Recent Trends in the Occurrence and Forecasting Procedures in the Brown Planthopper

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ABSTRACT

The brown planthopper, *Nilaparvata lugens* Stål, in Japan usually occurs upto the central part, but the population density is always higher in the southwestern part, being attributed to the transoceanic migration from overseas west or southwest into the country. The outbreaks of the brown planthopper have been very frequent in recent years especially after 1977: the most severest outbreak in the past 12 years occurred in 1983, extending to further north. Grassy stunt disease has occurred only in Kyushu since its discovery in 1978 while ragged stunt disease spotedly occurred there only in 1979 and 1980.

Forecasting work on the brown planthopper is carried out as part of the general forecasting program on ordinary crops under the charge of the national government. The work begins with the catch of immigrants by traps and field investigations during the immigration period (June-July), and thus determines the number of immigration waves, their dates, and the levels of immigrant population in each wave. The seasonal appearance of insect stages in a field is predicted by the effective temperature-sum rule. The second generation is characterized by the high proportions of brachypterous females. Surveys on the population density of brachypters (usually late July-early August) is essential to predict the occurrence of hopperburn in autumn: roughly 20 brachypterous females are the threshold. The major factors affecting the outbreaks of hopperburn are as follows: the levels of immigrant population, temperatures prevailing later than late August, and the time of major immigrations in relation to the number of generations occurring until rice harvest.

Introduction

The brown planthopper, *Nilaparvata lugens* Stål, is an old insect pest of rice in Japan, but, without overwintering there, it has been known as a long-distance migrant from overseas only since the early 1970's (Kisimoto, 1971 and others). This pest had been characterized by the sporadic outbreaks, but in recent years its outbreaks have been very frequent or almost every year especially in the southwestern part of the country. These sayings are also true for other long-distance overseas migrants of rice such as the white-backed planthopper, *Sogatella furcifera* Horváth, and the leafroller, *Cnaphalocrocis medinalis* Guenée in Japan. The origin of these migrants has not been definitely clarified but is considered to be the southern part of China mainland. The migrations of these insect pests in China mainland have also been reported in recent years (Cheng *et al.*, 1979; National Co-ordinated Research Group, 1981 and others).

The brown planthopper has become much more important in Japan like tropical Asian countries in recent years because of the occurrence of two virus diseases vectored by this pest: grassy stunt and ragged stunt, both being indigenous to tropical Asia. At present, the control of the brown planthopper has been the nucleous of the overall countermeasures of rice pests throughout the rice-growing season in the southwestern part of Japan. It has, thus, become

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much more important to forecast the outbreaks of the virus diseases as well as the brown planthopper with accuracy.

Outbreak Records in Recent Years

Planthoppers

The occurrence of the brown planthopper in Japan is characterized by the distinct geographical differences in insect population and damage, showing much more abundance in the more western or southern areas like Kyushu in contrast to no or least occurrences in the northern or eastern areas. The difference is attributable to the transoceanic movement of the migrants from the overseas west or southwest into Japan. The geographical difference is also true for the white-backed planthopper which immigrates simultaneously with the brown planthopper; however, the occurrence of the white-backed planthopper usually extends to further north upto Hokkaido compared with that of the brown planthopper because of the difference in migratory abilities of the two species. The brown planthopper usually occurs upto the central part of Japan.

Even in Kyushu, as shown in Table 1, the brown planthopper immigrants are usually abundant in number in the west (Nagasaki) and the south (Kagoshima) facing the East China Sea, followed by the southeast (Miyazaki) or the central north (Fukuoka), and the least in the northeast (Ohita). This saying is true for the white-backed planthopper.

Table 1. Total Numbers of Brown Planthoppers Captured by a Light Trap at the Experiment Stations in Kyushu During the Immigration Period upto July 20

Location in Kyushu	Central north	West	Northeast	Southeast	South
Year	Kyushu Natl. (Fukuoka Pref.)	Nagasaki	Ohita	Miyazaki	Kagoshima
1974	97	16,432	52	208	177
1975	266	950	6	5,434	607
1976	151	623	6	210	581
1977	125	1,035	181	339	1,613
1978	45	765	10	265	177
1979	201	680	28	41	470
1980	37	555	6	27	2,589
1981	151	233	69	16	34
1982[1]	176	6,013	83	1,670	8,368
1983	173	1,832	11	399	646

1) Upto the end of July because of prolongation of the rainy season in 1982.

