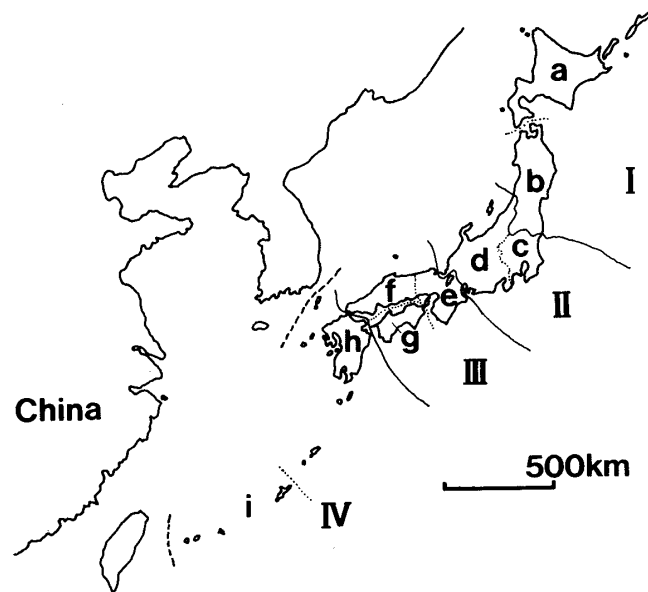


Fig. 1. Four regions and nine districts in Japan used in the text. I: (a) Hokkaido, (b) Tohoku. II: (c) Kanto, (d) Chubu. III: (e) Kinki, (f) Chugoku, (g) Shikoku. IV: (h) Kyushu, (i) Okinawa.

called '*Tsubo*' which the planthoppers use. *Tsubo* is the term given to a group of lowland paddy fields where the insects' first landing is most likely to occur due to favorable topographical conditions and wind direction. The rice plants in *Tsubo*, therefore, are apt to suffer insect attack and are vulnerable to hopper-burn. Theoretically, landing is a phenomenon quite independent from hopper-burn; however, the latter appears to be caused by a large influx of planthoppers. The two factors are therefore difficult to distinguish in the type of questionnaire we used and thus were dealt with together.

In this paper, we report the results of this nationwide survey on *Tsubo*.

METHODS

The survey questionnaires were distributed in 1986 and 1987. In 1986, we asked the names of places where the first landings and hopper-burns of the planthoppers were most likely to occur, in addition to the topographical conditions. In the second questionnaire in 1987, we asked for further information on these places and detail on the timing when landings and hopper-burns usually take place in an average year. The questionnaires were sent to the person in charge of the forecasting of pest occurrence in each of the 47 prefectures in Japan. Since the criteria used for *Tsubo* are not necessarily the same among the prefectures, in 1987 we sent a set of the 1986 responses and asked that the second questionnaire be made comparable. In both years, 100% of the questionnaires were returned, and the replies were analyzed in terms of regions, topographical and climatic conditions (Fig. 1).

RESULTS

The distribution of *Tsubo* throughout Japan is shown in Fig. 2. As the criteria

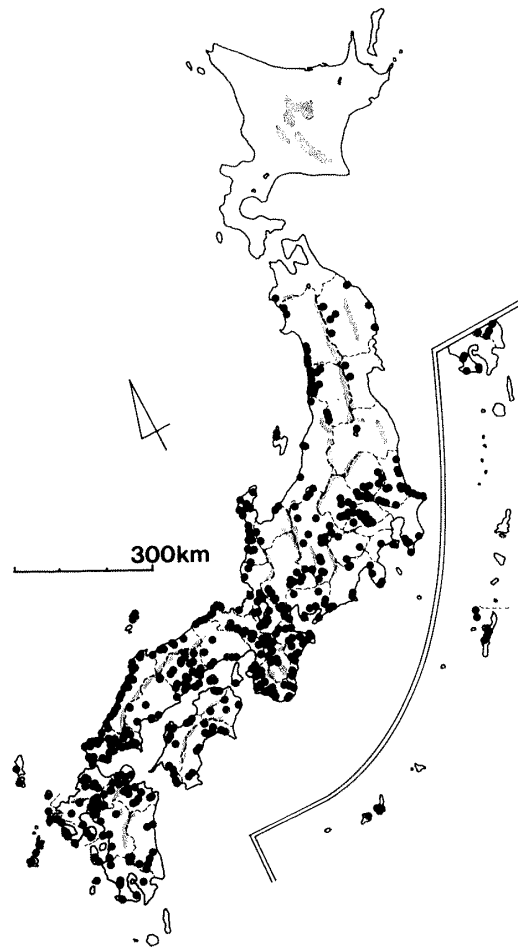


Fig. 2. Distribution of the *Tsubo* where planthoppers are most likely to land first and where rice plants often suffer hopper-burn. Shaded parts indicate major mountains.

