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ECOLOGY OF THE BROWN PLANTHOPPER (Nilaparvata lugens (Stal)) DURING THE WINTER SEASON IN TAIWAN【Research report】

在台灣褐飛蝨於冬季族群之生態研訂【研究報告】

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Abstract

In Taiwan, the brown planthopper (BPH), Nilaparvata lugens (Stal) is formerly considered to be able to overwinter on some alternate host plants, while the results of the present work reveal the fact that BPH is rather belong to a monophagous insect. They can complete their normal development on paddy plant only. According to the results of the inoculation test of BPH carry out in the winter season, among tested 35 species of plants, only the paddy plant, including the ratoon is recognized as mere host plant in strict sense. Besides, water wild-rice (Zizaania aquatica Linn.), Taiwan barnyard grass (Echinochloa crus-galli,(Linn.)), bareet grass (Leersia hexandra Swartz), corn (Zea mays, Linn.), and small flower umbrella plant (Cyperus difformis, Linn.) are recognized as tempor-ary host plants. The adults of BPH can survive for 8 to 20 days on these plants, but no progeny is emerged from them. Although the paddy plant is a favorable host plant for BPH, it complete l generation during the winter season in Taipei. The rate of population increment during this season is quite limited. The field survey on the BPH population is conducted from Feb. 1979 to Jan. 1982 with islandwide. It show the general tendency that the population begin to decrease from late autumn to the end of January. The minimum density is showed at the beginning or middle of February. However, the increment of the population is observed at the beginning of March. According to the laboratory test, the critical low temperature of BPH estimate as 11℃. On the other hand, the average temperature of the winter season is around 16℃ in the northern parts of Taiwan. The fact indicate that BPH is toleerable and can bear in winter season in Taipei. While, in the case of the cold climate striking in Taiwan, the temperature may be lower than 10℃ for temporarily. The influence of the cold climate attack on the BPH population is also analyzed in the present work. The result of the outdoor inoculation test suggest the possibility that the overwintered population of BPH produce 2 generations on the lst rice crop season from the end of March to the middle of June. and may occur 1 or 2 another generations to the harvest.

摘要

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Ecology of the Brown Planthopper (*Nilaparvata lugens* (Stål)) During the Winter Season in Taiwan

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ABSTRACT

In Taiwan, the brown planthopper (BPH), *Nilaparvata lugens* (Stål) is formerly considered to be able to overwinter on some alternate host plants, while the results of the present work reveal the fact that BPH is rather belong to a monophagous insect. They can complete their normal development on paddy plant only.

According to the results of the inoculation test of BPH carry out in the winter season, among tested 35 species of plants, only the paddy plant, including the ratoon is recognized as mere host plant in strict sense. Besides, water wild-rice (*Zizania aquatica* Linn.), Taiwan barnyard grass (*Echinochloa crus-galli*, **(Linn.)**), bareet grass (*Leersia hexandra* Swartz), corn (*Zea mays*, Linn.), and small flower umbrella plant(*Cyperus difformis*, Linn.) are recognized as temporary host plants. The adults of BPH can survive for 8 to 20 days on these plants, but no progeny is emerged from them.

Although the paddy plant is a favorable host plant for BPH, it complete 1 generation during the winter season in Taipei. The rate of population increment during this season is quite limited.

The field survey on the BPH population is conducted from Feb. 1979 to Jan. 1982 with islandwide. It show the general tendency that the population begin to decrease from late autumn to the end of January. The minimum density is showed at the beginning or middle of February. However, the increment of the population is observed at the beginning of March.

According to the laboratory test, the critical low temperature of BPH estimate as 11° C. On the other hand, the average temperature of the winter season is around 16°C in the northern parts of Taiwan. The fact indicate that BPH is tolerable and can bear in winter season in Taipei. While, in the case of the cold climate striking in Taiwan, the temperature may be lower than 10°C for temporarily. The influence of the cold climate attack on the BPH population is also analyzed in the present work.

The result of the outdoor inoculation test suggest the possibility that the overwintered population of BPH produce 2 generations on the 1st rice crop season from the end of March to the middle of June, and may occur 1 or 2 another generations to the harvest.

Introduction

Brown planthopper (*Nilaparvata lugens* (Stål) =BPH) is one of the most important insect pests of paddy plant in Taiwan, since 1960 (Tao,1963; Tao and Yao, 1967; Chen, 1980). The distribution of BPH covers from tropical, subtropical and temperate areas of whole the paddy cultivating countries of the East Asia. And it is recognized as the most destructive rice insect on those countries. While, the population succession of BPH is quite different among those countries. It is fundamentally due to the various situation of BPH during winter and spring seasons. Accordingly, in the tropical area where the paddy can grow all year round, owe to the existence of the suitable host plant and favorable climatic condition, BPH can survive all the seasons. And BPH is able to keep surely high level of population through the seasons (Dyck and Orlido, 1977; Dyck and Thomas, 1979; Mochida and Dyck, 1977).

On the contrary, in the temperate region, almost BPH disappear from this area in the winter season. The occurrence of BPH in the late spring or early summer is considered to be initiated by the trans-oceanic immigrated population (Kisimoto, 1971, 1976, 1979; Kisimoto *et al.*, 1982; Oya and Hirao, 1982). Therefore, the population increase gradually from this season and reach to the peak in the autumn. But it decrease suddenly towards the winter.