Fig. 1 shows that the outbreaks of the brown planthopper are accompanied by those of the white-backed planthopper in most of the years. In the past 12 years, the 1983 outbreak of both planthoppers in nation scale was the largest both in areas involved and in severity of damage: the total infested areas in the country amounted to 1,278,000 ha for the white-backed planthopper and 665,500 ha for the brown planthopper , accounting for 57% and 30% of paddy fields (2,230,300 ha), respectively. The yield loss caused by both planthoppers that year is estimated to be 123,900 t (1.2% loss). The 1983 outbreak of the brown planthopper is

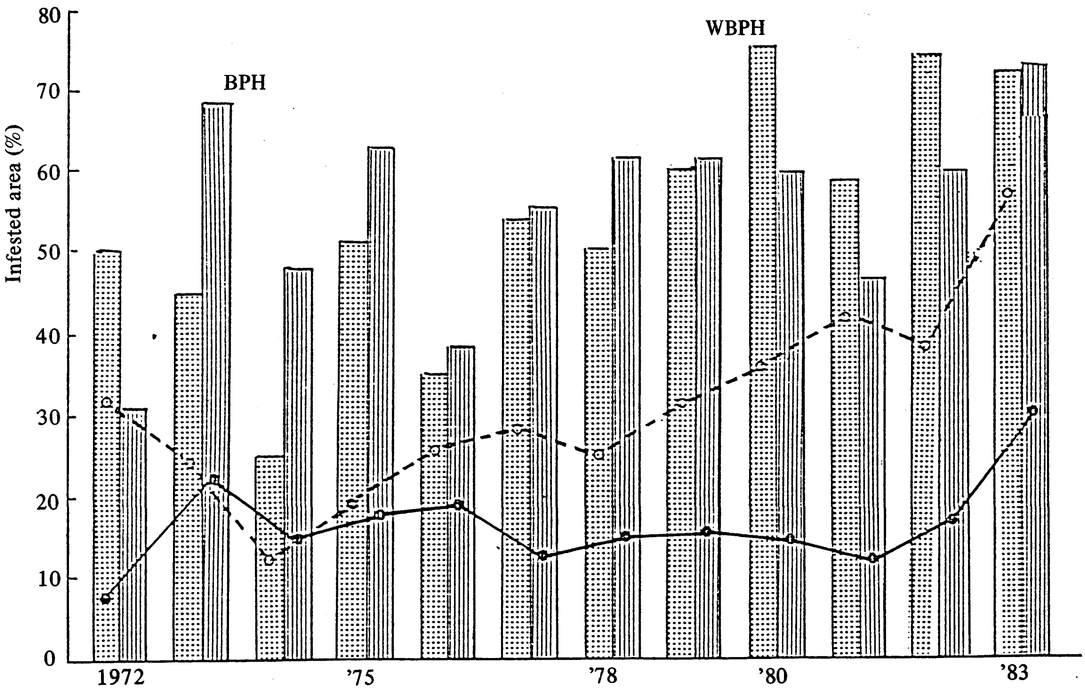

Fig. 1 Infested areas by planthoppers in Japan and Kyushu district.
Line: Japan; solid line = brown planthopper (BPH), dotted line = white-backed planthopper (WBPH), histgram: Kyushu district.

characterized by extending to further north upto the Tohoku district and by the occurrence of hopperburn on the Yaeyama Islands, Okinawa Pref., near Taiwan. The above-mentioned occurrences in terms of its wide-spread are the rear cases.

In Kyushu, the percentages of infested areas by both planthoppers always exceeded those of the country, reflecting the geographical difference. About 60% infested paddy fields by each planthopper occurred in most of the recent years especially after 1977. The most severest outbreak of the brown planthopper in Kyushu in the past 12 years was recorded in 1983, 190,400 ha (71%) being infested, followed by 228,400 ha (68%) in 1973, and that of the white-backed planthopper was in 1980, 226,800 ha (75%) being infested.

Concerning the cause of consecutive outbreaks of the migrating planthoppers in Japan in recent years, it may be considered that the extent and severity of the incidence of the planthoppers have become high in China mainland due to new rice cropping systems for high rice production; both planthoppers have been one of the most important insect pests of rice since the early 1970's (Cheng *et al.,* 1979 and others).

Virus diseases vectored by brown planthopper

The occurrence of grassy stunt disease was first observed in Kyushu in 1978 (Iwasaki and

Shinkai, 1979) and ragged stunt disease in 1979 (Shinkai *et al.,* 1980). Since then, grassy stunt disease has occurred in Kyushu every year, while only a few infected rice hills by ragged stunt disease were found in Kagoshima and Nagasaki prefectures in 1979 and 1980. The occurrence of these diseases has so far been restricted to Kyushu. The 1979 outbreak of grassy stunt disease was the severest: 30% of 35,000 ha were affected in Kagoshima. The incidence of the disease varied both in localities and in years (Table 2). The causes of fluctuation are strictly unknown though the population density of planthopper immigrants in Kagoshima and Nagasaki prefectures is always higher than that in other locations of Kyushu as shown in Table 1.

