Study on the Geographical Variations of the Brown Planthopper in Taiwan

Yau-I Chu and Rong Kou
Department of Plant Pathology and Entomology
National Taiwan University

ABSTRACT

The geographical variations of the brown planthopper (BPH) in Taiwan was studied in the purpose to clarify the existence of any geographical veriations in this island. The material used in this work were collected in October 1979, April 1981 and October 1981 from following 8 localities: Taipei, Ilan, Hualien, Taichung, Puli, Chiayi, Taitung, and Pingtung. Strains collected from above localities were reared on the rice cultivar of the Tainan No. 5 (Japonica type) in the laboratory for 1 or 2 generations and used for the experiments.

The 4 major parts in this experiment were the comparison of morphometric measurements, electrophoretic analysis of esterase variation, nymphal developmental period and percentage of brachypterous form. The result showed that the geographical variation are obvious in the population collected from October 1979 and October 1981, those were the heavier infested periods. But not in the population of April 1981, that was the earlier infested period.

The process and course of the occurrence of the geographical variation are also discussed.

Introduction

The brown planthopper (BPH) is one of the major rice pests in Taiwan, and the population sources here have never been mentioned before. According to Kisimoto and Dyck (1976), there have no much possibility of the BPH's overwinter in Taiwan. But, in fact, the high temperature in central and southern Taiwan really won't freeze this pest (Chu, 1977). And the adults and nymphs still can be collected in the fallowing field of the central Taiwan during the Mid-January. Even in the colder northern Taiwan, the overwintering individuals still can be found (Chu and Yang, 1980). Then, mentioning about the food source, because the ratoon still be remained in the field, there had no food deficiency during the winter time, so the BPH can doubtlessly overwinter and propagate in Taiwan.

On the other hand, according to Kisimoto (1975), there have two migratory waves of the BPH. The 1st one is coming from the southern tropical district and goes with the warm and miostured air mass reaching to the north Taiwan, Okinawa and Huana. The 2nd one is moving from Huanan to Japan. So, when considering about the direction of air currency and seasonal wind, there still have much possibility of the BPH moving from Philippine or south China to Taiwan (Chu, 1977).

So, in this experiment, we aimed to clarify the BPH source of the earlier and heavier infested periods whether be native or coming from overseas. If the BPH source here in Taiwan were native, they would propagate from generation to generation and the geographical variations would be formed. If they were coming from an overseas source, there would have no geographical variations.

This experiment were conducted with the BPH populations collected from 8 localities in 3 seasons. Those localities were Taipei, Ilan,

Taichung, Puli, Hualien, Chiayi, and Pingtung. The seasons were October 1979, April 1981 and October 1981. (Fig. 1). The 1st and the 3rd seasons represent the heavier infested periods and the 2nd season represents the earlier infested period. the four major parts of this experiment are described in the following.

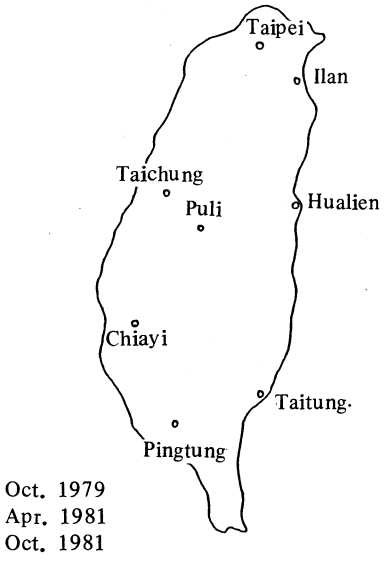

Fig. 1. Map of Taiwan showing the location of the places brown planthopper are collected.

I. Comparison of morphometric measurements

50 individuals of 2-days old macropterous females from each locality and season were used in this experiment. Firstly, the insects were paralyzed eith ethyl ether and put into 70% alcohol, then, the insects were measured immediately under the binomial microscope (Nikon type 102). The measured attributes were the body length, antenna length, stylet length, head width, thorax width, hind femur length, hind tibia length and ovipositor length. Then, those items which have shown more geographical variations been selected by the Duncan's multiple range test. Those items were the body length, the thorax width and the hind femur length.

The measured data of the BPH collected in Oct. 1979 are shown in Table 1. With the help of Roa's approximation of multiple variable analysis (Cooly & Lohnes 1971), those BPH can be grouped to "Ilan", "Taipei-Puli-Taitung", and "Hualien-Taichung-Chiayi-Pingtung". In Ilan, the BPH has the largest body size. In Chiayi and Pingtung, the BPH have the smallest body size.