Although, in the tropical and temperate areas, the pattern of population succession is quite different. They show considerably regular annual pattern, while in the subtropical areas, including Taiwan, the situation seems more complicated. Because both the local overwintering strain and immigrated population have the possibility to constitute the initiating population of the early spring. To indorse it, to compare with the tropical and temperate areas, the population succession of BPH in subtropical area is more irregular and unpredictable. However, the importance of the establishment of the long term forecasting system of BPH is emphasized by many workers. Also the evaluation of the importance of both local overwintering and immigrated strains as the initiating population is recognized as indispensable work to the long term forecasting system. Except some fractional observations, the scarcely systematic works have been done.

The present work is conducted in the purpose to clear the above mentioned problem. And as the first step, the work is concentrated on the overwintering strain. The work is constituted with the following 4 parts.

1. Population succession of BPH in paddy in the fallowing season.
2. Range of host plant and its suitability to BPH.
3. Influence of low temperature to the growth of BPH.
4. Field inoculation test of BPH in the spring season.

A. Population succession in the fallowed seasons of the paddy plant

The work is done from December, 1979 to February, 1981 at the fallowed paddy fields and weed land near the paddy fields. Also some rice seedling beds are chosen as the target of this investigation. The survey is done with sweeping net method.

Four plots of 20 to 40a. in area located in the Northern District are selected for the periodical survey plots. The BPH population is checked with 200 times sweeping for each plot with 2 weeks interval. Besides, some unperiodical survey are done in the Central and Southern parts of the island. The collected BPH are recorded with its growing stage, sexuality and wing forms. Number of collected BPH through the surveyed period at the Northern and Central Districts are given in Tables 1 to 4.

The results of the survey indicate the facts that: 1) Both in the Northern and Central areas throughout the winter season, BPH population is very low. In the Northern areas, population density of BPH is significantly lower than that of the Central areas. While it is also found that BPH is still exist throughout the winter season. But it knows that BPH can overwinter in the Central and Southern areas of Taiwan in the past. (Ho and Liao, 1969; Cheng, 1980; Chiu, 1970). 2.) As the component of the population of BPH, the adults is prevailing to nymphs during the winter season. 3.) The adult population is predominantly constituted with macropterous form, while a few brachypterous individuals are also collected. 4.) Sexual ratio of adults is almost 1 to 1. 5.) Since the middle or ending of January the population decreased significantly and keeps low density until the end of February While the individuals of every growing stage are more or less existing in the field.

B. The range of host plant and its suitability

The work is done from the winter of 1979 to 1981. Paddy, ratoon paddy and other 35 species of crops and weeds which ubiquitously found around the paddy field are provided as the tested plants.

The weeds or crops are planted in pots at first. After clipping old leaves, when the newly budded leaves grow about 5 cm, 10 individuals of 3rd to 4 th instar nymphs or 5 pairs of macropterous adults are inoculated on the tested plants. After the inoculation, the plants are covered with a screen cage and placed outdoors. Number of living individuals are counted every 3 days, and test is done with 5 duplications for each plant. Besides, on 12 species of plants which can sustain

Table 1. The Population Density (Ave. No./200 Sweeps) of the Brown Planthopper (*N. lugens* **(Stål)**) **of the Following** Paddy Fields at Chingmei District, Taipei from Jan. to Mar. 1980

Date of survey	Ave. no. of adults				Ave. no. of nymphs	Total
	Macropterous		Brachypterous			
	♀	♂	♀	♂		
1980. 1.3	9.58	7.02	1.25	2.08	0.42	20.35
1.10	20.00	8.33	9.17	0	0	37.50
1.17	12.29	16.45	0.83	0	0	29.57
1.31	10.00	13.13	2.08	1.25	3.75	30.21
2.13	6.52	12.08	0		0	17.70
2.28	1.04	3.13	1.25	2.09	0	7.51
3.15	0	3.74	0.63	0	0	4.37
3.22	0	1.65	0	0	0	1.65

Table 2. The Population Density (Ave. No/200 Sweeps) of the Brown Planthopper (*N. lugens* **(Stål)**) of the Following Paddy Fields at Chingmei District, Taipei from Dec. 1980 to Feb. 1981

Date of survey	Ave no. of adults				Ave. no. of nymphs	Total
	Macropterous		Brachypterous			
	♀	♂	♀	♂		
1980. 12.15	6.42	2.29	0	0	3.33	12.04
12.26	4.38	3.54	0	0	2.71	10.63
1981. 1. 5	1.25	3.96	0.83	0	0	6.04
1.20	1.88	2.71	0	0	2.29	6.88
1.31	2.50	6.04	2.50	1.46	1.67	14.17
2.11	2.50	0	2.29	3.33	2.50	10.62
2.19	4.18	0.63	3.33	0	0	8.14
2.28	2.08	1.04	0.42	0	0.42	3.96

Table 3. The Population Density (Ave. No./200 Sweeps) of the Brown Planthopper (*N. lugens* **(Stål)**) in the Following Paddy Fields at Wufeng, Taichung from Dec. 1979 to Feb. 1980

