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Correlation between Migratory Flight of Rice Planthoppers and the Low-Level Jet Stream in Kyushu, Southwestern Japan

Tomonari WATANABE,[1,5] Kazushige SOGAWA,[1,5] Yoshio HIRAI,[1,6] Masaichi TSURUMACHI,[2,5] Saburo FUKAMACHI[3,7] and Yoshio OGAWA[4]

[1]*Kyushu National Agricultural Experiment Station, Chikugo, Fukuoka 833, Japan*
[2]*Okinawa Branch, Tropical Agriculture Research Center, Ishigaki, Okinawa 907, Japan*
[3]*Kagoshima Agricultural Experiment Station, Kagoshima 891–01, Japan*
[4]*Nagasaki Agricultural and Forestry Experiment Station, Isahaya, Nagasaki 854, Japan*

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Relation between overseas immigration of rice planthoppers, *Nilaparvata lugens* and *Sogatella furcifera*, and development of low-level jet streams (LLJET) was investigated. Net traps were used at Chikugo, Isahaya and Kagoshima in Kyushu, and a light trap was employed on Ishigaki, Okinawa, to catch the planthoppers. Occurrence and development of LLJET were monitored by analyzing the wind data from 850 mb weather charts. Immigration area of the planthoppers was closely associated with the location of LLJETs. Synchronous catches of immigrants over a wide range of the Kyushu and Okinawa areas could be accounted for by localization of LLJET. Thus, monitoring of the LLJET in the Baiu season (June and July) is useful to predict the immigration of planthoppers into Kyushu and Okinawa. In Ishigaki, however, immigrants were occasionally caught without a LLJET present.

Key words: rice planthoppers, *Nilaparvata lugens*, *Sogatella furcifera*, overseas immigration, low-level jet stream

INTRODUCTION

The rice brown planthopper (BPH), *Nilaparvata lugens* (STÅL) and the white-backed planthopper (WBPH), *Sogatella furcifera* (HORVÁTH), have been known as long distance migrants infesting rice in Asia (KISIMOTO, 1976). Because they do not overwinter in Japan, their field populations start to increase from overseas immigrants appearing in the Baiu (rainy) season in June and July. Monitoring their immigration is one of the most important factors which decide control strategies. KISIMOTO et al. (1982) surveyed the migratory flights at four separate sites in southwestern Japan, and concluded that the frontal system played an important role in synchronous immigration.

SEINO et al. (1987) proposed a hypothesis that the migratory planthoppers were transported to distant places by low-level jet streams (LLJET), which is the southwesterly strong airflow which often appears along the Baiu frontal system at 1,000–3,000 m (NINOMIYA, 1979). They showed that rice planthoppers would immigrate

[5] Present address: *Kyushu National Agricultural Experiment Station, Nishigoshi, Kumamoto 861–11, Japan*
[6] Present address: *National Grassland Research Institute, Nishinasuno, Tochigi 329–27, Japan*
[7] Present address: *Osumi Branch, Kagoshima Agricultural Experiment Station, Kimotsuki, Kagoshima 893–16, Japan*

into northern Kyushu, when 1) maximum wind portion of a LLJET goes through northern Kyushu, 2) the wind trajectory is traced back to the rice cultivating areas in southeast China, and 3) the mean speed of LLJET along the trajectory is above 10 m/s (20 knots). These three points are hereafter called "SEINO's conditions". WATANABE et al. (1988) developed a computer program to analyze the wind condition at 850 mb.

SEINO et al. (1987) set up their hypothesis using the migrants data of two net traps at Chikugo, Fukuoka, Japan. Simultaneous monitoring of migrating planthoppers in a large area is very effective to verify the relationship between immigration and LLJET. The present survey was conducted to corroborate the hypothesis of SEINO et al. (1987) and its practical significance for monitoring the immigration of the planthoppers to the Kyushu and Okinawa areas.

METHODS

Locations of monitoring sites. Immigrations of the planthoppers were monitored at three separate localities in Kyushu: Chikugo (Fukuoka Prefecture, 33°12′N, 130°29′E), Isahaya (Nagasaki Prefecture, 32°49′N, 130°01′E), and Kagoshima (Kagoshima Prefecture, 31°34′N, 130°33′E). The same was done at Ishigaki (Okinawa Prefecture, 24°20′N, 124°10′E) an island located in the southern part of the Ryukyu Islands (see Fig. 2). The distances from Chikugo to Isahaya, Kagoshima and Ishigaki are about 60, 180 and 1,000 km, respectively.