Table 1. Typical landing places of planthoppers and times when landing and damage to rice plants is most likely to occur in Japan

Region ^a	Typical landing place	Landing time	Time damage occurs ^b
I. Tohoku district	coast	mid to late Jul.	(S): mid to late Aug.
II. Kanto and Chubu district	mountainous basin and river basin	mid Jun. to late Jul.	(S): late Jul. to early Sep. (N): Aug. to early Oct.
III. Kinki, Chugoku and Shikoku districts	coast, mountainous basin, and river basin	mid. Jun. to late Jul.	(S): late Jul. to mid Aug. (N): mid Aug. to early Oct.
IV. Kyushu district	coast and river basin	early Jun. to late Jul.	(S): late Jul. to late Aug. (N): late Aug. to early Oct.

^a Roman numerals indicate the regions shown in Fig. 1.

^b (S): sucking damage caused by adults of *S. furcifera*. (N): hopper-burn caused by *N. lugens*.

for identifying the *Tsubo* varied, the number of points in each prefecture does not necessarily indicate the extent of immigration and damage. The typical landing places of planthoppers and the times landing and causal damage were observed in each region

Table 2. Distribution of *Tsubo* in relation to topographical conditions

Topographical condition	No. of points	%
Coast	219	34.4
Mountainous area and basin	167	26.3
River basin	188	29.6
Plain	48	7.5
Lakeside	14	2.2
Total	636	100

Table 3. Number and proportion of *Tsubo* located on the east side of a hill and the end of a valley facing windward in relation to topographical conditions

	Topographical condition ^a			Total (%) ^b
	CO	MB	RB	
East side of a hill	39	18	0	57 (9.0)
End of a valley facing windward	0	15	75	90 (14.1)

^a CO: Coast, MB: Mountainous area and basin, RB: River basin.

^b Percentage indicates the proportion to total 636 points.

are summarized in Table 1. The number of *Tsubo* in various topographical conditions is summed up in Tables 2 and 3.

I. Hokkaido and Tohoku districts

The population densities of *N. lugens* and *S. furcifera* are so low in Hokkaido that no *Tsubo* were identified there.

In the Tohoku district, most of the *Tsubo* are located on the coast of the Sea of Japan. Some were also located on the east side of hills sheltered from westerly winds. Others are located on the east side of the Ōu Mountains and on the Pacific coast. Among the migrants, *S. furcifera* is dominant and damage by *N. lugens* rarely occurs in this district. The landing of *S. furcifera* is observed from mid July, one month later than in other districts (Table 1). Thereafter, the population grows rapidly and inflicts damage on rice plants from mid to late August.

II. Kanto and Chubu districts

Many of the *Tsubo* in this region are located in mountainous basins and river basins. Some are also distributed on the coasts of the Sea of Japan and the Pacific. Both *S. furcifera* and *N. lugens* migrate into this region from middle June to late July. But the timing of inflicting damage on rice plants differs between the two species (Table 1). *S. furcifera* leaves paddy fields before the onset of autumn, one generation earlier than *N. lugens*. Hopper-burns due to *S. furcifera*, therefore, were observed very rarely. This tendency was also true for the following districts.

III. Kinki, Chugoku, and Shikoku districts

Since various topographical conditions prevail this region, the locations of the *Tsubo* differed according to district. In Kinki, many *Tsubo* were in river basins, especially in the valley facing windward as observed on the Kii Peninsula. The *Tsubo* in

Chugoku were widely distributed in mountainous basins, river basins, and on the coasts of the Sea of Japan and the Inland Sea of Japan. By contrast, the *Tsubo* in Shikoku tended to be restricted to the coast.

IV. *Kyushu and Okinawa districts*

Higher density immigrations of planthoppers occur much more frequently in Kyushu than in other districts, and often seriously reduce rice yield. Since Kyushu is the nearest district to mainland China from which the planthopper apparently emigrates, many places in Kyushu are possible sites of the *Tsubo*. Generally speaking, most *Tsubo* in Kyushu are located on the coasts and in river basins. However, their location in any particular year rather depends on the weather patterns during migration and the extent of chemicals applied for control after immigration. Although the damage to rice plants in Kyushu occurs at almost the same time of year as in other districts (Table 1), small populations of migrant planthoppers sometimes land as early as April to June.

Tsubo in Okinawa are located only on the coast because this prefecture consists of subtropical islands. The arrival of planthoppers takes place earlier than in mainland Japan. Since rice is cropped twice a year, hopper-burns develop in June and from September to October.