Date of survey	Ave. no. of adults				Ave. no. of nymphs	Total
	Macropterous		Brachypterous			
	♀	♂	♀	♂		
1979. 12.27	46.00	80.50	7.33	3.33	0	137.16
1980. 1.11	53.33	62.00	0.33	1.67	0.83	118.16
1.21	22.50	43.67	0.67	1.17	0.33	68.34
1.31	1.25	3.00	0.83	0.33	0	5.41
2.12	3.17	6.33	0.67	0	0	10.17
2.28	2.50	5.33	0	0	0	7.83

Table 4. The Population Density (Ave. No./200 Sweeps) of the Brown Planthopper (*N. lugens* (Stål)) in the Following Paddy Fields at Wufeng, Taichung from Nov. 1980 to Feb. 1981

Date of survey	Ave. no. of adults				Ave. no. of nymphs	Total
	Macropterous		Brachypterous			
	♀	♂	♀	♂		
1980. 11.28	46.68	22.67	0	0	0	69.34
12.17	29.83	29.33	0.33	0.33	0.33	60.15
12.31	17.67	8.00	1.17	1.00	0.67	28.51
1981. 1.12	8.00	3.67	1.00	0	0	12.67
1.27	10.50	5.00	1.67	0	36.17	53.34
2. 6	9.50	6.50	0	0	10.83	26.83

BPH more than 12 days, amino acid and sugar contained in secreted honey-dew are estimated. Accordingly, honey-dew of BPH which excrete within 48 hours are collected with filter paper. Then amino acid and sugar quantitatively analyzed with Lowary's method and anthrone test respectively.

The results of nymphal and adult inoculation are given in Fig 1 and 2 respectively.

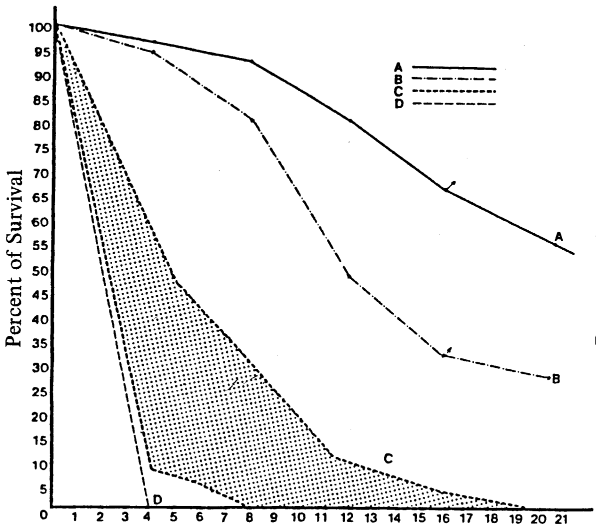

Fig. 1. Percent of survival of the 3rd and 4th instar nymphs of brown planthopper (*N. lugens* (Stål)) on the tested plants.

- A– rice plant (*Oryza sativa*) B. ratoon paddy (*O. sativa*).
- C– Including *Zizania latifolia, Echinochloa crus-galli, Leersia hexandra, Andropogon sorghum, Zea mays, Hordeum vulgare, Triticum sativum* var. *vulgare, Avena fatua, Saccharum officinarum, Cyperus diformis, C. iria, Paspalum conjugatum, P. distichum, Alopecures aegualis, Panicum dilatatum, Mazus pulmilus, C. rotundus, Sagittaria trifolia, Monochoria vaginalis, Eleusine indica, Polygonum hydropiper, Setavia geniculate, S. italica, Gnaphalium affine.*
- D– Including *Oplismenus compositus, Commelina diffusa, Cynodon dactylon, Miscanthus floridulus, S. palmifolia, Brachiaria mutica, Sporobolus fertilis, P. repens, Leptochloa chinensis, Ageratum conyzoides.*
- ↑. Adult emergence.

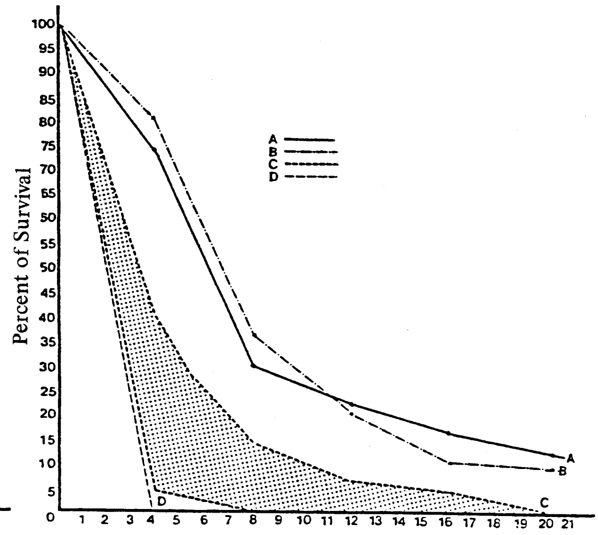

Fig. 2. Percent of survival of the brown planthopper (*N. lugens* (Stål)) adult on the tested plants.

