Analysis of the Data of the Brown Planthopper (*Nilaparvata lugens* (Stål.)) with Light Trap in Taiwan

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ABSTRACT

In Taiwan, the quantity of light trap's brown planthopper (BPH) was significantly, positively correlated with BPH density in the field (collected with sweep net). But the former pest was adults (macropterous form) that could fly toward light, while the latter pest included adults (brachypterous form) and nymphas that feeded on hosts and lived at nearby plants. So that the former occurred later. According to analysis, because of different localities the time is also differently lag. Lag days were 0-20 days.

The relation between light trap's BPH and climatic factors differed depending on localities and crops. In general, light trap's BPH was significantly and positively correlated with average temperature, duration of sunshine.

In normal years the infested area was below 20% of the total paddy fields, while in outbreak years it was over 23%. The percentage of the infested area had significant and positive correlation with the BPH density in paddy field. However, the light trap's BPH had no uniform relation with the percentage of the infested area all over the province.

Introduction

There have been 13 times of outbreaks of the brown planthopper in Taiwan since 1910. However, it had not become important insect pests to paddy rice in this Province until 1960. This pest not only can cause rice serious yield loss, but also can spread the virus diseases of paddy rice to cause more serious paddy rice loss. To meet the requirement of protecting rice crop throughout the Province, an island-wide field surveillance network was set up in 1966 to handle the work of monitoring the occurrence of major food crop's diseases and insect pests with 47 scouts sationed to various paddy rice growing regions to survey periodically and not periodically the changing situation of diseases and insect pests, the growing situation of crop, the change of environmental factors in the field, and to collect weather information, etc.; the setting up of light trap, collection and survey of pest amount trapped are all uninterrupted surveying task for months and years. The setting up of light trap is to trap adult pests by utilizing the nature of adults (or moths) that can fly toward light so as to get the time of occurring target pests and the information of population fluctuation. Then, scouts, according to their own experience, and data obtained from various surveys and pests control thresholds, analyze and interpret the extent of possibly occurring various disease and insect pests, and release the warning; thus farmers can adopt controlling in time. Now, from the data surveyed by scouts after setting up surveillance network in the Province, let us analyze the amount of brown planthoppers trapped by the light trap, and discuss the correlation between the data of light trap's brown planthoppers and climatic factors.

Method

This datum was obtained with light trap in the field surveyed by various scouts in seven agricultural improvement stations of the Province from 1967 to 1982. The amount of brown planthopper's adults trapped with light trap everyday was accumulated per 5 days, and the density occurred in the field of sweepping net was surveyed once every 5 days; the climatic

factors only include 4 records of the average temperature, relative humidity, precipitation and duration of sunshine in the atmosphere. The first 2 items are average in 5 days, and the last 2 items are of the sum accumulated in 5 days. By using the factor analysis and multiple regression analysis, the relationship between the amount of the light trap's brown planthoppers and climatic factors has been studied.

Results

a. Distribution of Surveillance Network in the Province and Intensity of Catching Brown Planthopper with Light Trap

Throughout the province, seven districts' agricultural improvement stations have been divided from north to south and from west to east; they are Taipei District (including Ilan), Hsinchu District, Taichung District, Hualien District, Tainan District, Taitung District and Kaohsiung District (Fig. 1). According to the 5-days average amount of pests trapped with light

Fig. 1. Map of Taiwan showing the localities and the intensity of catching brown planthopper with light trap.
I: <50 individuals; II: >50 individuals; III: >100 individuals; IV: >200 individuals; V: >500 individuals

trap from 1967 to 1982, the density of the light trap's brown plathopper in Taiwan can be divided into 5 districts. At Ilan in the 1st district, the average number was below 50 individuals; in the 2nd district including Hsinchu and Taichung; the average number was above 50 individuals; at Hualien in the 3rd district, the average number was above 100 individuals; in the 4th district including Tainan and Taitung, average number was above 200 individuals; at Kaohsiung in the 5th district, the average number was above 500 pests (Fig. 1, Table 1). This data indicate that the geographical distribution of brown planthoppers in the province gradually becomes serious from north to south, especially at the 2nd crop of paddy rice when there have been often the records of outbreaks; for example, in 1966, '67, '69, '74, '75 and '81 (Fig 3), brown planthoppers in the field were so greatly outbroken that the percentage of the infested area was over 23%.

