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CHEMICAL CONTROL OF THE BROWN PLANTHOPPER WITH SPECIAL REFERRENCE TO ITS POPULATION DYNAMICS

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ABSTRACT

The brown planthopper lay its eggs in the tissues of leafsheath and adults and nymphs feed on base-part of rice plant where the insecticides are difficult to conduct with due to dense canopy of rice plants. In addition, the residual effects of most insecticides used for controlling the hopper are not long enough to cover the egg stage of the hopper. Therefore, the population of the hopper is essy to recover from control because of newly hatch of the eggs. Natural poperties of insecticides, application techniques and time of application are greatly affect the effectiveness of control. In general, granular insecticides have longer effectiveness to control the population of the hopper than others. Placement of granules to rootzone area of rice plants provide a longer lasting control than that with conventional broadcasting method. Application of granules on moist soil with no surface water have more rapid and lasting control that apply into paddy water. In case of foliar application, spraying insecticides on the plant bases increase the effeciency by 10 to 30% as compared with those spray on the canopy. Insecticide in dust formulation generally offer a better protection of the crop from hopper's damage than that of liquid spray with especially in late stage of the crop. However, both liquid and dust application give only a short residual effectiveness, repeated application are usually necessary to depress the population of the hopper sufficiently. Application of insecticide at the maximum nymphal density when population of the hopper reach an economic threshold, 5 to 10 hopper per hill, obtained the highest net profit of control. Integrated use of resistant varieties and insecticide provide not only a more effective and more economic way for the hopper control but also provide a more favorable conditions for the pest's natural enmies to survive in paddy field.

The brown planthopper *Nilaparvata lugens* has been reported as an important insect pests of rice in Japan over a long period. (Suenaga and Nakatsuka, 1958), However, it have only been considerated as a pest of economic significance in Taiwan since 1961 and in most tropic Asian and Pacific countries in past few years (Cheng, 1977; Dyck and Thomas, 1979). The insect feeds directly on growing plant, reducing yield potential. Severe infestation caused by the insect result a complete drying of the crop, a conditions is commonly known as hopperburn. In addition to direct damage, the brown planthopper is also a vector of the grassy stunt, ragged stunt and wilted stunt virus diseases in subtrpic and tropics which make its status as a pest even more serious (Ling, 1977; IRRI, 1977; Chen, et. al., 1978; Chen, et. al., 1979). Epidemic of grassy stunt have followed the brown planthopper outbreaks in India, Indonesia and the Philippines

(Ling, 1977).

The potential of the brown planthopper to be one of the most serious insect pests attacking rice plants was reported depending on its high reproductivity, high tolerance to crowing, high migratory ability of the adult insect and its high adaptability to various type of rice plant (Kisimoto, 1977). Because of such characters that enable the insect to expand its population steaply. Moreovere, the brown planthopper lay its eggs inside the tissues of leafsheath and the adults and nymphs feed on lower part of rice plant where the insecticides are difficult to contact with due to dense canopy. In addition, the residual effects of most insecticides used for controlling the brown planthopper are not long enough to cover the egg stage of the insect. So that the population of the insect is easy to recover from control due to newly hatch of the eggs. This phenomenon is evident particularly as generations of the insect overlap with each other during the later part of the crop season. Therefore, repeated applications of insecticide usually are necessary.

Present paper discusses some factors which may affect the effectiveness of chemical control of the brown planthopper in paddy field with special referrence to the population dynamics of the pest after chemical application.