- A– rice plant (*Oryza sativa*). B– ratoon paddy (*O. sativa*).
- C– inclduing *Echinochloa crus-galli, Leersia hexandra, Zizania latifolia, Andropogon sorghum, Zea mays, Hordeum vulgare, Triticum sativum* var. *vulgare, Setaria italica, Saccharum officinarum Cyperus diformis, C. iria, Alopecures aegualis, Panicum dilatatum, C. rotundus, Sagittaria trifolia, Monochoria vaginalis, Eleusin indica, Polygonum hydropiper, Gnaphalium affine, Mazus pulmilus.*
- D– Including *Commelina diffusa, Oplismenus composilus, Cynodon dactylon, Miscantnus floridulus, Setaria palmifolia, Brachiaria mutica, Sporobolus fertilis, Panicum repens, Leptochloa chinensis, Ageratum conyzoides.*

It is obvious that in the inoculation of nymphs. Both paddy and ratoon paddy showed superior rate of survival. Accordingly,8 days after the inoculation, 92 and 80 pencent of survivedare obtained on paddy and ratoon respectively. Although the rate of survival decrease to 66 and 32 percent on the 16th day after the inoculation. The survived individuals develop to adults. The survival rate of BPH inoculated on the other plants are apparently inferior. However, on the following 11 species still show the rate of survival above 10 percent on the 8th day: vegetable wild-rice

(*Zizania latifolia* Tuicz) 30%, Taiwan barnyard grass (*Echinochloa crusgalli* Beauv.) 16%, arrow head (*Sagittaria trifolia* Linn.,) 16%, Jerseycutweed (*Gnaphalium affine* D. Don.,) 14%, pruple nutsedge (*Cyperus rotundus* Linn.,) 14%, bareet grass (*Leersia hexandra* Swartz,) 12%, *Mazus japonicus* Kuntz. 12%, Dillis grass (*Paspalum dilatatum* Poiret,) 10%, wheat (*Triticum sativum* Linn. var *vulgare* Vill.) 10%, small flower umbrella plant (*Cyperus difformis* Linn.,) 10%, and Monochoria (*Monochoria vaginalis* Presl.,), 10%. While on the other 10 species of provided weeds, all the inoculated nymphs died within 4 days.

As shown in Fig. 2, host suitability of tested plants to the adults of BPH almost shows the similar tendency of the inoculation of nymphs. The result indicates that 30 and 36 percent of survival are obtained on the paddy and ratoon paddy on the 8th day after inoculation respectively. However, the adult administrated on Taiwan barnyard grass, corn (*Zea mays* Linn.), and small flower umbrell plant show the percentage of survival above 10 percent on the same day. On the other tested plants, the rate of survival ranged between 0-6 percent.

And on the 16th day after the inoculation, the rate of survival on paddy and ratoon are however decrease to 16 and 10 percent respectively. On that day, new progeny of BPH are emerged on those provided plants. On the same day, a few adults are still survived on Taiwan barnyard grass. While they are extinguished on the 20th days. And no progeny are observed on this grass.

Although all the tests are done under the screen cage covered condition, it is obvious that BPH not only can sustain their life for a certain long duration but can produce their progeny either paddy or ratoon in the winter season of the Northern area of Taiwan. While on the contrary, the result it also postulate the fact that the possibility of the overwintering on the other plants are scarce. But according to Fukuda (1934), Ho and Liao (1969), Chiu (1970) and Chou *et al.* (1969) reports, BPH can overwinter on many crops and grasses.

Sugar and amino acid contents of honeydew of BPH which inoculated on various plants are given in Table 5 and 6.

It is apparent that BPH inoculated on paddy plant excrete a large amount of sugar. Besides, BPH on vegetable wild-rice, bareet grass, Taiwan barnyard grass also excrete the high sugar content hony-dew. The result of amino acid content estimation also show the similar tendency of that of sugar content. Accordingly, honeydew from BPH on paddy show the highest content, and on Taiwan barnyard grass, vegetable

Table 5. Carbohydrate Content in the Honeydew Excreted by the Brown Planthopper (*N. lugens* (Stål)) Fed on Various Plants

Tested plant	Carbohydrate content (nm)	Index
Rice (*O. sativa*)	0.104	100
Vegetable wild-rice (*Z. latifolia*)	0.081	78
Bareet grass (*L. hexandra*)	0.078	75
Taiwan barnyard grass (*E. crus-galli*)	0.072	69
Corn (*Z. mays*)	0.050	48
Goose grass (*E. indica*)	0.044	42
Purple untsedge (*C. rotundus*)	0.043	41
Small flower umbrella plant (*C. diformis*)	0.032	31
Jersey cutweed (*G. affine*)	0.022	21
Arrowhead (*S. trifolia*)	0.021	20
Sorghum (*A. sorghum*)	0.017	16
Monochoria (*M. vaginalis*)	0.006	6

Table 6. Amino Acid Content in the Honeydew Excreted by the Brown Planthopper (*N. lugens* (Stål)) Fed on Various Plants

Tested plant	Amino acid content (nm)	Index
Rice (*O. sativa*)	0.0094	100
Vegetable wild-rice (*Z. latifolia*)	0.0038	40
Bareet grass (*L. hexandra*)	0.0024	26
Taiwan barnyard grass (*E. crus-galli*)	0.0065	69
Corn (*Z. mays*)	0.0031	33
Goose grass (*E. indica*)	0.0014	15
Purple nutsedge (*C. rotundus*)	0.0019	20
Small flower umbrella plant (*C. diformis*)	0.0011	12
Jersey cutweed (*G. affine*)	0.0018	19
Arrowhead (*S. trifolia*)	0.0035	37
Sorghum (*A. sorghum*)	0.0016	17
Monochoria (*M. vaginalis*)	0.0021	22

wild-rice comes next, while on bareet grass, the content is rather low.