b. Seasonal Occurrence of the Light Trap's Brown Planthoppers

As for the amount of the light trap's brown planthoppers in Taiwan, its density at the early stage each year everywhere is low, but increases gradually after early April. There are two times each year to peak brown planthoppers under light trap, occurring at the 1st crop and the 2nd crop of paddy rice once respectively, and the 1st peak exceeds the 2nd peak. Its peak is apparently from north toward south, and its earlier occurrence is shown on Fig. 2; at Kaohsiung in southern part, its 1st peak time occurs in the middle of May; the north of Hsinchu in northern part, the 1st peak time occurs after late June, and its peak has not been apparent. Therefore, the time of catching 50 adults trapped every 5 days advances earlier from north to south. At Kaohsiung, the adults trapped have amounted to 50 at the 6th 5-days in April; at Hualien and Tainan this number is caught at the 3rd 5-days in May; for Taichung at the 3rd 5-days in June, and for Hsinchu at the 4th 5-days in June; at Ilan, the number of 50 adults trapped can not be attained until the 2nd 5-days in July. The time of catching the same density of brown planthoppers occurred under light trap in the various fields in the province is different for three months between northern part and southern part (Table 1). Not only the times of catching brown planthoppers at various districts are different, but also its amount of occurrence is greatly different; the accumulated average number per 5 days is only 14.43 at Ilan in northern part, but up to 549.92 at Kaohsiung in southern part. Obviously the fluctuation of occurrence is affected by the local climatic factors and other

Table 1. The Average Value, Appearing Date of Average 50 BPH Accumulated and Climatic Factors per 5 Days at Different Localities

Localities	Appearing date of 50 adults per 5-days	Average no. of trap's BPH	Average temperature (°C)	Relative humidity (%)	Precipitation (mm)	Duration of sunshine (hr)
I-lan	July 2nd-5-day	14.43	22.54	84.73	40.37	18.80
Hsinchu	June 4th-5-day	81.08	22.74	83.21	18.56	19.12
Taichung	June 3rd-5-day	89.67	22.74	78.40	24.05	30.19
Hualien	May 3rd-5-day	172.00	22.90	79.88	27.14	21.10
Tainan	May 3rd-5-day	223.00	22.87	83.64	25.06	25.59
Taitung	April 3rd-5-day	276.20	23.78	77.54	27.45	25.56
Kaohsiung	April 6th-5-day	549.92	24.34	81.93	27.78	24.41