Traps. Two net traps (1 m wide × 1.5 m deep) were placed at about 10 m above the ground at Chikugo, Isahaya and Kagoshima. At Ishigaki, a light trap equipped with a 20 W chemical fluorescent lamp in a transparent box (45 × 45 × 80 cm) with a louver structure was employed, designed to effectively capture planthoppers and rice leafroller, *Cnaphalocrocis medinalis* GUENÉE (YAMASHITA and FUKAMACHI, 1982). In all cases, the traps were emptied daily at 0900 Japan Standard Time (JST). Surveys were carried out in June and July, 1987.

Analysis of LLJET. Occurrence and development of LLJET were detected by computer programs (WATANABE et al., 1988) applying wind data from 850 mb weather charts which were transmitted by radio facsimile at 0900 and 2100 JST on a daily basis. We considered wind reaching speeds above 10 m/sec (20 knots) on the 850 mb chart as LLJET.

RESULTS AND DISCUSSION

Dialy records of the number of immigrant planthoppers by traps at each sites are shown in Fig. 1. The patterns of immigration were similar at the three locations in Kyushu. The patterns at Ishigaki differed. Development of LLJETs and the total catches of planthoppers in each immigration period are summarized in Table 1.

Synchronous immigrations were found to occur in the areas covered by LLJETs (Table 1 A, B, D, E and G).

June 1–10 (Table 1A)

Immigrations were observed synchronously at Ishigaki, Isahaya and Chikugo, only when LLJET appeared continuously from the South China Sea to the Ryukyu Islands and Kyushu (Fig. 2-A).