Table 2. Affected Areas (ha) by Grassy Stunt Disease in Kyushu

Prefecture	1979	1980	1981	1982	1983
Fukuoka	spot	1	0.1	3	0.2
Saga	spot	spot	spot	spot	0
Nagasaki	7,000	6,000	600	4,000	1,900
Kumamoto	34	spot	0.2	spot	21
Ohita	1	0	1	0	0
Miyazaki	44	10	2	5	1
Kagoshima	10,618	2,956	71	1,974	100
Okinawa	spot	1	spot	0	0
(Total)	(17,697)	(8,968)	(674.3)	(5,982)	(2,022.2)

Both brown planthopper and diseases can not survive the winter season in Japan and all of them are renewed every year by the overseas immigrants. Viruliferous immigrants for grassy stunt disease were detected though their proportions were extremely low (Hirao *et al.,* 1984).

Organization and General Forecasting Work

The forecasting program for the occurrence of diseases and insect pests on ordinary crops (rice and wheat) was initiated in 1941. And then, the regular program on fruits and tea was started in 1965 after the 4-year experimental program and on vegetables in 1980 after the 11-year experimental program.

Organization of national program

All of the forecasting programs are under the charge of the Plant Protection Division, Agricultural Production Bureau, MAFF (Fig. 2). Part of business such as relating to the grant of subsides is shared by the Plant Peotection Section belonging to seven regional agricultural administration offices, MAFF, over the country. Some researches on diseases and insect pests which are basic to establish the methods for forecasting are carried out by the national research organizations such as agricultural experiment stations in regions, fruit tree research stations, and vegetable and ornamental crops research stations.

Organization of prefectural program

The prefectural program for forecasting is under the charge of the plant protection section belonging to the prefectural government. There are two or three officers per section per prefectural government (47 prefectures). The officers have administration work about plant protection in the prefecture. Resonsibility for the forecasting program in terms of technical work is assumed by full-time researchers for forecasting at the experiment station or other