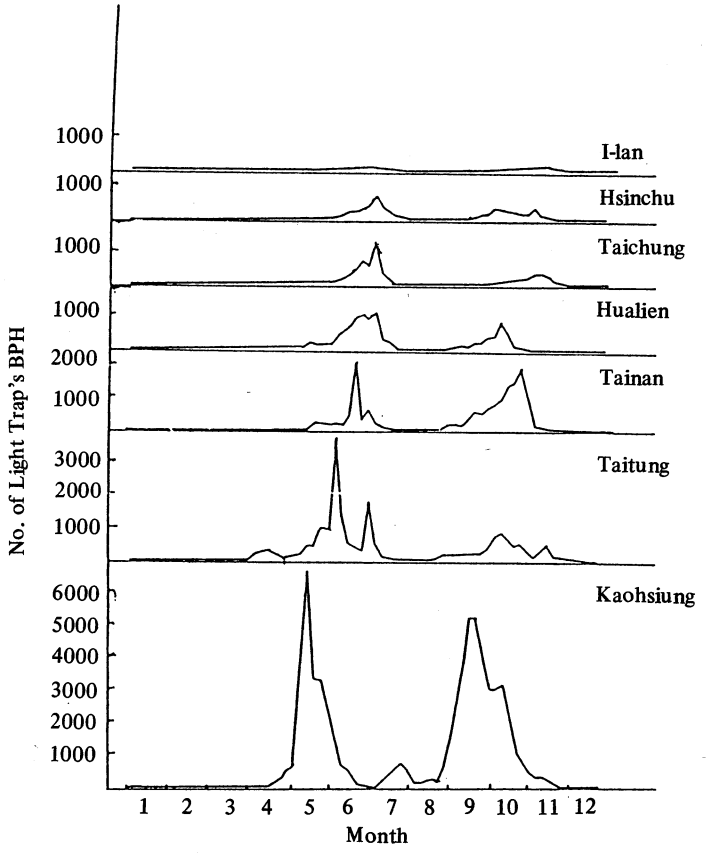

Fig.2. Annual fluctuation of BPH obtained by ligt trap.