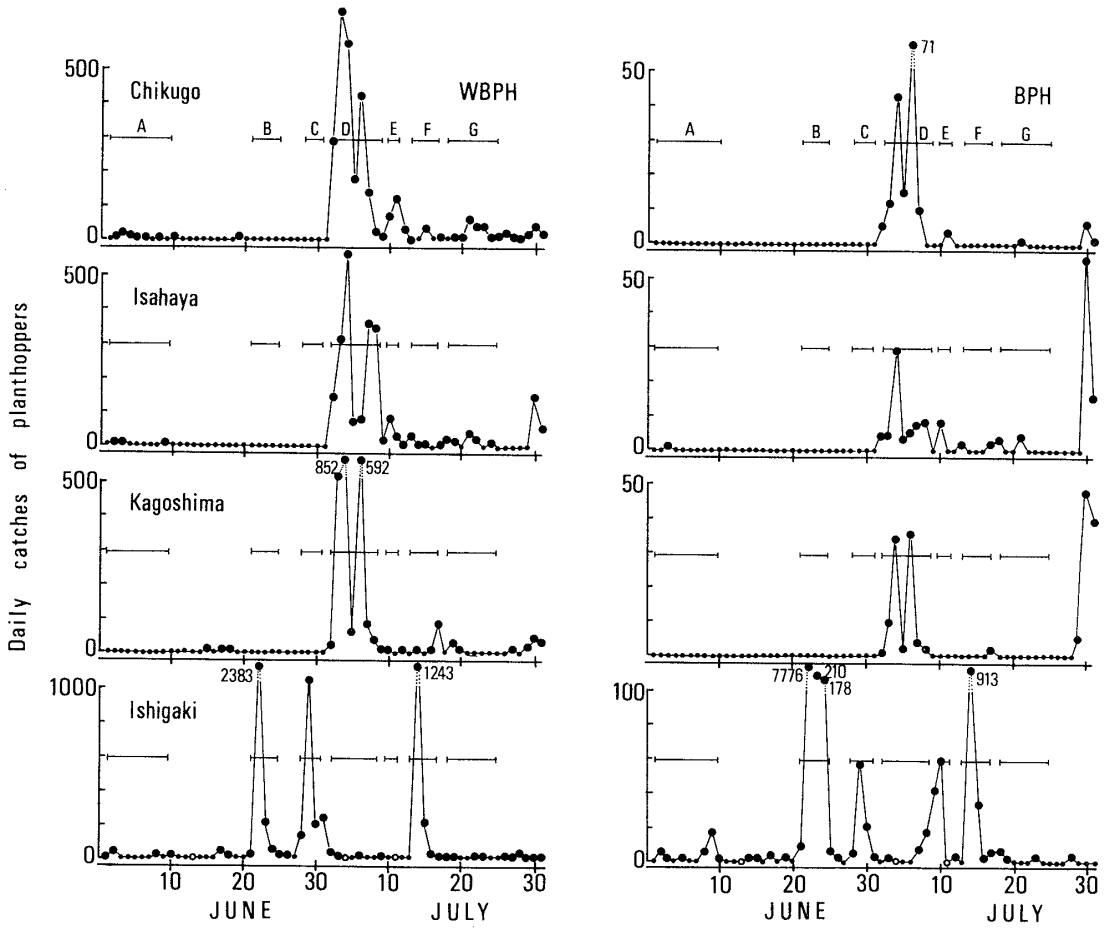

Fig. 1. Daily catches of planthoppers by 2 net traps at Chikugo, Isahaya and Kagoshima, and a light trap at Ishigaki, June to July, 1987. WBPH: *Sogatella furcifera*, BPH: *Nilaparvata lugens*. Small closed circles show days when no immigrations were recorded. Small open circles show days when no observations were made. Horizontal bar and figures A to G indicate the immigration periods.

June 21–25 (Table 1B)

At Ishigaki, BPH-dominated mass immigrations occurred (Table 1B), when a LLJET restricted above Taiwan and the Ryukyu Islands developed (Fig. 2B).

July 2–9 (Table 1D)

Massive and synchronous immigrations of WBPH and BPH took place in Kyushu. During this period, a typical LLJET developed and extended from south China to Kyushu, via the Yangtze river delta and East China Sea (Fig. 3D). Planthoppers were caught at Ishigaki during this period, but these catches did not synchronize with the immigration peak which occurred in Kyushu.

July 10–11 (Table 1E)

When LLJET appeared in the northern part of Kyushu (Fig. 3-E), immigrants were trapped at Chikugo and Isahaya. Only one WBPH was trapped at Kagoshima.

Table 1. Relationship between the immigration period and the location of low-level jet stream

		Chikugo			Isahaya			Kagoshima			Ishigaki		
		WBPH[a]	BPH[b]	LLJET[c]	WBPH	BPH	LLJET	WBPH	BPH	LLJET	WBPH	BPH	LLJET
A	June 1–10	28[d]	0	○	11	1	○	0	0	○	21	31	○
B	21–25	0	0	×	0	0	×	0	0	×	3,111	8,168	○
C	28–July 1	0	0	×	0	0	×	0	0	×	1,603	80	×
D	July 2–9	2,325	156	○	1,857	60	○	2,154	86	○	25	69	×
E	10–11	202	3	○	103	8	○	1	0	×	10	59	×
F	13–17	44	0	×	34	2	×	91	1	×	1,467	953	×
G	18–25	162	1	○	76	9	○	25	0	○	7	9	×

[a] WBPH; *Sogatella furcifera*, [b] BPH; *Nilaparvata lugens*

[c] Low-level jet stream, ○; Occurring under SEINO's condition, ×; not occurring.

[d] Number of catches between immigration periods. Two net traps were used at Chikugo, Isahaya and Kagoshima. A light trap was used at Ishigaki.