Table 1. Comparison of Morphometric Measurements of the Female Brown Planthopper Collected in Oct. 1979

Locality	Length of body	Width of thorax	Length of hind femur
Ilan	3770.9^{a}	1059.8^{a}	999.1^{b}
Taipei	3739.1^{ab}	967.4^{b}	937.3^{b}
Puli	3599.4^{bc}	930.3^{bc}	882.6^{cd}
Taitung	$3752.7^{ab}\pm22.8$	$969.5^{b}\pm7.3$	$936.6^{b}\pm7.1$
Hualien	3531.0^{c}	899.5^{cd}	860.3^{cd}
Taichung	3538.0^{c}	931.0^{bc}	896.7^{bc}
Chiayi	3466.4^{c}	860.2^{d}	833.5^{d}
Pingtung	3452.4^{c}	869.3^{d}	856.1^{cd}

Characteristic data followed by the different letter in each column are significant at p=0.05 according to Roa's approximation of multiple variable analysis.

The measured data of the female BPH collected in Apr. 1981 are shown in Table 2. Then, with the method of Roa's approximation, those BPH can be grouped to 2 groups. The BPH of Taitung were the biggest of all. The other 7 localities' BPH could be viewed as one group, among which, the geographical variation were not significant, but the BPH of Chiayi still be the smallest.

Table 2. Comparison of Morphometric Measurements of the Female Brown Planthopper Collected in April, 1981

Locality	Length of body	Width of thorax	Length of hind femur
Taitung	3741.5^{a}	1012.2^{a}	975.1^{a}
Taipei	3497.9^{bc}	950.6^{b}	909.3^{b}
Ilan	3525.9^{bc}	942.2^{b}	914.9^{b}
Hualien	$3538.5^{bc}\pm25.6$	$942.2^{b}\pm6.1$	$900.9^{b}\pm7.2$
Taichung	3505.6^{bc}	970.2^{b}	947.1^{ab}
Puli	3548.3^{bc}	959.7^{b}	917.0^{b}
Chiayi	3381.0^{c}	955.5^{b}	898.8^{b}
Pingtung	3587.5^{ab}	968.8^{b}	923.3^{b}

Characteristic data followed by the different letter in each column are significant at p=0.05 according to Roa's approximation of multiple variable analysis.

Table 3. Comparison of Morphometric Measurements of the Female Brown Planthopper Collected in Oct. 1981

Locality	Length of body	Width of thorax	Length of hind femur
Taitung	3752.7^{a}	1059.1^{a}	994.7^{ab}
Hualien	3640.0^{ab}	1043.7^{ab}	1018.5^{a}
Taichung	3660.3^{ab}	1015.7^{b}	988.4^{ab}
Puli	3657.5^{ab}	1034.6^{ab}	982.8^{ab}
Chiayi	$3729.6^{a}\pm22.8$	$1028.3^{ab}\pm5.3$	$975.8^{ab}\pm6.8$
Pingtung	3698.8^{ab}	1031.8^{ab}	1001.7^{ab}
Taipei	3710.0^{a}	1011.5^{b}	963.9^{b}
Ilan	3537.8^{b}	1030.4^{ab}	974.4^{ab}

Characteristic data followed by the different letter in each column are significant at p=0.05 according to Roa's approximation of multiple variable analysis.

As mentioned before, the BPH collected from October 1981 also been measured with the 3 items. The measured data are shown in Table 3. Then, with the method of Roa's appeoximation of multiple variable analysis, those BPH can be grouped to "Taitung", "Hualien-Taichung-Puli-Chiayi-Pingtung", and "Taipei-Ilan". Among which, the BPH of Ilan are significantly larger than the others, and smaller body size been observed in Ilan's BPH. The other 5 localities' BPH in the 2nd group have no significant difference to "Taitung" and "Taipei-Ilan".

Then, the seasonal change of the morphometric measurements so each locality's BPH also been compared between 3 collecting seasons. The BPH of Ilan and Pingtung are the most representative ones, as shown in Table 4.