C. Influence of low temperature to the growth

The test is initiated with the 2nd instar nymphs which pretreated under 22°C. Then they are administrated to 22°C, 16°C, 10°C and 5°C constant temperature. And the number of survived individuals are recorded every day. Besides, the effect of gradual decrement of temperature are studied with the following series of temperature:

$$22°C \xrightarrow{\text{1 day}} 16°C \xrightarrow{\text{7 days}} 10°C \xrightarrow{\text{7 days}} 5°C$$

All the tests are taken place with 5 nymphs and 20 duplications. They are afforded with paddy seedling throughout the tested duration.

Besides, under the assumption on a cold current attacks the Northern part of Taiwan, another experiment is carried out in a following series of temperature.

For daytime:

$$8°C \xrightarrow{\text{7 days}} 13°C \xrightarrow{\text{4 days}} 16°C \xrightarrow{\text{3 days}}$$

$$8°C \xrightarrow{\text{2 days}} 13°C \xrightarrow{\text{4 days}} 16°C \xrightarrow{\text{7 days}} 20°C.$$

For night:

$$8°C \xrightarrow{\text{7 days}} 8°C \xrightarrow{\text{4 days}} 13°C \xrightarrow{\text{3 days}}$$

$$6°C \xrightarrow{\text{2 days}} 8°C \xrightarrow{\text{4 days}} 10°C \xrightarrow{\text{7 days}} 16°C.$$

The daytime is set for 11 hours.

Then, 200 individuals of 4th-5th instar nymphs are administrated, and the test is done with 2 duplications. Number of alive nymphs are recorded daily. The cold tolerance on adults are also tested under the temperature of 16°C and 10°C for daytime and night respectively. They are provided with ratoon paddy. Then, 100 pairs of adults are inoculated for this test.

The field test is also conducted with 5 pairs of adults which inoculated on 4 stubs of ratoon paddy.

When the nymphs are provided under constant 22°C, as shown in Fig. 3, their development is normal and the rate of survival is very high, namely 94 percent on the 10 day after inoculation. All the survived individuals develop

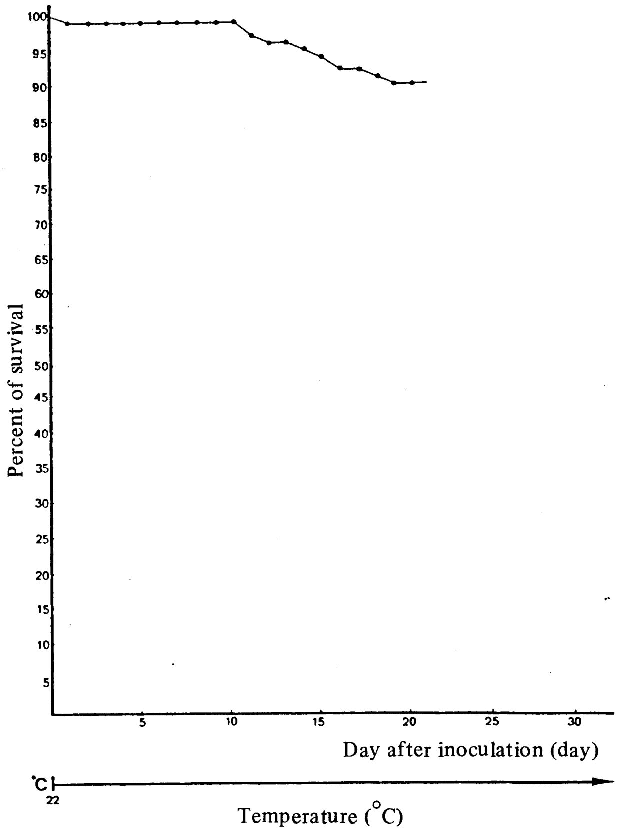

Fig. 3. Percent of survival and development of the 2nd instar nymphs of planthopper (*N. lugens* (Stål)) nymphs reared at a constant temperature of 22°C.

to adults. The rate of adult emergence is above 90 percent.

It is obvious that under constant 22°C condition, the 2nd instar nymphs is able to develop to adults, and the peak of adults emergence appears on the 18th day after the inoculation.

While the rearing under the lower temperature. All show quite different results. When they are removed to 16°C from 22°C, the rate of survival decrease to 74 percent within 6 days. And the first adult emerge on the 23rd day after the inoculation. On the 50th day, 20 individuals are still remained at the 5th instar nymphal stage.

The temperature of 10°C and 5°C are more unfavorable for the nymphs of BPH. Within 1 day, 89 and 96 percent of administrated nymphs died under 10°C and 5°C respectively. The last nymph die on the 46th and 36th day in those cold treatments. During these period, no molting is observed. Accordingly, they stay on the instar stage of the inoculated stage.

The result of the rearing under the gradually decreasing temperature is given in Fig. 4.