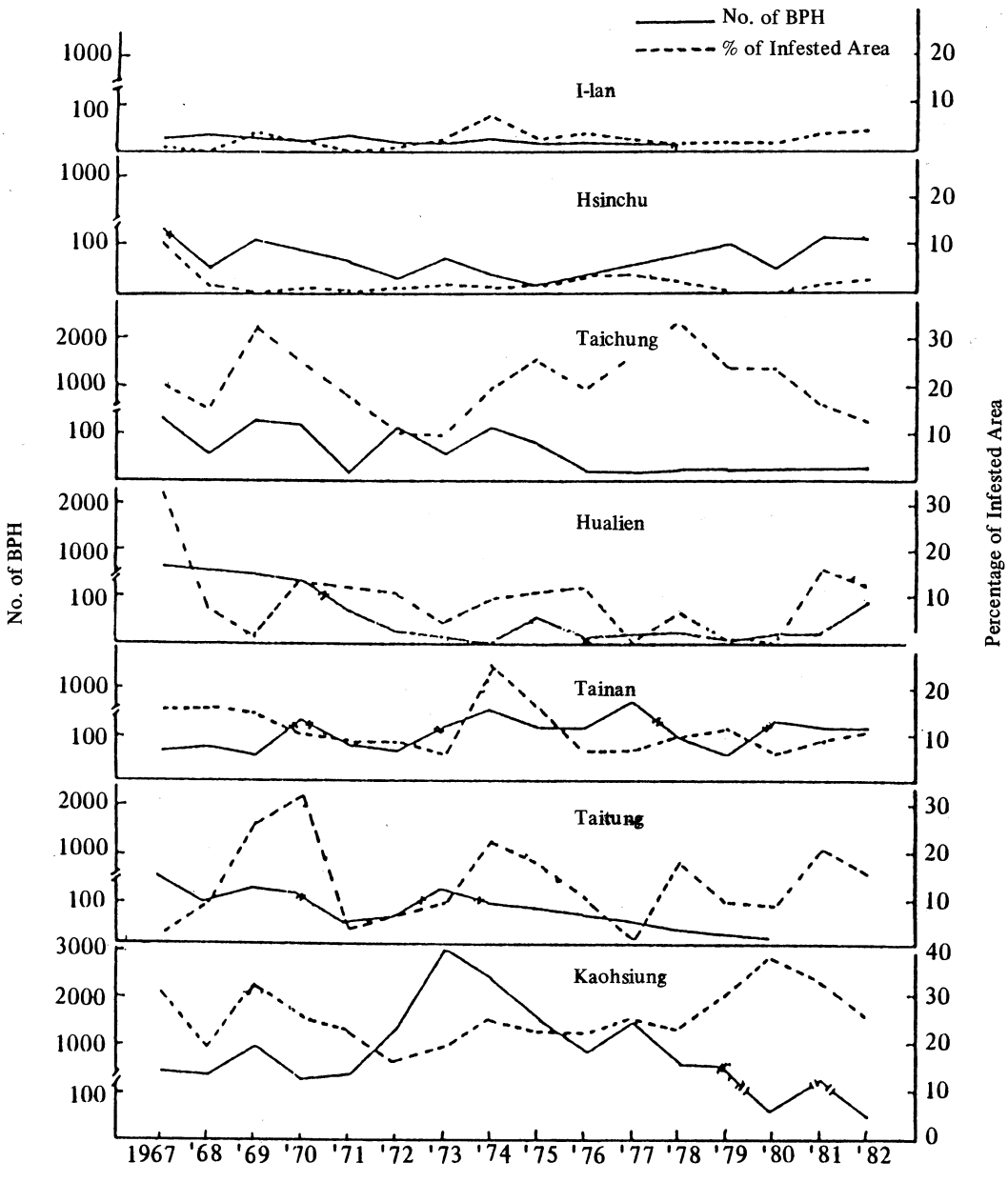

Fig. 3. Fluctuation of light trap's BPH in relation to percentage of infested area in Taiwan during 1967-1982.

environments factors. Among the main climatic factors, average temperature and duration of sunchine increase gradually from north to south, but precipitation and relative humidity decrease gradually (Table 1). The former two items are significantly, positively correlated with the amount of occurring brown planthoppers', but the latter two items are negatively but insignificantly correlated (Table 4).

As for the density of occurring brown

Table 2. Occurrence of the Light Trap's BPH in Relation to Population Density of Sweep's Collection during 1967-1982 in Taiwan

Localities	No. of light trap's BPH Average	No. of sweep net's BPH Average	Correlative coefficient (r)						
			lag 0 day	lag 5 days	lag 10 days	lag 15 days	lag 20 days	lag 25 days	lag 30 days
I-lan	14.43	8.31	0.97**	0.95**	0.87**	0.74**	0.57**	0.38**	0.19
Hsinchu	81.08	74.17	0.73**	0.83**	0.85**	0.76**	0.56**	0.40**	0.29*
Taichung	89.69	13.00	0.19	0.33**	0.44**	0.46**	0.49**	0.42**	0.36**
Hualien	172.00	168.60	0.69**	0.80**	0.80**	0.76**	0.64**	0.58**	0.37**
Tainan	223.00	26.60	0.76**	0.64**	0.53**	0.43**	0.31*	0.20	0.05
Taitung	276.20	26.85	0.36**	0.44**	0.39**	0.34**	0.47**	0.43**	0.26*
Kaohsiung	549.92	16.35	0.38**	0.57**	0.71**	0.72**	0.70**	0.71**	0.71**

** 1% of Significance * 5% of Significance

Table 3. Autocorrelation of Light Trap's BPH at Different Localities in Taiwan

Localities	No. of light trap's BPH	Correlation coefficient (r)					
		lag 5 days	lag 10 days	lag 15 days	lag 20 days	lag 25 days	lag 30 days
I-lan	14.43	0.96**	0.85**	0.69**	0.50**	0.29*	0.10
Hsinchu	81.08	0.81**	0.65**	0.46**	0.31*	0.17	0.05
Taichung	89.69	0.69**	0.59**	0.33**	0.16	0.03	-0.06
Hualien	172.00	0.84**	0.70**	0.48**	0.28*	0.11	-0.01
Tainan	223.00	0.66**	0.53**	0.34**	0.20	0.14	0.06
Taitung	276.20	0.49**	0.31**	0.18	0.18	0.30*	0.07
Kaohsiung	1549.90	0.75**	0.53**	0.39**	0.25*	0.12	0.04

** 1% Significance * 5% Significance

Table 4. Correlative Coefficient of Light Trap's BPH and Climatic Factors at Different Localities in Taiwan