Table 4. Comparison of Morphometric Measurements of of Female Brown Planthopper in Taiwan Collected in 3 seasons

Locality	Season	Length of body	Width of thorax	Length of hind femur
Ilan	I	3770.9^{a}	1059.8^{a}	989.1^{a}
	II	$3525.9^{b}\pm24.5$	$942.2^{b}\pm6.2$	$914.9^{b}\pm6.5$
	III	3537.8^{a}	1030.4^{a}	974.4^{a}
Pingtung	I	3452.4^{c}	869.3^{c}	856.1^{c}
	II	$3587.5^{b}\pm21.4$	$968.8^{b}\pm6.1$	$923.3^{b}\pm6.7$
	III	3698.8^{a}	1031.8^{a}	1001.7^{a}

Characteristic data followed by the different letter in each column are significant at p=0.05 according to Roa's Approximation of multiple variable analysis.
(I: Oct. 1979, II: Apr. 1981, III: Oct. 1981)

In Ilan, the BPH which collected in the heavier infested periods (Oct. 1979 and Oct. 1981) are significantly larger than which collected in the earlier infested period (Apr. 1981). This phenominum also be observed in other localities like Taipei, Taichung, Puli and Hualien. But in Chiayi and Pingtung, there have very significant difference in the morphometric measurements between 3 seasons (Table 4).

II. Comparison of electrophoretic analysis of esterase variations

50 individuals of 6-days old macropterous pregnant females from each locality and season were used in the esterase analysis. Each individual was ground in 30 ul homogenization buffer which was composed of 4 parts of 40% sucrose solution and 1 part of 5% triton X-100 (Takada 1979), with 0.5% BPB as the tracking dye. Then, 20 ul homogenized body solution was used for the electrophoretic analysis. The electric current was 25mA, all the process takes about 3 hours under 4°C.

The method of 10% vertical polyacrylamide slab gel electrophoresis was employed for the esterase analysis. After completion of the electrophoresis, the gel was stained with α-naphthyl acetate, β-naphthyl acetate, and Fast Garnet GBC. In the polyacrylamide gel, the esterase moved from acthod to anode as shown in Fig. 2, and then be numbered from 1 to 11 as

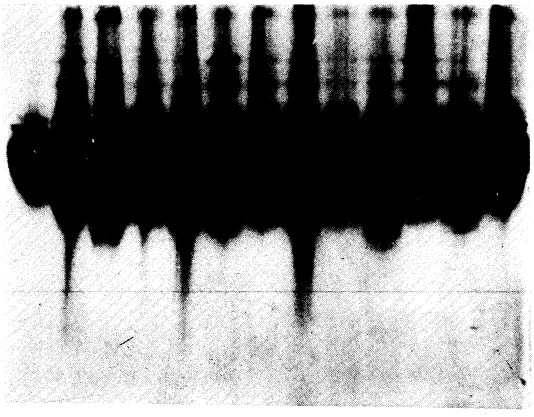

Fig. 2. Esterase bands of the female brown planthopper moved from cathod to anode in the polyacrylamide gel.

Table 5. The Frequency of Alleles of the Macropterous Female Brown Planthopper Collected in Oct. 1979

Alleles	Locality							
	A	B	C	D	E	F	G	H[1)]
Est-3	.22	.36	.28	.00	.30	.52	.16	.02
Null	.78	.64	.72	1.00	.70	.48	.84	.98
Est-4	.62	.24	.30	.16	.74	.44	.46	.04
Est-4'	.06	.06	.00	.06	.06	.10	.04	.00
Null	.32	.70	.70	.78	.20	.46	.50	.96
Est-8	.10	.12	.00	.40	.04	.06	.14	.06
Null	.90	.88	1.00	.60	.96	.94	.86	.94

1) A: Taipei, B: Ilan, C: Hualien, D: Tiachung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung

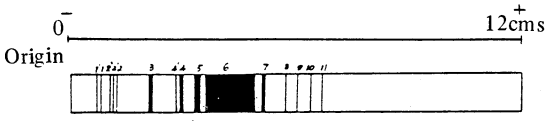

Fig. 3. The esterase bands of the macropterous female brown planthopper resulted from electrophoresis development.

Fig. 3. The calculated frequency of alleles of the BPH collected in Oct. 1979 are shown in Table 5. The alleles appeared from 2 to 11, among which the Est-5 and Est-6 were the most common alleles, and the most variable ones are listed in Table 5 as Est-3, Est-4 and Est-8. The esterase of BPH are more variable in Ilan, and less variable in Hualien and Taichung. Then, with the use of UPGMA clustering method (Nei 1972), the phylogenetic tree of the BPH collected in Oct. 1979 could be founded as shown in Fig. 4.