When the temperature decrease to 16°C from 20°C, on the 7th day after the inoculation, the rate of survival shows 79%, and above 80 percent of living nymphs develop to the 3rd instar nymph. While, when the temperature decrease to 10°C, the rate of survival suddenly decrease to 11 percent within 2 days. After 7 days under this condition, only 6 percent of the

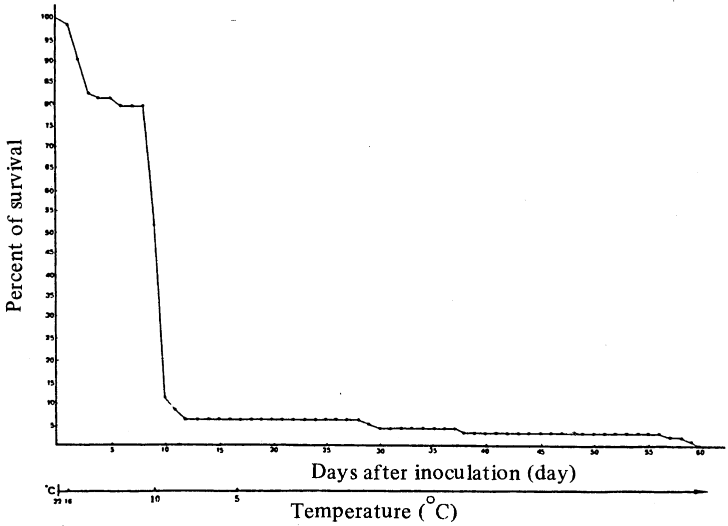

Fig. 4. Percentage of survival and development of the 2nd instar nymphs of brown planthopper (*N. lugens* (Stål)) reared at the temperature regions of 22°C $\xrightarrow{\text{1 day}}$ 16°C $\xrightarrow{\text{7 days}}$ 10°C $\xrightarrow{\text{7 days}}$ 5°C.

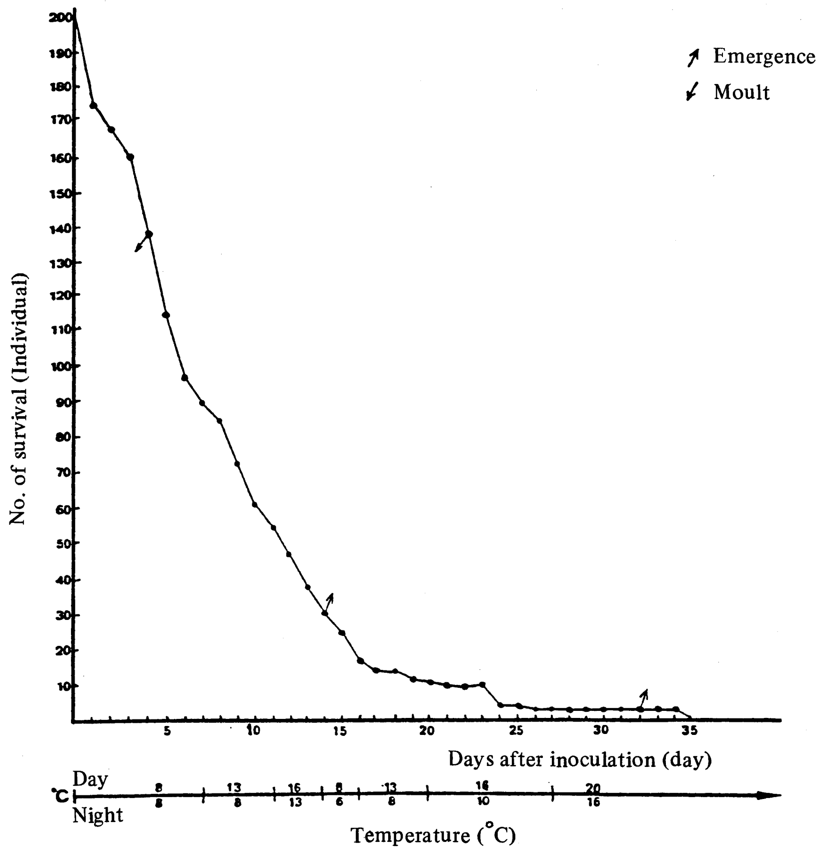

Fig. 5. Percentage of survival and development of the 4th-5th nymphs of brown Planthopper (*N. lugens* (Stål)) under the lower dynamic temperature in plant growth chamber.

nymphs are living. And they still keep at the 3rd instar stage. When the temperature down to 5°C, the survived nymphs decrease gradually and the last nymph die on the 60th day after the inoculation. No additional molting occur during those treatments.

The result of the test under the assumpted cold current attacking condition is given in Fig. 5.

Although the rate of survival is not high, and around 75 percent of afforded nymphs die within 15 days. While several adults still emerge on the 15th day after the cold treatment.

The effect of low temperature on adults are tested both on indoor and outdoor conditions. In the former, adults are provided to a condition which set 16°C and 10°C for daytime and night respectively. And the latter, namely outdoor test is conducted with the adults inoculated on screen cage covered or uncovered paddy plants. The results are given in Table 7 and 8.