Localities	Average temperature	Relative humidity	Precipitation	Duration of sunshine
I-lan	0.33**	0.17	0.22	0.41**
Hsinchu	0.40**	-0.20	0.07	0.49**
Taichung	0.26**	-0.10	0.04	0.30*
Hualien	0.49**	0.12	0.09	0.60**
Tainan	0.25*	0.19	-0.11	0.23
Taitung	0.39**	-0.02	0.13	0.39**
Kaohsiung	0.35**	0.36**	0.00	-0.22

**: 1% Significance * 5% Significance

planthoppers in the field in Taiwan, there are the survey of adults trapped by light trap and the density of adult and nymph that feeded on hosts and lived at nearby plants in the field or ridges between plots of sweep net. According to the result of analysis, there is significant positive correlation between them at various localities in the province. Therefore, the changing of the brown planthoppers under light trap in Taiwan can respond to the density of brown planthoppers in the field. However, the data of light trap and sweep net indicate that the number of pests obtained by the light trap is more than the sweeping net (Table 2), but the pests under light trap appear later than adults and nymphs in paddy field. The length of this time lag is different depending on district (Table 2). At Ilan, the time of appearing pests under light trap and that of appearing sweep net's brown planthoppers had the most correlated coefficient at that time, but it's still significantly correlated after five 5-days later. Tainan's correlated coefficient was also the highest at that time, but its significant correlation lagged to four 5-days. At Hsinchu and Hualien, it lagged two 5-days. At Kaohsiung, four 5-days with the highest positive correlation coefficient. Furthermore, there were about 9-10 generations each year in Taiwan, and often there are overlapped between generations in the field. Therefore, the light trap's pests accumulated every 5 days have their autocorrelation, and this autocorrelation is different at various localities (Table 3); lag 10-25 days there is still significant, positive correlation.

c. Relationship between Occurrence of Light Trap's Brown Planthopper and Climatic Factors

The amount and time of occurring brown planthoppers each year in Taiwan has close relationship with environmental factors which include climatic factors, nutrition, biology and control method, etc.. Now only climatic factor is discussed. The number of pests trapped by light trap is easily affected by light intensity, light source, temperature, precipitation, and sunshine, etc.. The movement of pests of brachypterous form is small, but pest's with macropterous form is great; the pests trapped by light trap are that with macropterous form. The light intensity when the pests with macropterous form fly is 21 lux-200 lux, the temperature when they fly is 17°C, and wind velocity is below 11Km/hr. (Ohkubo & Kishimoto 1971). The climatic factor not only can affect the pest's activities, but also affect the birth of pests, breed of population, and growth of paddy rice; also the proportion of wing-form of brown planthopper is different depending on the population density and the situation of paddy growth. Now the results of analyzing light trap data during 1967-1982 are given in Table 4-10. The data of light trap's BPH at various localities in a year had significant and positive correlation with average temperature and duration of sunshine, but relative humidity and precipitation affected differently and insignificantly at various localities (Table 4). However, the influence of climatic factors on various crops in various districts each year also changed greatly. In Ilan district (Table 10), the average temperature and duration of sunshine at the 1st crop was positively correlated, but negatively correlated at the 2nd crop. At the 1st crop, its influence increased as the time went, most intensified at occurrence, but the negative correlation for the 2nd crop was the highest before 30 days; the negative correlation decreased as the time went. However, in Hsinchu district, it's not the same (Table 9); the average temperature at the 1st crop was positively correlated, but negatively correlated at the 2nd crop; at the 1st crop also the influence of temperature increased as the time went, most intensified when trapped, but at the 2nd crop the influence of temperature decreased as the time went, most intensified before 30 days as trapped. The relative humidity was negatively correlated at the 1st crop with increasing its influence as the time went, but positively correlated at the 2nd crop with increasing its influence as the time went; both were significantly correlated when trapped. Precipitation and duration of sunshine were all negatively correlated at two crops, but the influential time was not the same; precipitation had the highest negative correlation coefficient at the 1st crop when trapped, and did the same at the 2nd crop before 25 days. The influence of duration of sunshine was just contrary to that of precipitation; at the 1st crop the negative correlation coefficient before 30 days was the highest; at the 2nd crop the correlation coefficient was the highest when trapped. In central and south-