INSECTICIDAL ACTIVITIES OF CHEMICALS

There are many insecticides having been tested for control of the brown planthopper both in laboratory and field conditions. In Taiwan, more than 50 insecticides in various formulations have been registrated with the government for controlling the brown planthopper. Among them, about 70% is cabamates, 20% is organophosphates and others are the mixture of cabamate and organophosphous insecticides. The toxicity of various insecticides on the brown planthopper have been estimated by several workers and reviewed recently by Moriya (1977) and Heinrichs (1979). In general, carbamates are more toxic to the brown planthopper than organophosphates and chlorinated hydrocarbon insecticides (Fukuda and Nagata, 1969; Tang and Hsu, 1969; Choi and Lee, 1976; Ku, et. al., 1976). However, it should be recognized that insecticidal activity of chemicals sometimes varied with the method of evaluation due to the differences in natural properties of the chemicals. Many insecticides are effective when applied as foliar spray, but only some are effective as they are applied to paddy water, soil surface or the rootzone (Heinrichs, 1979). On the other hand, besides contact toxicities and systemic action, the fumigation effect also cause the motality of the insect. Koyama and Tsurumachi (1968) reported that the main effect of granular applications in paddy fields was not only due to the effect of the penetration of the chemicals into the plant, but also to the lethal action of the vaporized chemicals. In a foliar spray study, Heinrichs et. al. (1978) indicated that all of tested insecticides had a distinct fumigation effect on the brown planthopper with Carbofuran and Perthane being the most effect. These facts show the importance of using proper technique in evaluation of insecticidal activities of chemicals. Nevertheless, it is well understood that the effectiveness of chemical control conducted in laboratory or tested with potted plants are usually better than those conducted in fields. Therefore, from the view of practical uses, recommendation of chemical for pest control should be based primarily on the results of field tests. At present, at least more than 31 different insecticides are recommended throughout Asia. Among them, BPMC, Carbaryl, Carbofuran, MIPC, and Diazinon are the most widely recommended (Heinrichs, 1979).

Since the brown planthopper lay eggs inside the tissues of leafsheath, an ideal insecticide must not only have a fast knochdown effect to adults and nymphs of the insect but should also have ovicidal effect or possess a sufficiently long residual activity to last through all the stage of egg development. Although some chemicals, eg. Propoxur, MIPC, BPMC, Diazinon, Carbofuran, Metalkamate as granular application (Cheng, 1979; Valencia and Heinrichs, 1978; Moriya, 1977; Toyoda, 1968) and Carbofuran, Triazophos, Methyl Parathion, Propoxur, Metalkamate, Hokbal and BPMC as foliar spray were reported to have ovicidal effect against the brown planthopper (Cheng, 1979; Preedasuvan and Pura, 1973; Valencia and Heinrichs et. al., 1977; Heinrichs, 1978). However, such results are basing on potted-plant experiments, the effectiveness of such ovicides in the field has not been determined.

Most insecticides used for the brown planthopper control have fast knockdown effect, but have short residual activity. Table 1 shows the residual effectivenes of some Taiwan registrated insecticides applied as floiar spray and as paddy-water application from a potted-plant experiment. Both foliar spay and paddy-water application caused high mortality of the brown planthopper at 1 day after treatment. However, in case of foliar spray, all tested insceticides had poor effect for the insect control at 7 days after treatment. Paddy water application provided a longer effectivenes but their residual activity were yet less than 14 days. Similar result were also reported by Heinrichs (1979), Nogata (1978), Toyota and Kythuson (1967), Israel, et. al. (1968) and Lim (1971).

Persistance of insecticide as applied in paddy field vary greatly depending on application techniques, environment conditions and stage of the insect which chemicals are applied for control. For instance, chemical application in avoidance of egg-laying period would obtain a longer control effect. However, it does not a real persistant period of a insecticide but just show a period for insect population to recover under a condition being tested. Nagata (1968, 1978) has developed a method to estimate the residual effective of insecticide by using sticky board method, which was consisted of holding a 18 x 25cm celluloid board coated with water repellent adhesive horizontally at the lower part of rice hill, lightly patting rice stem with hand so as to stick the planthopper on the board and then counting the number of the insects collected on the board. By using this method the structure of the planthopper population after insecticidal treatment can be analyzied. One of such study show as Fig 1. In general, the number of young nymph of the brown planthopper in the population are the bigest to be afftected after treatment, and followed by middle-aged nymphs, old nymphs and adults are the least. The residual effect period of an insecticide can be estimated from the number recovery of the young nymphs. Based on this techniques, Nagata (1978) estimated the residual effect of MIPC G. 4% at rate of 4kg/10a lasted for 7 days and 8kg/10a for 13 days while Diazinon G.3% lasted less than 4 days despite of the dosage used at rate of 4kg/10a. or 8kg/10a.