As shown in Table 7, under the 16°C and 10°C variable temperture, 50 percent of 200 tested adults are survived for 11 days. There is no difference on the cold hardiness between male and female. While further exposure to the low temperature seems more strict to the male than to the female. Accordingly, all the tested male die on the 33rd day after the cold treatment,

Table 7. The Longevity of the Brown Planthopper (*N. lugens* (Stål)) Adults Reared on Rice Plants in Growth Chamber (Temperature: Day–16°C, Night–10°C, 10 Hrs Light)

Day after inoculation	No. survived ♀	♂	Total
1	100	100	200
2	98	92	190
3	80	78	158
4	70	69	139
5	69	68	137
6	69	66	135
7	66	60	126
8	61	60	121
9	58	57	115
10	54	56	110
11	49	53	102
12	43	51	94
13	38	25	63
14	32	23	55
15	32	22	54
16	30	22	52
17	30	20	50
18	28	18	46
19	25	16	41
20	24	14	38
21	24	12	36
22	21	10	31
23	21	10	31
24	19	10	29
25	17	8	25
26	17	6	23
27	15	6	21
28	13	4	17
29	12	4	16
30	11	4	15
31	10	2	12
32	10	1	11
33	7	0	7
34	4	–	4
35	4	–	4
36	3	–	3
37	2	–	2
38	2	–	2
39	2	–	2
40	2	–	2
41	1	–	1
42	1	–	1
43	0	–	0

while 10 female are still surviving, and the last female died on the 42nd day. The same tendency is also observed on the outdoor experiment. Adults are inoculated on 7th January to the screen covered paddy plants, then the last male and female are survived until on 29th January and 2nd February respectively. Namely, they show 24 and 32 days longevity at maximum. On the uncovered paddy plants, BPH are inoculated on 29th December. The maximum longevity for male and female are 23 and 35 days respectively. But under 20.00 ± 0.03°C to 29.4 ± 0.07°C, the longevity of male and female are 10.50 ± 1.27 to 4.70 ± 3.03 days respectively (Tao and Yao, 1967). Then Mochida and Okada's (1979) report indicate at 25°C constant temperature, the longevity of macropterous male and female are 11.6, 27.6 days respectively. And Kisimoto's report (1981) reveal the longevity of brachypterous female is 8 to 9 days in the field, but they are 26.1, 33.5 days in branchypterous male and female indoors.

It is worthy to note that from December 29th, 1982 to January 23rd, 1983, the outdoor temperature decrease gradually. And during this period it falls on the rainy season of the Northern part of Taiwan. Although the daily rainfall recorded only 20mm. It drizzled throughout the tested period. Especially from 20th to 23rd, January, an attack of a cold current decrease the daily average temperature below 10°C (Anonymous, 1971-1983). The high mortality of inoculated adults on covered and uncovered paddy plants occur in this duration.

D. Field inoculation test in the spring season

This test is started on 28th March till June, 1980 with the inoculation of 1 or 2 pairs of adults BPH per plot which consist with 20 tillers of paddy. Although all the inoculated adults disappear on 11th to 18th April, the nymphs of the next generation emerged arround those days. There is no remarkable difference on the development of population between 1 and 2 pairs BPH inoculated plots. After 1 and half months later, the population of BPH increase apparently. And on the beginning to the middle of June the population already reach to its peak. The adults of the next generation are observed on 6th May. After that day, the individuals of the every growing stage are overlappingly emerge.

The maximum population of adults are observed on the middle of May. Majority of them belong to brachypterous. On the end of May, the population rise to above 400 individual per plot. It is almost composed with the 1st and 2nd instar nymph. And they are considered to be the beginning of the 3rd generation. They develop to adults on the beginning of June, and the population zoom up to around 900

Table 8. The Longevity of the Brown Planthopper (*N. lugens* Stål) Adults in Following Paddy Fields During Winter Season (From Dec. 1982 to Feb. 1983) in Taipei

Date of survey	Covered with screen cages			Exposed		
	♀	♂	Total	♀	♂	Total
1982. 12.29				300	300	600
1983. 1. 5				201	113	314
1. 7	300	300	600			
1.10				101	34	135
1.11	243	139	382			
1.14				68	20	88
1.17				67	18	85
1.18	88	23	111			
1.21				16	4	20
1.24				5	0	5
1.25	32	11	43			
1.28				3	0	3
1.29	17	2	19			
1983. 2. 1	4	0	4			
2. 2				1	0	1
2. 6	1	0	1			
2. 7	0	0	0	0	0	0

individuals per plot. Since 27th May, part of the paddy plant show a symptom of hopperburn. The hopperburn becomes more serious till the end of June.

To conclude the above results, in the Northern area of Taiwan, under the screen covered condition, it takes 2 generations of BPH from the inoculation to the occurrence of the hopperburn. In the Northern part of Taiwan, the trans-planting season of the 1st rice crop season falls on the middle to the end of March, and the paddy plant harvests from the end of June to the middle of July. The result of the present work reveal that the adult of the 1st generation emerge about 40 days from the inoculation of the end of March in the paddy field. It generally falls on the middle of May. And the peak of adult emergence of the 2nd generation appear around 75 days later, namely on the middle of June. Although before the middle of May, the population density of BPH is still low, it increases to approximately 450 times of the initial population at the beginning of June. From June the temperature rises to high, so there are 1 or 2 additional generations may occur until the harvest.