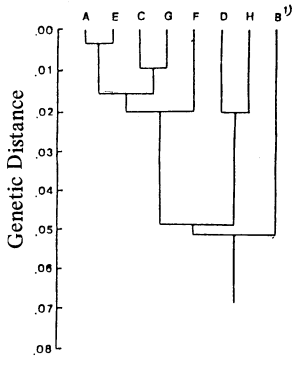

Fig. 4. The phylogenetic tree of the macropterous female brown planthopper of Taiwan collected from 8 localities in Oct. 1979. (A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung)

There are 3 groups, the first group is Taipei-Puli-Hualien-Taitung-Chiayi, the second group is Taichung-Pingtung, the third group is Ilan. The genetic distance almost be .05 between the 1st and the 2nd group, and .052 between the 3rd and the former 2 groups. So, the BPH of Ilan have shown the significant genetic difference from the others.

The frequency of alleles of the BPH collected in Apr. 1981 are shown in Table 6, most variable ones are Est-4 and Est-10. In Taipei and Hualien, the esterase are more polymorphic than the others. Then, also use Nei's method to found the phylogenetic tree as shown in Fig. 5. Although there are 2 groups, Ilan-Taitung-Taichung-Puli-Chiayi-Pingtung and Taipei-Hualien, the genetic distance beween these 2 groups were less than .01. So, there obviously had no geographical variation between the BPH of those 8 localities.

The frequency of alleles of the BPH collected in Oct. 1981 are shown in Table 7.

Table 6. The Frequency of Alleles of the Macropterous Female Brown Planthopper Collected in Apr. 1981

Allels	Locality							
	A	B	C	D	E	F	G	H[1)]
Est-4	.18	.04	0.6	.06	.02	.12	.04	.20
Null	.82	.96	.94	.94	.98	.88	.96	.80
Est-10	.20	.00	.16	.00	.00	.00	.00	.02
Null	.80	1.00	.84	1.00	1.00	1.00	1.00	.98

1) A: Taipei, B: Ilan, C: Hualien, D: Taitung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung

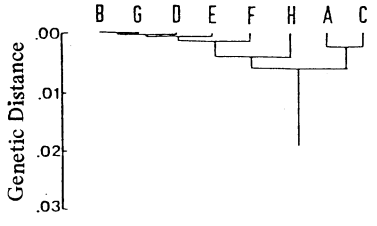

Fig 5. The phylogenetic tree of the macropterous female brown planthopper of Taiwan collected from 8 localities in April of 1981. (A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung)

Table 7. The Frequency of Alleles of the Macropterous Female Brown Planthopper Collected in Oct. 1981

Alleles	Locality							
	A	B	C	D	E	F	G	H[1]
Est-2	.00	.38	.04	.30	.24	.30	.18	.00
Null	1.00	.62	.96	.70	.76	.70	.82	1.00
Est-4	.08	.62	.16	.74	.56	.62	.36	.16
Est-4'	.00	.00	.00	.00	.22	.00	.06	.00
Null	.92	.38	.84	.26	.22	.38	.58	.84

1) A: Taipei, B: Ilan, C: Hualien, D: Taitung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung

The alleles appeared from Est-1 to Est-10, among which, the Est-2 and Est-4 were the most polymorphic ones. The esterase of the BPH in Taipei and Pingtung were less variable than the others. Then, also use Nei's method to found the phylogenetic tree as shown in Fig. 6. All these BPH can be divided into 2 groups, Hualien-Pingtung-Taipei and Ilan-Chiayi-Puli-Taitung. The genetic distance between these 2 groups is near .05. This data almost the same as what we had got from Oct. 1979.

According to the UPGMA clustering method, the phylogenetic tree of each locality's BPH between 3 seasons were founded as shown in Fig. 7. The BPH of Ilan and Taitung had shown obvious seasonal difference in its genetic distance, almost near .06 and .07. But, the seasonal difference were very small in Pingtung and Hualien.