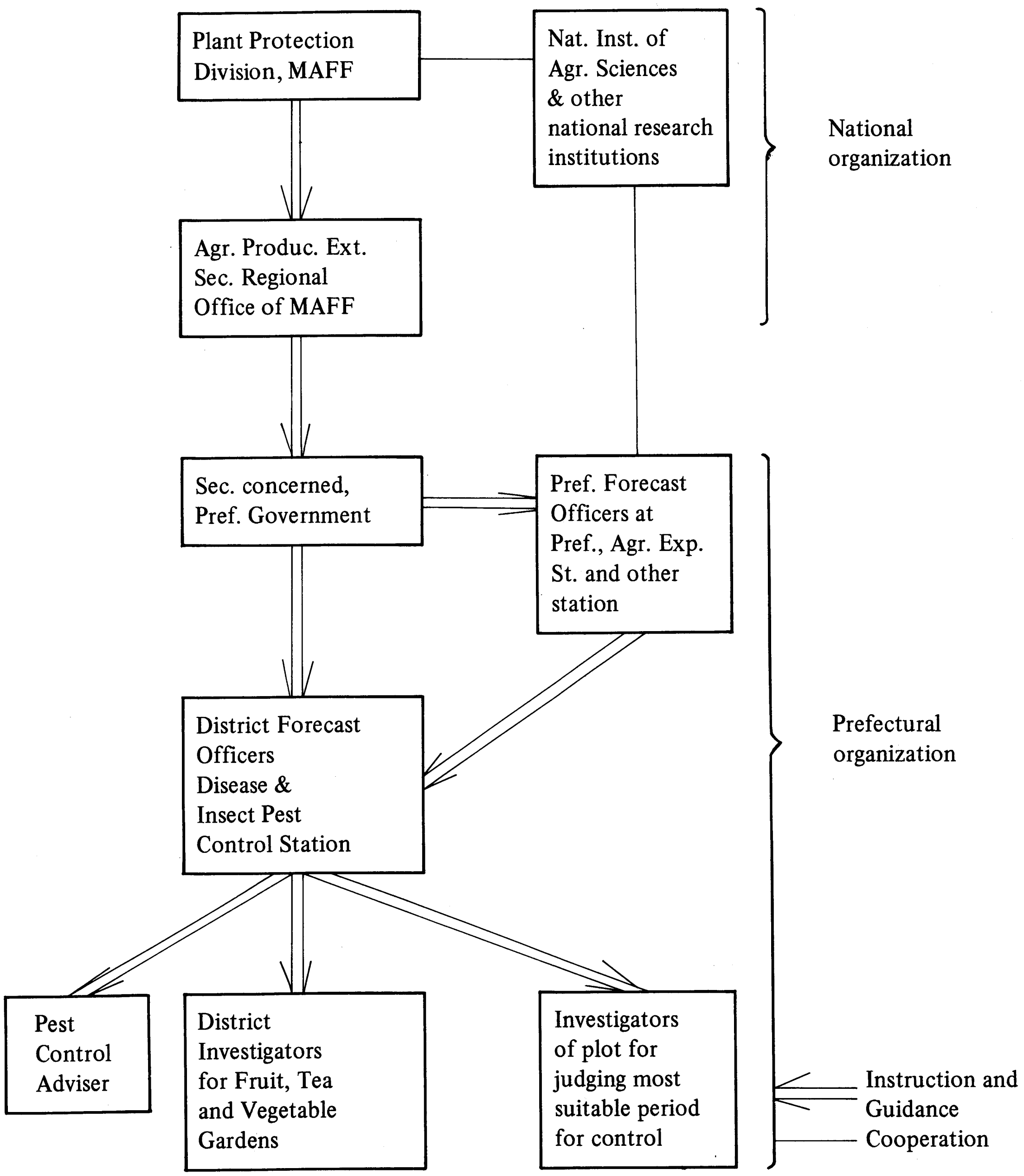

Fig. 2. Organization of forecasting program (Yasuo *et al.*, 1980).

research station (173 researchers in national total, 1982; ca. 4 researchers/pref.). Besides, a national total of 433 district forecast officers in 203 plant protection offices (avg. 2.1 officers/office and 4.3 offices/pref.) over the country. Additionally, there are 11,149 part-time persons such as pest control advisers who mostly are farmers and employees of agricultural co-operatives and of local administration offices.

General forecasting work

The forecasting work is carried out by

"Details for the Enforcement of Disease and Insect Pest Outbreak for Forecasting Work" established by the national government. The details have partially been amended and now are under rivision and a completely-revised edition is issued in 1986.

At the fixed points, investigations on the occurrence of pests are conducted in the observatory rice fields and traps at regular intervals. Besides, plant protection officers regularly carry out monitoring observations in the fields at observatory points. The results of these investigations and observations are discussed by the staff members concerned, and the reports are issued: forecasting, caution, warning, and a special report on new or unusual pest occurrence. The reports are delivered to the organizations concerned in and outside the prefecture. Finally, an annual report is issued. Additionally, national forecasting reports are issued by the Plant Protection Division several times a year based on the reports by the prefectural governments.

Procedures for Forecasting Outbreaks

Methods for catching planthopper immigrants

The forecasting work on migratory planthoppers begins with the catches of their immigrants. The immigration of the brown planthopper together with the white-backed planthopper usually occurs for about one month during the Bai-u (rainy) season from mid-June to mid-July, but occasionally lasts longer when the rainy season unusually extends longer upto the end of July. To know the dates and frequencies of immigration waves and the population density of immigrants, we usually use a light trap (a 60W bow-frosted bulb with double filament) and an airborne net (lm in diameter) at a height of about 10m above the ground. Additionally, the following traps, if necessary, are used: a yellow-pan water trap (60cm in diameter, water filled with a few drops of detergent) and a sticky trap (80 x 25cm in size, coated on bothside of wire gauze with an adhesive). Trap records are taken every day throughout the immigration period. Field surveys by visual counting are essential to record the population density of immigrants every time when the immigrations are observed by those traps.

Methods for surveying planthopper population in a field

After the establishment of immigrants in a paddy field, the following methods are used to record the population density. The tap-and-count and push-aside methods are employed for counting nymphs. Visual counting is also available for adults of the second generation occurring during late July to early August when rice plants are before the maximum tillering stage. When plant growth advances further, the tap-and-count and push-aside methods are used for both nymphs and adults. As the insect population density becomes much more higher, the sticky board method is effective to estimate the absolute population of nymphs on a sampling hill from the catch on a board using a conversion equation (Nagata and Masuda, 1978).

Forecasting outbreaks

The planthopper immigration can roughly be predicted by weather conditions. Immigrations are observed when the passage of depression on the Bai-u front occurs from the west or south-west (Fig. 3).