Table 1. Knockdown and residual effects of chemicals registered in Taiwan for the brown planthopper control. a/

Methods of appl. / Chemicals	Mortality b/					
	Foliar Spray			Granular Application		
	1 DAT	7 DAT	14 DAT	1 DAT	7 DAT	14 DAT
Cabamate						
MIPC	100	21	4	95	74	22
Hokbal	100	38	9	–	–	–
Carbofuran	100	68	20	100	92	54
Propoxur	100	39	5	100	82	39
Matalkamate	85	26	12	100	76	29
BPMC	92	18	9	–	–	–
MTMC	76	9	4	–	–	–
MPMC	73	15	8	–	–	–
FMC 27289	93	48	15	–	–	–
Fican	84	22	9	–	–	–
Carbaryl	85	34	22	–	–	–
Organophosphate						
Acephate	100	25	5	–	–	–
Acephate-met	95	21	2	–	–	–
Geophos	–	–	–	94	62	14
Organophosphate mixt with cabamate						
Furathion	100	44	13	–	–	–
Furamidan	100	38	9	–	–	–
Trimip	97	23	9	–	–	–
Kayaphosbassa	100	24	10	–	–	–
Tribassa	98	18	7	–	–	–
Imibassa	100	23	11	–	–	–
Padanbassa	96	32	6	–	–	–
Phosmac	100	16	2	–	–	–
Dyfobassa	97	21	3	–	–	–
Ofunak-M	98	19	4	–	–	—

a/. Chemicals were applied at 0.05% as foliar spray and 1.5 kg ai/ha as granular application. Experiment was conducted at wire house conditions with potted plants.

b/. 2nd to 3rd instar nymphs were used for testing, mortality based on 48 hrs after infestation.