Conclusion

As the results of the present work, BPH reveals as a monophagous insect. They can neither develop to the further stage nor produce their progency on any plant except paddy. Therefore the paddy is recognized as the sole suitable host plant to maintain its normal population. Furthermore, in paddy fallowing season, ratoon paddy becomes the only favorable food source for the BPH.

Results of the field investigation indicate the fact that the population density of BPH in ratoon paddy is very low in the winter season. But still can find some individuals of every growing stage. However, the population density remarkably fluctuates with climatic and other factors. The results of indoor and outdoor experiments postulate the fact that the low temperature of the Northern area of Taiwan didn't entirely extinguish BPH, and a part of individuals are still tolerable to such level of cold condition. As the rising of temperature from the end of February the survived individuals of BPH begin to be active and reproduce their population.

The result of the outdoor inoculation test suggest the possibility that the overwintered population of BPH produce 2 generations on the 1st rice crop season from the end of March to the middle of June. And they have a potential to occur a hopperburn at the beginning of June. Of course in the case of the immigration occurr, and the additional population of BPH join to the

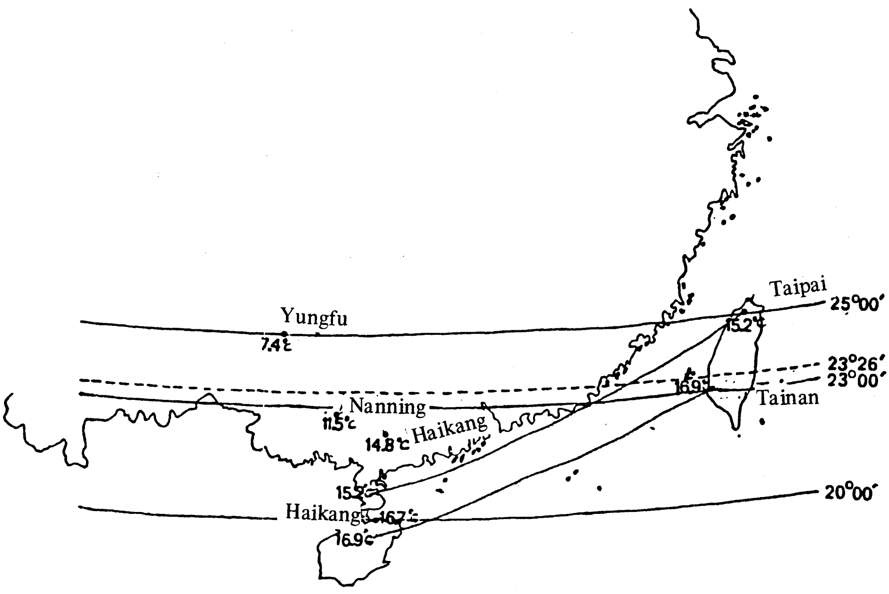

Fig. 6. The isotherm (°C) of Taipei, Tainan; Taiwan; and Prov. Kuangtung, Kuanghsi, Jan., 1974-1978.

local ones, the menace to the paddy plant will be enhanced.

However, according to the result of the investigation regarded to the BPH overwintering situation in Mainland China, they divide whole the Mainland into 3 parts. Those are 1.) Favorable overwintering area: Areas of the Southern parts to 19° Northern Latitule. 2.) Partly overwintering area: Areas between 19° Northern Latitute and Tropics of Cancer (23° 26' Northern Latitute). 3.) Non-overwintering area: North to Tropics of Cancer (Cheng et al., 1979). If set this criterion on Taiwan, the Southern parts of Taiwan belong to the partly overwintering area, and the other areas of Taiwan will be designated as non-overwintering area.

While such assumption doesn't coincide to the result of the present work. It is evident that even the Northern area of Taiwan, BPH can overwinter with low density level. But this conflict is easy to be explain if take the temperature of the winter season into the consideration. Due to the effect of "Kuroshiho = Black tide current", the climate in Taiwan especially in the winter is apparently warmer than the Mainland China. For example to accord to the above criterion, Taipei (25° 02' Northern Latitute) and Tainan (23° 00' Northern Latitute) are located between Non-and partly overwintering areas. The average temperature and average minimum temperature of January in Taipei is 15.2°C and 12.6°C, and those of Tainan are 16.9°C and 12.9°C (Anonymous, 1982). If compare with the data of the same degree latitute in the Mainland China, Yung Fu (25° 00' Northern Latitute) and Nan Ning (22° 49' Northern Latitute). At the former locality, the average and minimum average temperature in January are 7.4°C and 4.6°C respectively. And those of at the latter locality are 11.5°C and 8.5°C respectively (Chent et al., 1979) (Fig. 6).

It is obvious that the isotherm of 15.2°C in January connect Taipei to the southern part of Lei-chou Peninsula where designated as a partly overwintering area in the Mainland China. As well as the isotherm of 16.9°C extend from Tainan to the Central parts of Hainan and transversing the favorable overwintering zone of the Mainland China. Therefore, regard to the temperature of January, it is rather reasonable that to designate the Northern parts of Taiwan as the partly overwintering zone of BPH. And the results of the present work also indorse it.

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