The population density of white-backed planthopper immigrants always exceeds that of brown planthopper, and the number of both planthoppers captured is usually larger in a light trap than that in two airborne nets (Table 3). The 8-year records on the immigration of planthoppers at the Kyushu National Agricultural Experiment Station (Chikugo, Fukuoka Pref.) are shown in Fig. 4. The beginning, the end, and the number of immigration waves differ markedly in years. For instance, the immigration period lasted for about two months in 1980 and 1982 while it was one month in 1976, 1977, and 1981. Seven immigration waves occurred in 1980 but only two in 1978 or three in 1976 and 1981. The pattern of immigration is erratic, depending on weather conditions. The dates of immigration, therefore, differ slightly or greatly in geographical locations.

The number of planthopper immigrants is small during the period earlier than June 20 and most of them are the white-backed planthopper.

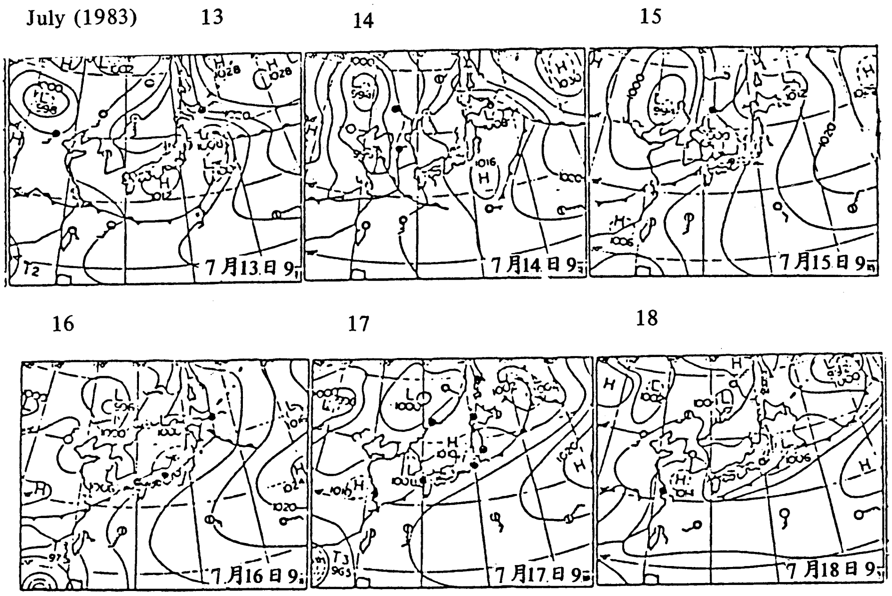

Fig. 3. Synoptic weather maps (9:00 AM) when planthopper immigration occurred in Japan.
Planthopper immigration occurred over the country during the period from July 14 to 17 but not on July 13 and 18.

Table 3. Comparisons of Planthopper Immigrants Captured Between a Light Trap and 2 Airborne Nets at Kyushu Natl. Agric. Exp. Stn., Chikugo, Fukuoka

Year	Light trap		Ratio of BPH (WBPH = 1)	2 Airborne nets		Ratio of BPH (WBPH = 1)
	WBPH	BPH		WBPH	BPH	
1974	96	88	0.92	65	8	0.12
1975	528	262	0.50	485	16	0.03
1976	150	151	1.01	49	12	0.25
1977	331	120	0.36	224	5	0.02
1978	116	42	0.36	227	29	0.13
1979	872	194	0.22	178	9	0.05
1980	1,139	115	0.10	1,094	11	0.01
1981	1,549	148	0.10	2,236	20	0.01
1982	2,592	170	0.07	542	12	0.02
1983	1,734	173	0.10	954	12	0.01

Figures show total numbers of planthoppers captured upto the end of immigration. WBPH = white-backed planthopper and BPH = brown planthopper.