Table 5. Correlative Coefficient of Climatic Factors and Light Trap's BPH in Different Seasons in Kaohsiung

Time	Average temperature		Relative humidity		Precipitation		Duration of sunshine	
	1st Crop	2nd Crop	1st Crop	2nd Crop	1st Crop	2nd Crop	1st Crop	2nd Crop
Bef.30 days	0.12322*	-0.03679	-0.08421	-0.01373	-0.05722	-0.06466	-0.04656	0.02537
Bef.25 days	0.1561*	-0.04520	-0.07737	0.00854	-0.037	-0.06533	-0.04381	0.05179
Bef.20 days	0.17497*	-0.03185	-0.10238	-0.01181	-0.01503	-0.0531	-0.03224	0.018
Bef.15 days	0.15033*	-0.02889	-0.02545	-0.00767	0.07963	-0.05212	-0.08282	-0.034
Bef.10 days	0.12177*	0.01580	0.00168	-0.02034	0.08855	-0.05282	-0.12669*	-0.04885
Bef.5 days	0.11357	0.03283	0.04552	-0.03693	0.10449	-0.0617	-0.14764*	-0.03452
Bef.0 day	0.05495	0.05554	-0.00551	-0.06430	0.12386*	-0.08104	-0.16469*	-0.03833

** 1% of Significance * 5% of Significance

Table 6. Correlative Coefficient of Climatic Factors and Light Trap's BPH in Different Seasons in Taitung

Time	Average temperature		Relative humidity		Precipitation		Duration of sunshine	
	1st Crop	2st Crop	1st Crop	2nd Crop	1st Crop	2nd Crop	1st Crop	2nd Crop
Bef.30 days	0.08677	-0.07968	0.03149	-0.04894	-0.05499	0.04868	0.03246	0.00311
Bef.25 days	0.05162	-0.04242	-0.00293	-0.01036	-0.03306	0.14018	-0.03833	-0.05202
Bef.20 days	-0.02119	-0.00137	0.05556	0.05126	0.08886	0.0472	-0.03477	0.01584
Bef.15 days	-0.02931	0.0022	0.07965	0.04718	0.15404*	0.14807	0.52776**	-0.00432
Bef.10 days	-0.06026	-0.04053	0.1745*	0.05965	0.05265	0.08558	-0.14883*	-0.14566
Bef.5 days	-0.03535	-0.03558	0.04852	0.08214	0.08303	-0.01897	-0.11184	-0.03301
Bef.0 days	-0.03442	-0.06173	0.11415	0.10941	0.01533	0.00463	-0.01251	-0.11731

** 1% of Significance * 5% of Significance

Table 7. Correlative Coefficient of Climatic Factors and Light Trap's BPH in Different Seasons in Tainan

Time	Average temperature		Relative humidity		Precipitation		Duration of Sunshine	
	1st Crop	2nd Crop	1st Crop	2nd Crop	1st Crop	2nd Crop	1st Crop	2nd Crop
Bef. 30 days	0.04429	-0.04236	0.09723	0.11869*	0.23654**	-0.02924	-0.06221	0.07716
Bef.25 days	0.07661	0.02105	0.01719	0.08703	0.04336	-0.05942	-0.00463	0.07405
Bef.20 days	0.08565	-0.04662	0.02540	0.06124	0.02765	-0.07017	-0.02759	0.06692
Bef.15 days	0.06107	-0.00906	0.02250	0.07839	0.08105	-0.07715	-0.01424	0.08946
Bef.10 days	0.03669	-0.01803	0.02840	0.08438	0.12106*	-0.07652	-0.03468	0.04999
Bef.5 days	0.03928	-0.03656	0.02083	-0.01958	0.03951	-0.06949	0.02222	0.00726
Bef.0 days	0.07581	-0.03178	-0.03049	0.04643	-0.02573	0.04383	0.05481	0.03677