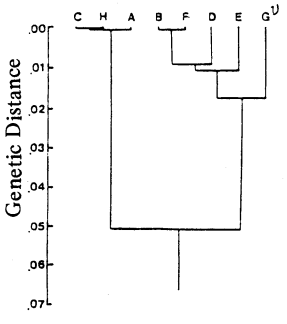

Fig. 6. The phylogenetic tree of the macropterous female brown planthopper of Taiwan collected from 8 localities in Oct, 1981. (A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung)

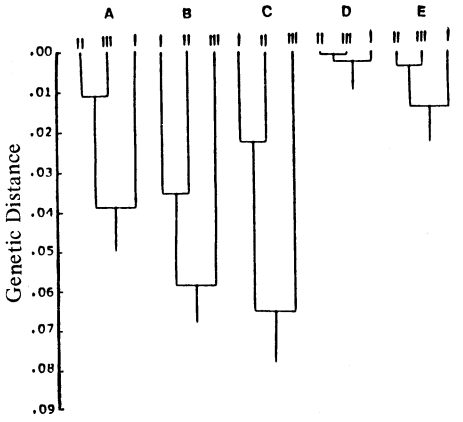

Fig. 7. The phylogenetic tree of the macropterous female brown planthopper collected from 8 localities between 3 different seasons. (A: Taipei, B: Ilan, C: Taitung, D: Pingtung, E: Hualien. I: Oct, 1979 II: Apr, 1981 III: Oct, 1981)

Then, by means of Nei's method, the degree of heterozygosity ($H=1-\Sigma X_i^2$) of the BPH in each locality between 3 seasons are listed in Table 8. The degree of heterozygosity can indicate the genetic variability. The higher degree of heterozygosity appeared in the BPH collected in Oct. 1979 and Oct. 1981, and lower in Apr. 1981. In Ilan the BPH had the highest degree of heterozygosity than the others, that means the BPH of Ilan had the more stronger fecundity, more stronger adaptation to the environment, more broader geographical distribution and more active enzymes (Nei, 1975). But, in Apr. 1981, the BPH of Ilan, Puli and Taitung had shown the lower degree of heterozygosity. That means the BPH of such localities had the weaker living ability and the lower enzymatic activity (Nei, 1975).

III. Comparison of nymphal developmental period

Table 8. The Degree of Heterozygosity of Macropterous Female Brown Planthopper from 8 Loalcities of 3 Seasons

	Locality[1]							
	A	B	C	D	E	F	G	H
I[2]	.1353	.2911	.1131	.1293	.1104	.1927	.1641	.0422
II	.0910	.0096	.0477	.0141	.0049	.0585	.0096	.0817
III	.0164	.2318	.0599	.1490	.1919	.1714	.1408	.0298

1) A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung
2) I: Oct. 1979, II: Apr. 1981, III: Oct. 1981

Ten pairs of 3-days old macropterous adults of each locality and season were reared on the Tainan No. 5 (Japonica type) rice cultivar under 25-27°C, and 12 hours light. After 10-11 days, the hatched nymph were transmitted to the small test tube (2cm x 9.5cm) and reared under the same comdition as described above. There have 30 repeats in each locality and season. The experimental results were analyzed with the Duncan's multiple range test, in order to find out whether there had the significant geographical and seasonal difference. The nymphal period were investigated from 2nd instar stage to the emergence of adult.

The nymphal developmental period of Oct. 1979 are shown in Table 9. In the brachypterous male and female, there had no geographical variation. But, there had geographical variation in the macropterous male, that is, the longer nymphal period in Taitung and the shorter in Ilan and Hualien. The nymphal period of the BPH in Apr. 1981 are shown in Table 10. there, almost all have no geographical variation in the nymphal period of the brachypterous and macropterous male. But in the brachypterous female, the nymphal period is shorter than the others. The nymphal period of the BPH in Oct. 1981 are shown in Table 11, and the geographical variations appeared in all 3 wing forms, especially in the brachypterous female amd macropterous male. In the brachypterous female, the nymphal period are shorter in Taipei, Hualien and Taitung, but longer in Puli and Pingtung. In the macropterous male, it were also shorter in Taipei, Hualien and Taitung, but longer in Puli and Pingtung. The seasonal difference of the nymphal period were shown in Table 12. The BPH of Taipei, Ilan, Puli and Chiayi all had some degree of seasonal variation. The BPH collected in early infested period (Apr. 1981) had the longer nymphal period than which collected in the heavier infested period. And the nymphal period of the Oct. 1981 are always longer than which in Oct. 1979.