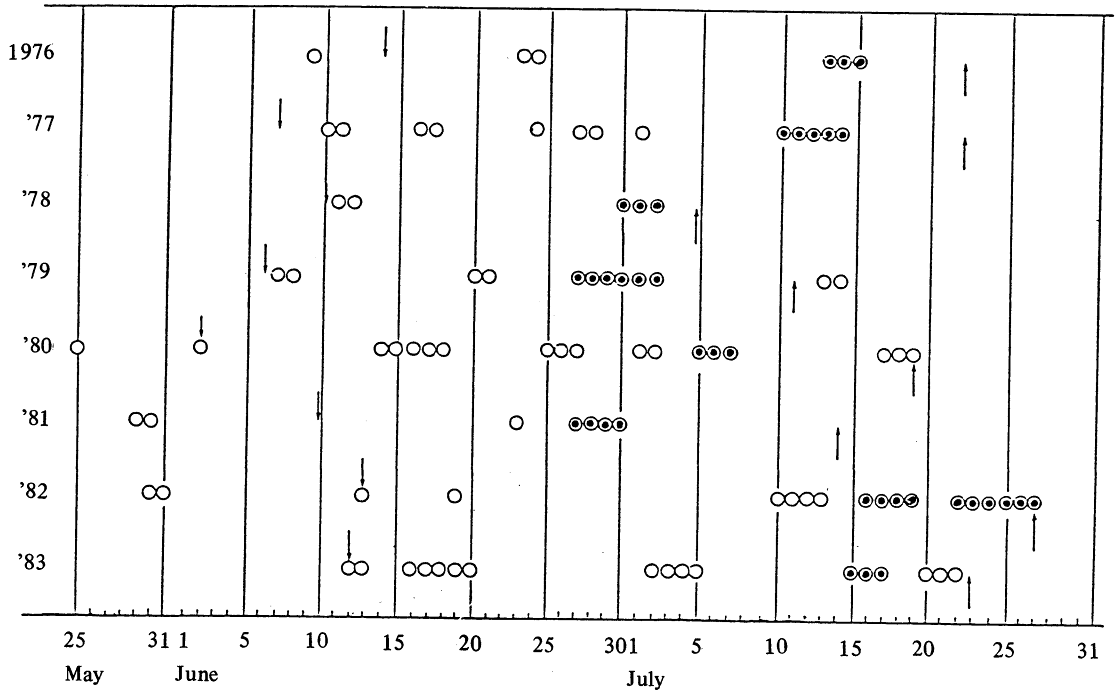

Fig. 4. Immigrations of planthoppers recorded at Kyushu Natl. Agric. Expt. Stn., Chikugo, Fukuoka
Double circles (⊙) show the maior wave of immigration in terms of the abundance of immigrants and arrows the beginning (↓) and end (↓) of the Bai-u (rainy) season.

It is generally said that the major wave of plant-hopper immigrations in terms of their popula-population density occurs during the period from late June to mid-July.

Investigators, thus, can know the most important wave of brown planthopper immigration. The occurrence of each insect stage is predicted by applying the effective temperature-sum rule to determine the suitable timing of insecticide application in the subsequent generations. At the same time, the possibility of the occurrence of hopperburn in autumn can roughly be predicted by the total number of immigrants trapped during the immigration period (Fig. 5).

The brown planthopper usually repeats three complete generations in a paddy field in south-western Japan, multiplying abundantly as the generations advance until harvest. When the immigration occurs earlier than early July, or when high temperatures prevail later than late August, the planthopper is able to extend one more generation. These factors are taken into consideration in the overall forecasting work.

The adults of the second generation appear about one month after the immigration. This generation is characterized by the facts that most of the females are brachypterous but that males are macropterous. It is important to record the population density of brachypterous females for forecasting the outbreaks of hopperburn in autumn. There is a positive correlation coefficient of 0.877 (significant at the 1% level) between the population of immigrants and that of branchypterous females in two generations (Table 4). It is said that 20 brachypterous females per 100 hills at the peak time are a threshold for the occurrence of hopperburn in autumn. When there are more than 30 females per 100 hills, hopperburn usually occurs. The