** 1% of Significance * 5% of Significance

Table 8. Correlative Coefficient of Climatic Factors and Light Trsp's BPH in Different Seasons in Taichung

Time	Average temperature		Relative humidity		Precipitation		Duration of sunshine	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop	1st crop	2ad crop
Bef. 30 days	0.14488	-0.02441	-0.05619	-0.0118	0.11477	-0.05659	-0.04869	0.02509
Bef. 25 days	0.04369	-0.12088	-0.11282	-0.01741	0.03717	-0.06214	0.08887	0.00757
Bef. 20 days	0.14451	-0.11758	-0.03555	-0.01029	0.12030	-0.08455	0.01517	-0.00408
Bef. 15 days	0.15523*	-0.10785	-0.00512	-0.02799	0.19179*	-0.07455	-0.02221	0.04923
Bef. 10 days	0.1513*	0.10867	-0.03785	-0.01857	0.07765	-0.07595	-0.06485	0.016164
Bef. 5 days	0.18132*	0.0648	0.00454	0.05441	-0.01874	-0.05651	0.04247	-0.11256
Bef. 0 days	0.16422*	0.00808	0.00709	0.03069	-0.02164	-0.03235	0.11469	-0.02999

** 1% of Significance * 5% of Significance

Table 9. Correlative Coefficient of Climatic Factors and Light Trap's BPH in Different Seasons in Hsinchu

Time	Average temperature		Relative humidity		Precipitation		Duration of sunshine	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Bef. 30 days	0.23235**	-0.17775**	-0.08169*	0.03747	-0.0063	-0.08322*	-0.09023*	-0.07023
Bef. 25 days	0.04264	-0.15351**	-0.12589**	0.04665	-0.02767	-0.09513**	-0.04702	-0.04902
Bef. 20 days	0.28115**	-0.1395**	-0.20701**	0.03912	-0.02988	-0.08924*	-0.02594	-0.06022
Bef. 15 days	0.28903**	-0.09376*	-0.20791**	0.03659	-0.03811	-0.04999	-0.0238	-0.08482*
Bef. 10 days	0.27119**	-0.08118	-0.15989**	0.0368	-0.09798**	-0.04798	-0.02243	-0.11976**
Bef. 5 days	0.24852**	-0.09519**	-0.19853**	0.07394	-0.08266*	-0.04851	-0.02986	-0.13305**
Bef. 0 days	0.26347**	-0.00912	-0.21105**	0.12855**	-0.10955**	-0.03621	-0.03222	-0.12912**

** 1% of Significance * 5% of Significance

Table 10. Correlative Coefficient of Climatic Factors and Light Trap's BPH in Different Seasons in I-lan

Time	Average temperature		Relative humidity		Precipitation		Duration of sunshine	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Bef. 30 days	0.05569	-0.30797**	0.05707	0.03076	0.15194**	0.27677**	0.0605	-0.19171**
Bef. 25 days	0.09322	-0.28816**	0.10784	0.06717	0.11415	0.27525**	0.1636**	-0.19869**
Bef. 20 days	0.10646	-0.32978**	0.08388	0.08232	0.03652	0.14884**	0.15578**	-0.10433
Bef. 15 days	0.09774	-0.26034**	0.00349	0.02037	0.00506	0.05143	0.18932**	-0.06788
Bef. 10 days	0.13859**	-0.22727**	-0.04308	-0.10237	0.06345	-0.01346	0.22903**	-0.02002
Bef. 5 days	0.14741**	-0.13755*	-0.06937	0.00768	0.0147	-0.01794	0.24951**	-0.05467
Bef. 0 days	0.19688**	-0.06397	-0.07324	0.02277	-0.0562	-0.04571	0.22864**	-0.02019