DISCUSSION

Many *Tsubo* are located along the coasts, in the mountainous basins, and in basins along the middle and lower courses of rivers (Table 2). As the first landing place of planthoppers, however, two typical types of *Tsubo* were identified by topographical conditions and wind direction. One is lowland paddy fields located on the east side of a hill sheltered from westerly winds (Fig. 3A). This type was frequently found on the coast of the Sea of Japan. In Kagoshima Prefecture in southern Kyushu, this type was only observed when the prevailing wind was westerly for a few successive days and the size of the migrant population was small (Fukamachi, personal communication).

Another type of *Tsubo* is found at the end corner of a valley facing windward. This type was distributed in mountainous and hilly areas like the Kii Peninsula (Fig. 3B). In Kagoshima Prefecture also, this type was found when the prevailing wind was westerly. SEINO et al. (1987) hypothesized that planthoppers are transported from mainland China to northern Kyushu by a low-level jet stream which blows south-westerly at a speed of more than 10 m/s at a height of 1,000–2,000 m. Below the jet-stream, a great deal of vertical atmospheric circulation may exist between the ground surface and the upper air layer. Therefore, some of the airborne planthoppers may be caught in a downdraft before landing on the eastern side of a hill or the end of a valley facing windward.

Although these two typical types of *Tsubo* accounted for ca. 23% of all of the points (Table 3), the replies to questionnaires suggested that most *Tsubo* seemed related to the wind direction during migration, irrespective of their topographical conditions.

In this survey, we could not distinguish the *Tsubo* where the first landing occurs from those where hopper-burns are likely to be found. In northern Japan (Region I in Fig. 1), however, the locations where rice plants suffered damage unquestionably coincide with those where the first landing of *S. furcifera* took place, because immigrating planthoppers were mostly composed of *S. furcifera* whose following generation

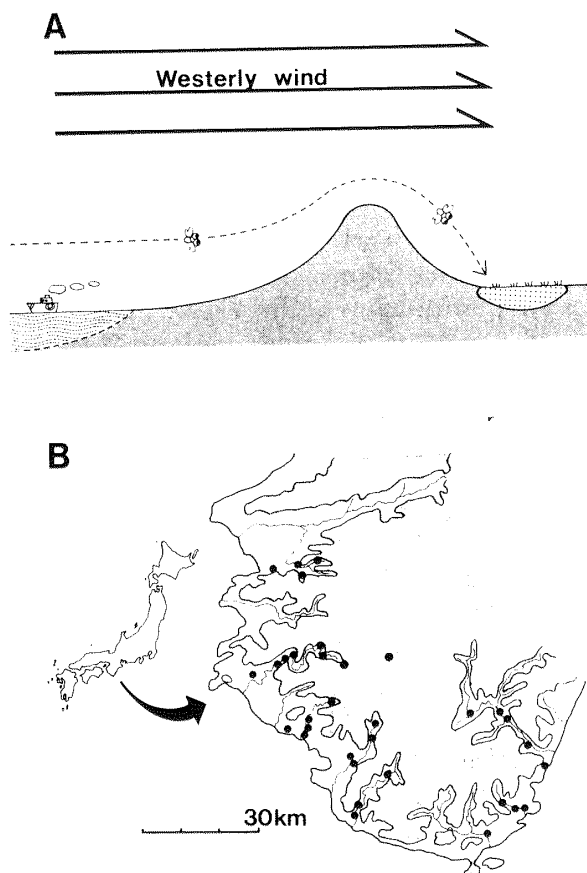


Fig. 3. Topographical conditions of two typical types of *Tsubo* where first landing of planthoppers is most likely to occur. A: the east side of a hill sheltered from westerly winds. B: Valley locations on the Kii Peninsula whose windward ends attract the insects. Shaded parts indicate mountainous areas 200 m above sea level.

damages rice plants, one generation earlier than *N. lugens* (Table 1). The fact that the migration into northern Japan takes place one month later, in mid to late July, suggests that some individuals may be adults which emerged in the southern districts in Japan.

On the other hand, in central, western, and southwestern Japan (Regions II-IV), *S. furcifera* and *N. lugens* infest rice plants simultaneously. Since *N. lugens* inflicts damage about two and a half months after its migration, some *Tsubo* may be difficult to identify owing to the intervening chemical control done to prevent hopper-burn.

Identification of *Tsubo* and survey of immigrated planthopper population in *Tsubo* will help not only the early assessment of planthopper abundance in paddy fields, but also the analysis of their landing behavior in relation to weather and topographical conditions.

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