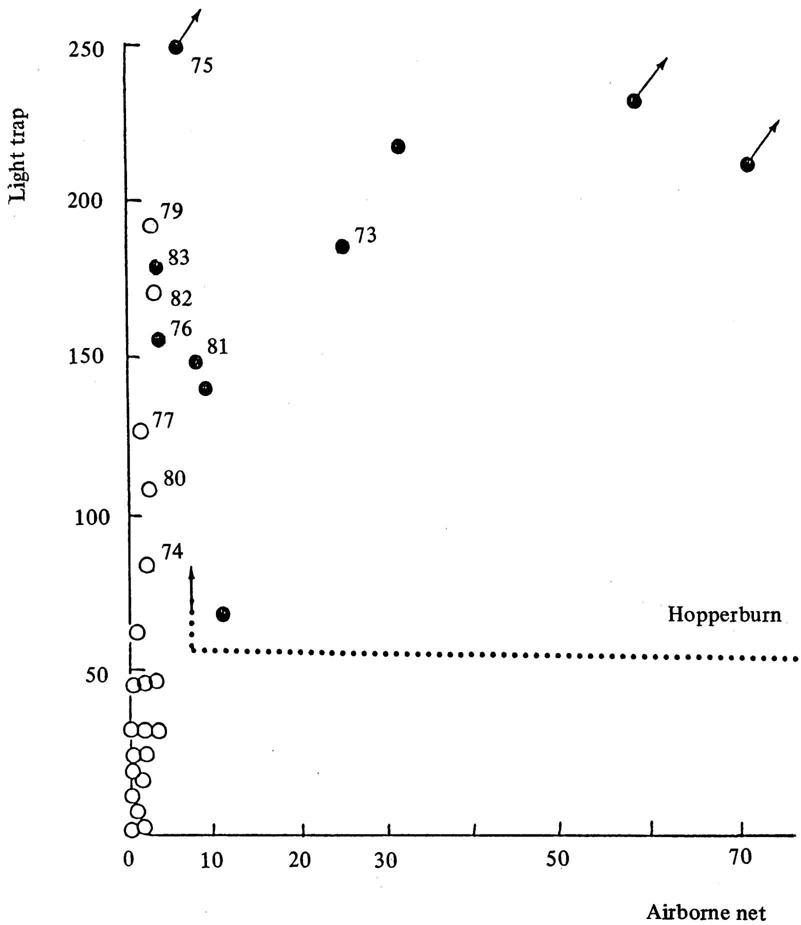

Fig. 5. Correlation between catches of brown planthopper immigrants in a light trap and in an airborne net (Kyushu Natl. Agric. Expt Stn., Chikugo, Fukuoka).
Solid circles show the occurrence of hopperburn in the field near the traps and open circles no occurrence.

brachypterous females, unlike the macropterous immigrants of the previous generation, concentrate at certain areas of the field. On the other hand, it should be mentioned that hopperburn occurs earlier on the early-maturing varieties than on the late-maturing ones, even with similar insect population density probably because tolerance of rice plants to attack reduces as the plant reaches maturity. This fact should be considered in forecasting and chemical control.

There was a sharp contrast between the population levels of the brachypterous females and the occurrence of hopperburn in years (Table 4). The population density of the insects both in 1975 and in 1976 is nearly the same, but hopperburn occurred in 1975 but not in 1976. Contrarily, the population of brachypterous females of the second generation in 1982 doubled that in 1983, but hopperburn occurred in 1983 but not in 1982. Concerning the temperature conditions in those contrasting years, higher temperatures prevailed in 1975 and 1983 compared with low temperatures in 1976 and 1982 (Fig. 6). Thus, one of the important factors affecting the population growth is tem-

Table 4. Population Density of Brown Planthopper Immigrants Recorded at Kyushu Natl. Agric. Expt. Stn., Chikugo, Fukuoka

Year	Light trap[1]	Airborne nets (2 nets)[1]	Population density[2]		Hopper-burn[4]
			Immigrant	B. female[3]	
1973	89	50	0.009	0.030	+
1974	88	8	0.032	–	+
1975	262	16	0.041	1.020	++
1976	151	12	0.043	1.163	-
1977	120	5	0.019	0.143	-
1978	42	29	0.250[5]	2.600[5]	++[5]
1979	194	9	0.018	0.192	-
1980	115	11	0.175	1.105	-
1981	148	20	0.021	0.440	+
1982	170	12	0.250	2.433	-
1983	173	12	0.025	1.253	++

1) Total numbers of brown planthoppers captured by trapa up to the end of immigration.
2) Average number of females per rice hill at the peak in the field transplanted near the traps around on June 20.
3) Average number of brachypterous females per hill at the peak in the second generation.
4) ++ = overall, + = patch, - = none.
5) Transplanted 10 days earlier than usual.