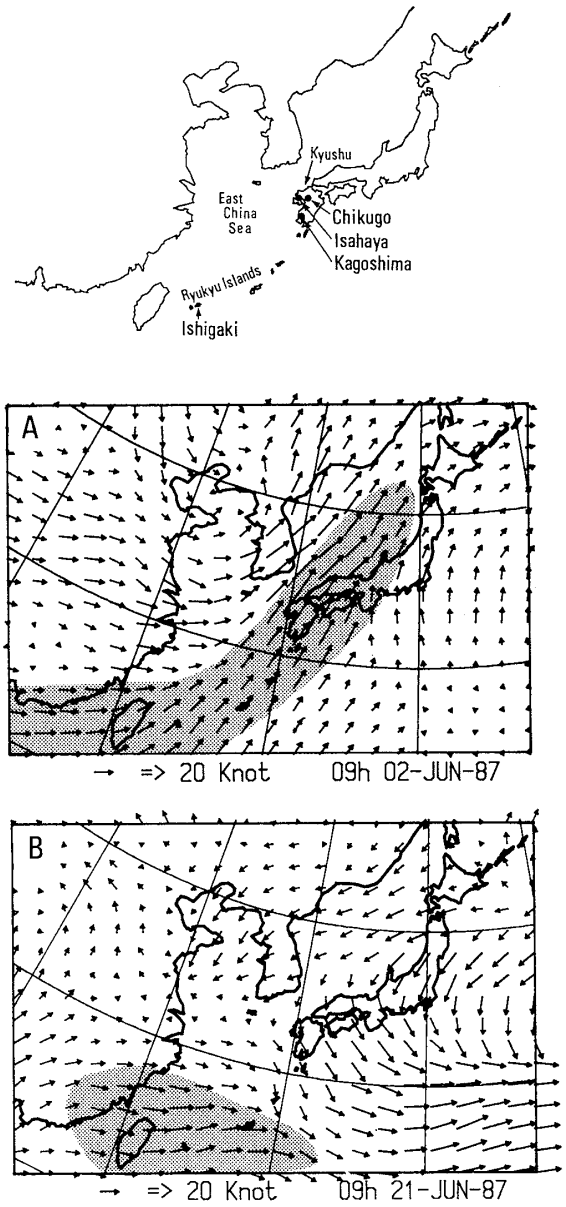

Fig. 2. Map of survey sites in Kyushu (top), and mesh map of the wind direction and speed at 850 mbanalyzed with WATANABE's (1988) computer program, on 0900 2 June (A) and on 0900 21 June (B) in 1987 Japan Standard Time (JST). Shaded area indicates the strong wind area with wind speeds greater than 20 knots.

July 18–25 (Table 1G)

LLJET developed from the central part of China to Kyushu through the East China Sea (Fig. 4-G), but there were few immigrants into Kyushu. The localization pattern of LLJET in this period was similar to that from July 2 to 9 (Fig. 3-D). This is probably due to the low density of emigrant populations in China.

SEINO et al. (1987) analyzed weather conditions during the Baiu season from 1980 to 1986, collating the possible migration days with those of actual migration in Chikugo.

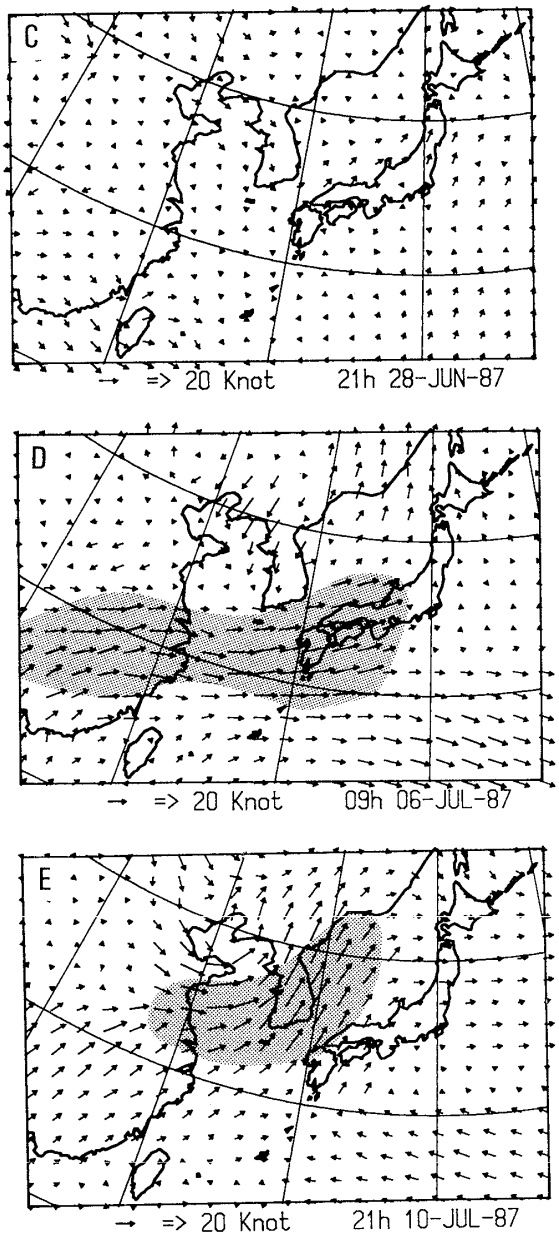

Fig. 3. Mesh map of the wind direction and speed at 850 mb. C: 2100 28 June, D: 0900 6 July, E: 2100 10 July.

There were 37 cases of possible migration, and 30 cases coincided with actual ones. In 1987, our analysis revealed close relationships between the localization of LLJET and immigration areas of the planthoppers, especially in Kyushu (Table 1, used 2×2 contingency table and tested by χ^2. $\chi_0^2=8.291$, $d.f.=1$, $p<0.01$).