Table 9. Comparison of Nymphal Deveopmental Period (2nd Instar Stage - Emergence of Adult) of BPH Collected in Oct. 1979

Total nymphal period	Locality[1]							
	A	B	C	D	E	F	G	H
Bơ[2]	12.0^{a}	10.5^{a}	11.7^{a}	12.5^{a}	14.0^{a}	12.0^{a}	9.5^{a}	10.3^{a}
B♀	12.8^{a}	11.8^{a}	12.4^{a}	12.1^{a}	11.7^{a}	11.2^{a}	11.5^{a}	12.2^{a}
Mơ	12.3^{ab}	10.7^{d}	10.9^{cd}	12.6^{ab}	11.6^{bcd}	11.4^{bcd}	13.3^{a}	12.2^{abc}

1) A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung
2) B: Brachypterous form M: Macropterous form

Table 10. Comparison of Nymphal Developmental Period (2nd Instar Stage-Emergence of Adult) of BPH Collected in Apr. 1981

Total nymphal period	Locality[1]							
	A	B	C	D	E	F	G	H
Bơ[2]	13.1^{a}	11.0^{b}	13.0^{a}	13.3^{a}	12.5^{a}	13.0^{a}	13.0^{a}	12.3^{a}
B♀	13.5^{ab}	12.3^{c}	13.3^{ab}	13.7^{ab}	13.8^{a}	12.9^{bc}	13.4^{ab}	13.1^{ab}
Mơ	13.6^{a}	11.8^{a}	12.1^{a}	12.7^{a}	12.3^{a}	12.6^{a}	13.2^{a}	12.3^{a}

1) A: Taipei, B: Ilan, C: Hualien D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung
2) B: Brachypterous form M: Macropterous form

Table 11. Comparison of Nymphal Developmental Period (2nd Instar Stage-Emergence of Adult) of BPH Collected in Oct. 1981

Total nymphal period	Locality[1]							
	A	B	C	D	E	F	G	H
Bơ[2]	10.1^{b}	14.0^{a}	10.0^{b}	10.0^{b}	12.2^{ab}	11.1^{ab}	12.0^{ab}	12.0^{ab}
B♀	11.0^{d}	12.6^{abc}	10.5^{d}	11.8^{cd}	13.5^{ab}	12.6^{abc}	10.6^{d}	13.6^{a}
Mơ	10.5^{c}	12.4^{b}	10.1^{c}	12.2^{b}	14.1^{a}	12.4^{b}	10.4^{c}	13.4^{ab}

1) A: Taipei, B: Ilan, C: Hualien, D: Taichung, E: Puli, F: Chiayi, G: Taitung, H: Pingtung
2) B: Brachypterous form M: Macropterous form

Table 12. Comparison of Nymphal Developmental Period (2nd Instar Stage-Emergence of Adult) of BPH Collected in 3 Season

	Taipei		Ilan		Puli		Chiayi	
1 Season	B♀	Mơ	B♀	Mơ	B♀	Mơ	B♀	Mơ
Oct. 1979	12.8^{a}	12.3^{b}	11.8^{a}	10.7^{b}	11.7^{b}	11.6^{b}	11.8^{b}	11.4^{a}
Apr. 1981	13.5^{a}	13.6^{a}	12.3^{a}	11.8^{ab}	13.8^{a}	12.3^{b}	12.9^{a}	12.6^{a}
Oct. 1981	11.0^{b}	10.5^{c}	12.6^{a}	12.4^{a}	13.5^{a}	14.1^{a}	12.6^{ab}	12.4^{a}

1) B: Brachypterous form, M: Macropterous form

IV. Comparison of the percentage of brachypterous form

20 pairs of 3-days old brachypterous adults of each locality and season were reared on the Tainan No. 5 rice cultivar under 25-27°C, 12 hours light. 13-14 days later, the hatched nymphs had grown to the 2nd instar nymph and be used for this experiment under the same condition. There are 2 factors have been done in this study.

1. Density effect

   The density being used were 1, 5, 10, and 20 2nd instar nymphs/test tube (2.5cm x 9cm). There have 2-3 rice cultivars (2 leaf-stage) in each test tube, and these food were changed every 2 days. The result were shown in Fig. 8. The response of those BPH can be divided into 3 groups. In the A group (Ilan, Hualien and Taitung), the percent-brachypterous were higher in the 1st and 2nd collecting seasons, almost near 100% except in the male with lower rearing density, but were lower in the 3rd season. In the B group (Taipei, Puli and Chiayi), the percent-brachypterous are very high, near 100% in the 1st and 2nd seasons. But, the percent-brachypterous are much lower in the 3rd season than the A group, and it seems going down with the increasing of the rearing density. In the C group (Taichung and Pingtung), the percent-brachypterous are very high, between 100% and 75% in all 3 seasons, the rearing density having no much effect.