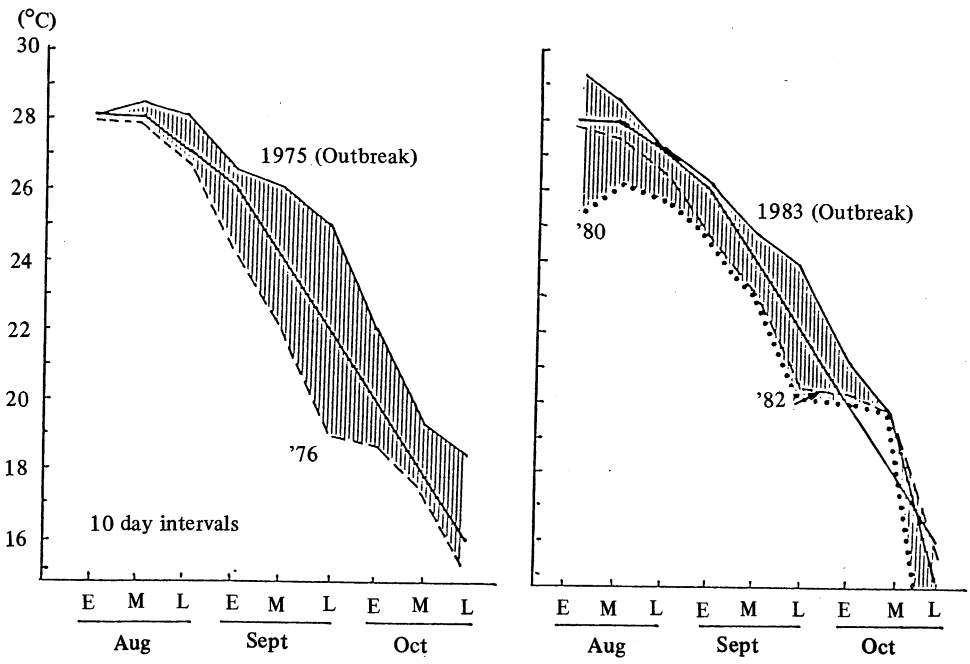

Fig. 6. Differences in mean temperatures later than August in contrasting years. Outbreaks of hopperburn in 1975 and 1983 but not in other years indicated (see text in detail).

perature conditions prevailing later than late August. The weather forecast should be accounted in the forecasting work of the brown planthopper.

Factors affecting the outbreaks of rice damage caused by the brown planthoppers are summarized in Fig. 7. The major factors in order of importance are as follows: 1) the levels of immigrant population, 2) temperatures prevailing later than late August, and 3) the time of major immigrations in relation to the number of generations until rice harvest.

As to forecasting models, multiple regression analysis is used for forecasting the population of the migratory planthoppers in relation to insecticide applications one month in advance in the different regions of Hiroshima Prefecture (Kono, 1979). On the other hand, a computer model was constructed to simulate the process of population growth in a field (Kisimoto and Takeushi, 1978). The dynamic nature of damage requires systems model based on the data including a control threshold in relation to plant factors, etc. Much more work towards this direction is necessary in future.

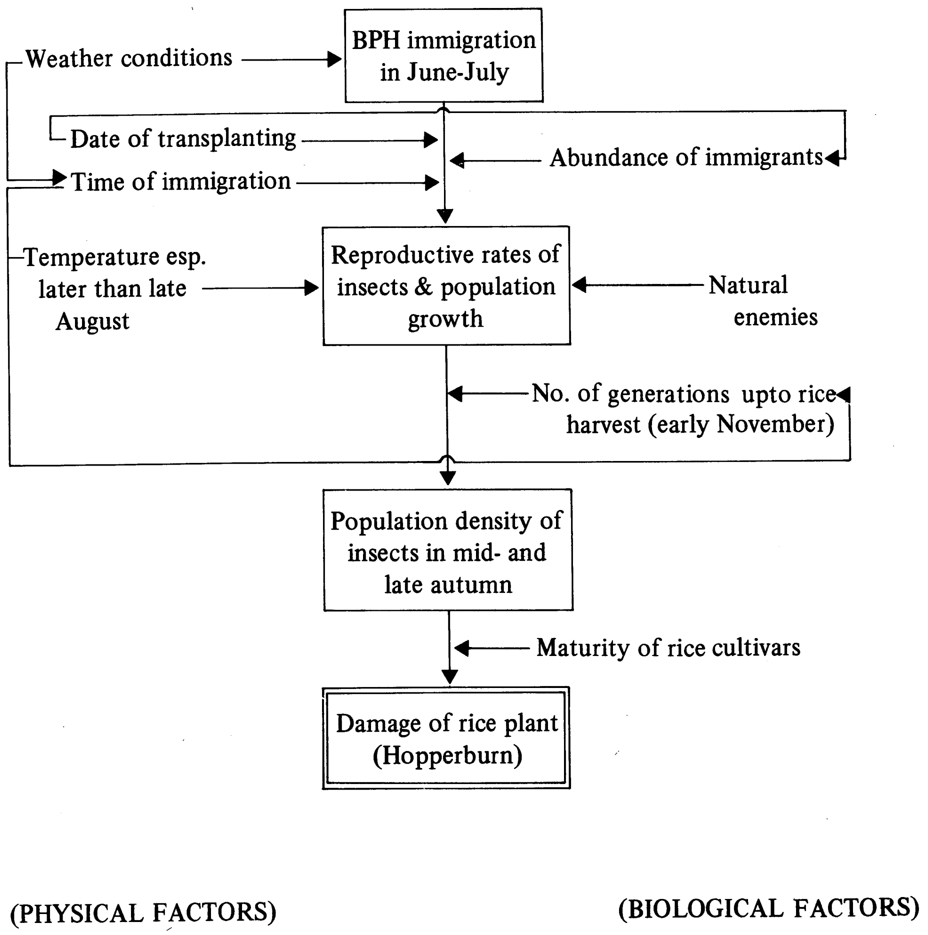

Fig. 7. Major factors affecting the outbreak of rice damage caused by brown planthopper.

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