Immigrations into Ishigaki occurred sometimes without concurrence of LLJET (Table 1C and F).

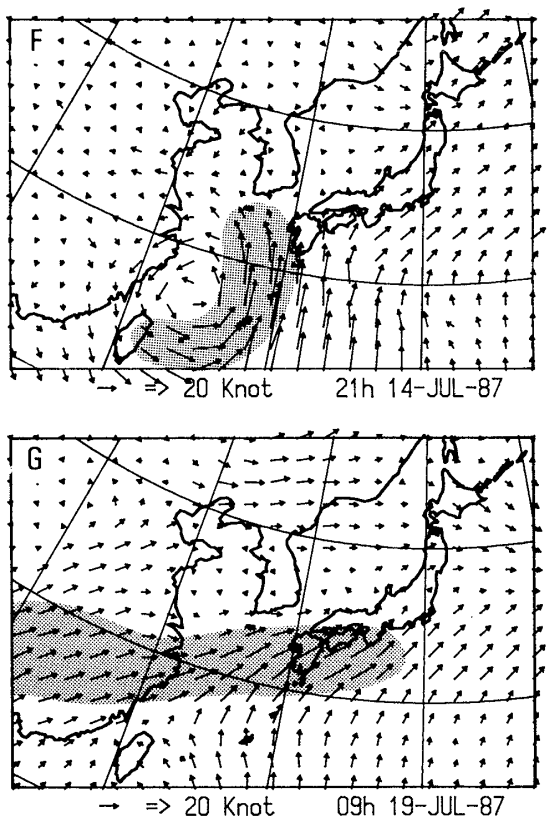

Fig. 4. Mesh map of the wind direction and speed at 850 mb. F:2100 14 July, G: 0900 19 July.

June 28–July 1 (*Table 1C*)

Significant WBPH-dominated catches were recorded at Ishigaki. In this period, indigenous adult populations of WBPH were not observed in the field (based on the field observation by TSURUMACHI). This was possibly an overseas influx of planthoppers not associated with LLJET, although there was a steady air flow below 20 knots from the Chinese continent to Ishigaki. Because of shorter distance, the LLJET might not be necessarily needed for immigration from China to Ishigaki.

July 13–17 (*Table 1F*)

Almost the same numbers of BPH and WBPH were caught at Ishigaki on 14 to 15 July. Although no LLJETs were occurring at this time, the typhoon No. 5 1987, passed through Ishigaki at 0900, 14 July, on the way to the Korean peninsula (Fig. 4-F). Small numbers of planthoppers were also recorded in Kyushu during this period, but immigration peaks did not coincide in the three monitoring sites.

We concluded that the monitoring of the development pattern and the localization of the LLJET is very useful to predict immigration days and areas in Kyushu during Baiu season. Further investigations are necessary for understanding of the immigration conditions at Ishigaki and other Okinawa areas.

REFERENCES

KISIMOTO, R. (1976) Synoptic weather conditions inducing long-distance immigration of planthoppers, *Sogatella furcifera* HORVÁTH and *Nilaparvata lugens* STÅL. *Ecol. Entomol.* **1**: 95–109.

KISIMOTO, R., J. HIRAO, Y. HIRAHARA and A. TANAKA (1982) Synchronization in migratory flight of planthoppers, *Nilaparvata lugens* STÅL and *Sogatella furcifera* HORVÁTH (Hemiptera: Delphacidae), in the south-western Japan. *Jpn. J. Appl. Ent. Zool.* **26**: 112–118 (in Japanese with English summary).

NINOMIYA, K. (1979) Low-level jet stream and rain band on the Baiu front. *Kisho Kenkyu Note* **138**: 118–141 (in Japanese).

SEINO, H., Y. SHIOTSUKI, S. OYA and Y. HIRAI (1987) Prediction of long distance migration of rice planthoppers to northern Kyushu considering low-level jet stream. *J. Agric. Meteorol.* **43**: 203–208.

YAMASHITA, Y. and S. FUKAMACHI (1982) Collection of rice leafrollers and brown planthoppers in traps equipped with fluorescent lamp and rice seedlings. *Proc. Assoc. Plant Prot. Kyushu* **28**: 111–113 (in Japanese).

WATANABE, T., H. SEINO, C. KITAMURA and Y. HIRAI (1988) Computer program for forecasting the overseas immigration of long-distance migratory rice planthoppers. *Jpn. J. Appl. Ent. Zool.* **32**: 82–85 (in Japanese with English summary).