2. Photoperiodism effect

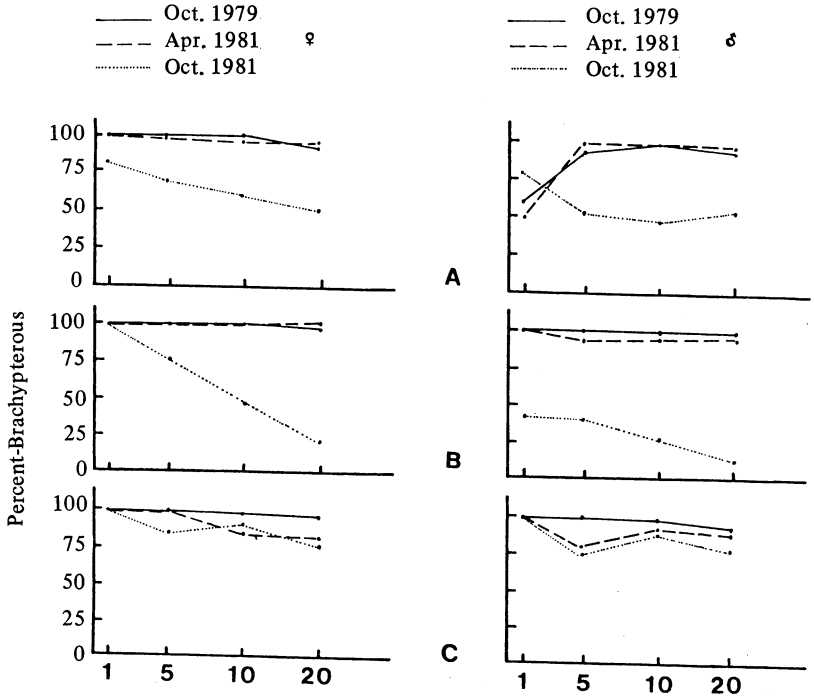

Fig. 8. Relationships between the rearing density in nymphal stage and the percentage of brachypterous form emergence of brown planthopper. (A: Ilan, Hualien, Taitung. B: Chiayi, Puli, Taipei. C: Taichung, Pingtung)

The raering condition were the same as the density effect, and the treated light period were described as the following:

(1) 11 hr : 13 hr = L : D
(2) 12 hr : 12 hr = L : D
(3) 13 hr : 11 hr = L : D
(4) 13 hr : 10 hr = L : D
(5) 15 hr : 9 hr = L : D
(6) 16 hr : 8 hr = L : D

The result were shown in Fig. 9, and also can be divided into 3 groups. In the A group (Ilan, Hualien and Taitung), the percent-brachypterous are much higher in the 1st and 2nd collecting seasons in which the percent-brachypterous seems to go down with the increasing of the photoperiod. In the B group (Taipei, Puli and Chiayi), the photoperiodism had some effect on the