** 1% of Significance * 5% of Significance

ern districts (Table 5-8), these 4 climatic factors had no significant correlation with the amount of occurring brown planthopper under light trap, and also in various crops their influence didn't increase or decrease as the time went. The possible reasons are because the cultural system was changed, or pesticides were used in large quantity, or other environmental factors were changed so as to interfere the activities of pests, and even affect the accuracy of light trap's brown panthopper and information of what light trap's brown planthopper could provide.

d. Relationship between the Occurrence of Light Trap's Brown Planthopper and the Percent of the Infested Area of the Total Paddy Fields

Although there was significant and positive correlation (Table 2) between the amount accumulated in 5 days of light trap's brown planthopper and the density in the field obtained with sweeping net once in 5 days, and this result is the same as that of Hirao (1972) and Cheng (1983), the occurrence of light trap's brown planthopper had no significant correlation (Fig. 3) with the percentage of infested paddy field. When brown planthoppers in the field outbroke tremendously, and the percentage of infested paddy field was over 23%, but the accumulated pests of light trap did not change in positive ratio. According to the result of analysis, although the data of light trap could reflect the density of the pests in the field, there were lag phenomena at various localities, and so the data of light trap could only provide intelligence afterward (Lin 1979, Kuno 1968).

Discussion

Light trap is to trap brown planthoppers by utilizing their nature of flying toward light (Tao 1963, Ho, et al. 1969), then infer the occurrence of brown planthopper in the field, and decide the suitable timing to control. The brown planthopper's adults can be divided into two types of wing-forms macropterous form and brachypterous form, and the ratio of occurring these two types in the field is affected by such factors as the population density, daylength and nutrition of host of paddy rice, etc. (Miyake, 1959; Suenaga, 1963; Kishimoto, 1965; Kuno, 1968; Chu, 1982). Generally, the movement of brachypterous form is small, and macropterous form is the main object of light trap to collect. When flying, macropterous form is affected by light intensity, temperature and wind velocity (Ohkubo and Kishimoto, 1971). These factors not only can affect the pests' reaction on light, but also can increase or inhibit the activities of insect pests, metabolism of nymphs and propagation of adults (Kishimoto, 1965). Kuno (1968) reported that the highest density of brown planthoppers in the field is related with the amount of pests first invading the field and the propagative ratio of the 1st generation; among them 50% is decided by the density invading at the initial stage, and another 50% decided in the propagative ratio of the 1st generation. In addition, Kishimoto (1965) observed those brown planthoppers that invade the field over winter are macropterous form, brachypterous form propagates, and then macropterous form scatters. However, this pests in Taiwan is not over winter apparently (Cheng, 1977; Chu and Yang, 1980). After the 2nd crop harvested, the pests moves to the grass on the foot-path for resting with low density. After the 1st paddy rice transplanted next year, they move to paddy field to infest with low density at the first stage because of scattering population. After propagating for 2-3 generations, their density gradually increase; after paddy rice has grown the heading period, the density greatly increases, and now there appears the first peak under light trap. However, after the 1st crop of paddy rice harvested with destroying living environment, their density decreases suddenly; adults and nymphas move to weeds on foot-path or reborn rice. After the 2nd crop of paddy rice is transplanted, they again move to the field to infest, and the density increases through 1-2 generations; before or after heading period of the 2nd crop of paddy rice, the 2nd peak appears, and the density declines again after paddy rice harvested. The data of light trap's brown planthoppers are the same as mentioned above. Therefore, the occurrence of brown planthoppers under light trap had significant correlation (Table 2) with the seasonal occurrence in the field. This result is the same as Hirao's (1972), but had no significant correlation with the percentage of the infested area. As the multiple correlation of the density of brown planthoppers in the field with the amount of

pests invading at the first stage and the propagating ratio of the 1st generation was as high as 0.7-0.8 (Kuno, 1968), the data of light trap can only provide 50% of information. Furthermore, this pest occurs many generations each year, there is very high correlation (Table 3) between observation values, and it's difficult to forecast the population fluctuation by using factor analysis or multiple regression analysis (Lin, 1979).

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