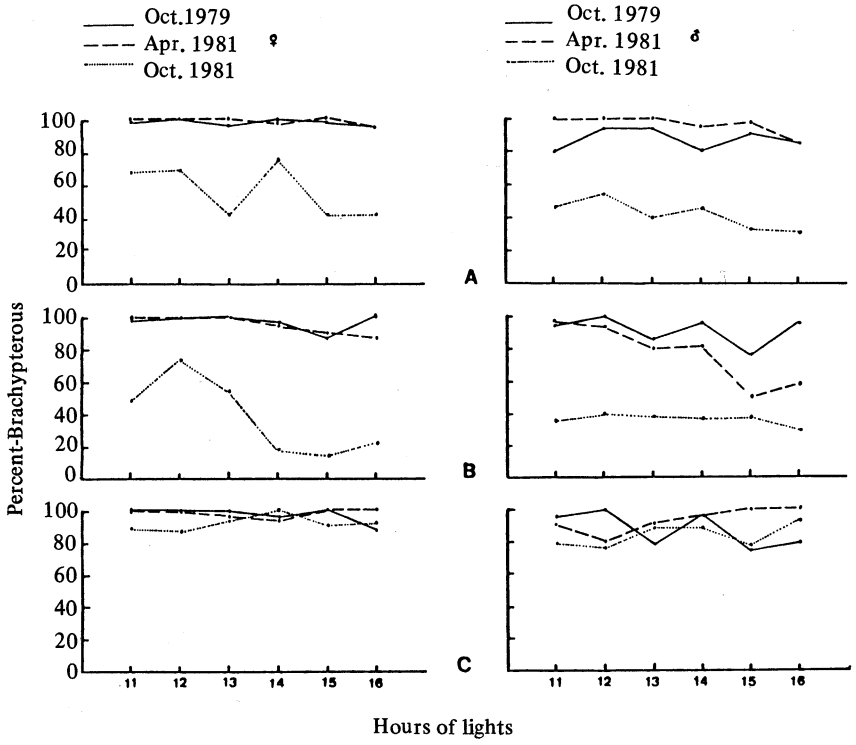

Fig. 9. Relationships between the photoperiodism and the percentage of the brachypterous form emergence of brown planthopper. (A: Ilan, Hualien, Tiatung. B: Chiayi, Puli, Taipei. C: Taichung, Pingtung)

female BPH of the 3rd season, and on the male of the former 2 seasons. In the C group (Taichung and Pingtung), the photoperiodism had no much effect, and the percent-brachypterous are very high, between 80% and 100% in all 3 seasons.

So, in the study of the percent-brachypterous, not only the geographical variations being investigated between the different localities during the same season, the seasonal difference are also existed.

Considering about the reason why the geographical variations occurred on the populations of the heavier infested period. Firstly, the spring population which had no geographical variation had been affected by much environmental factors during the rice cultivated periods in summer and autumn, and then, developed the geographical variations. This had been shown in the paper of Nagata and Moriya (1974). In their study, the BPH would produce 14-19 folds resistance to BHC after 3 generations if treated with 4 times BHC during summer and autumn in Japan. And according to Kisimoto

(1981), the BPH would produce new biotype after 10 generations if reared with special rice varietyin the laboratory. So, "the wild population of BPH are much more adaptive and variable to certain environment" almost can be concluded. In addition, the temperature are higher from Apr. to Oct. So, there have much possibility of the BPH to produce geographical variations in order to suit for the environment. And in Taitung and Chiayi, there had 3 years' and 1 year's high net collecting data respectively. Those data had shown much possibility about the immigration of the BPH to Taiwan (unpublished). If the immigrated population mixed with the 8 localities' BPH in different numbers and seasons, the variation should be increased.

Then, considering about the disappearance of the geographical variations in the population of earlier infested period, the temperature of the North and Central Taiwan is not very suitable for the BPH survival. As to the South Taiwan, although the temperature can't freeze the BPH, the fallowing fields are much occupied by the winter crops. And the ratoon, the only food for the BPH in the winter time, won't have good growth. So, there may have certain type of BPH which can live under such bad environment, and the geographical variations been gradually developed till Oct. When winter comes, the certain typed BPH been selected by the winter's bad environmetnal factors again.

As to the real migratory routes, further study and international coorporation are still needed.

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QUESTION:

Dr. Hsieh: Why do you loss the period of 1980?

Dr. Kou: In 1979, we just aimed at the build up of the experimental method, and 1 year's later we considered about the seasonal factor, that means the earlier and the heavier infested period. So, we loss the data of 1980 during these time.

Dr. Kisimoto: In my experiment, if reared with low density, the male will be macropterous and the female will be brachypterous, but in your experiment, almost all be brachypterous, why?

Dr. Kou: There may be 2 reasons, the 1st one is that we use the brachypterous form as the parents, and the 2nd one is that we start with the 2nd instar nymph, but you start from the 1st instar nymph.

Dr. Kisimoto: Yes, may be the difference occurred during the 1st-2nd instar period, you should try that.

Dr. Nagata: In your experiment, the BPH of Ilan are significantly different from others in the esterase analysis, how do you think about the possibility that the application of pesticide in Ilan may result in the special esterase variation?

Dr. T.C. Wang: This may not because of the pesticide, the Drosophila also have special esterase pattern in Ilan.

Dr. Ma: So did the diamond-back moth in Ilan.

Dr. Chu: We have collected the BPH every 5 kilometers in Ilan District, and found the esterase pattern are special in the northeastern part of Ilan. In that place have no much rice culture, so the pesticide application may be not too heavy.

Dr. Hirao: I suggest that may be you can do some experiment from the view of transmission of virus disease.

Dr. Kou: Yes, thanks.