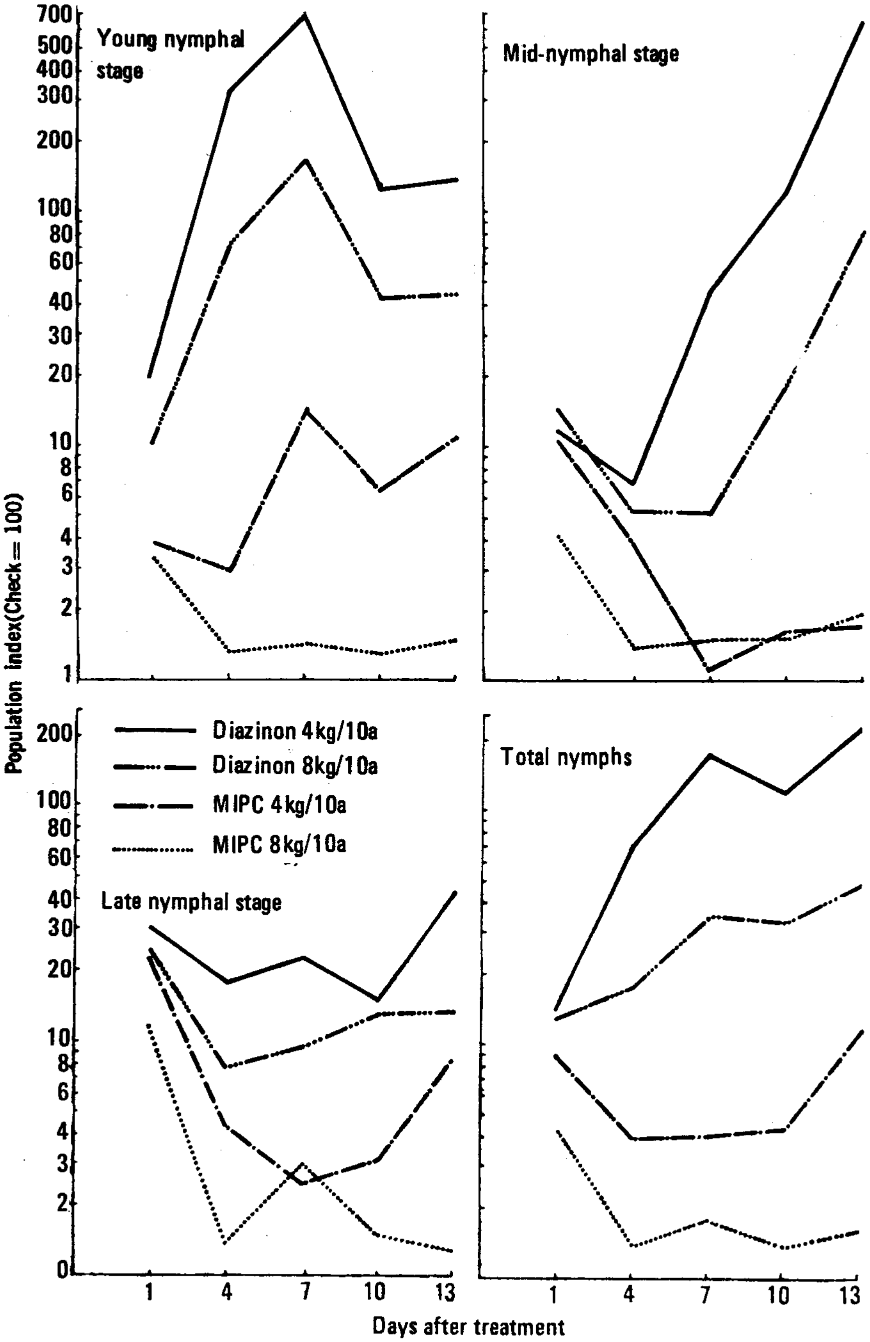

Fig. 1 Changes of nymphal stage-structure of the brown planthopper after insecticidal application (Nagata, 1977)

APPLICATION METHODS

Several application methods have been developed and used commonly for the brown planthopper control. Foliar spray with liquit insecticides have been most commonly used in Taiwan as well as in tropics, while dusts most commonly used in Japan. The reason for these two application methods being adoped widely by the farmers probably are because of the commercial availability and lower cost of the formulations. Broadcast of granules into paddy water or on soil surface and placement of insecticide into rootzone of rice plants are either easy for application or provide a wide-spectrum activity and longer period of pests control. They have gradually gained interest to the farmers with especially in the tropics in recent years.

Foliar spray usually has fast knock down action but provided only a short period of brown planthopper control. In general, population density of the brown planthopper reduced remarkably 3 days after treatment but recovered greatly from the treatment 7–10 days after application during the period of outbreak. In such conditions, two consecutive sprays with 7–10 days interval were required to control a generation population under the levels of economic damage, 5–10 insect per hill (Table 2) (Cheng and Liu, 1978).

Inadequate of planthopper control with foliar spray is mainly due to insufficient amount of chemical to deposit on the basal part of plant where the insect feed due to dense conopy and short residual activity of insecticide. Therefore, spray should be directed toward the plant base with either by using a high pressure spray aplicator or multihand sprayer with drop nozzles. (Heinrichs, 1979 and Liu, 1979), Liu (1979) reported that control by Monocrotophos increased by 39%, and that by Hokbal and Carbofuran by 11 and 7%, respectively when the insecticides were applied to the plant bases instead on the canopy (Table 3). The result is generally agreed with Heong (1975) and Heinrichs, et. al. (1979). However, Heinrichs, et. al. (1979) indicated that such differences between the sits of spray were not distinct by using Monocrotophos due to its systemic action. On other hand, proper mixtuxe of chemical can increase the toxicity and residual effect of insecticide to a certain extend against pests. Ku, et. al. (1977) evaluated the paired insecticide mixtures and indicated that the mixtures of MIPC+Propoxur, Acephate+ Propoxur, Hokbal + MIPC, Hokbal + Acephate, Carbofuran + MIPC, and MIPC + Acephate have synergistic effects on brown planthopper (Fig. 2). Some of these mixtures were tested by Yen, et. al. (1979) and Lin, et. al. (1980) in paddy field and indicated that the paired insecticide mixture provided better control of the brown planthopper and obtained a higher grain yield and return profit than that treated with single insecticide (Table 3). For instance, control with Acephate or MIPC singly have litter effects than that treated with Carbofuran, but the effect of mixture of Acephate and MIPC is comparable with carbofuran. Similar experience was also observed by Cheng (1980 unpublished data) with mixture of MIPC + Carbaryl which have significantly better effect on the brown planthopper than that treated singly.

Spray volumes seem not a major factor to affect the effectiveness of the brown

Table 2. The effect of various insecticides applied as foliar sprays on the population of the brown planthopper. 2nd crop, 1977 (Cheng and Liu, 1978)

Treatments	No. BPH/hill					
	Before appl.	1st appl. (72 DAT) a/		2nd appl. (82 DAT)	3rd appl. (87 DAT)	
		3DAA a/	10 DAA	3 DAA	3 DAA	10 DAA
50% Propoxur WP 0.6 kg ai/ha	42.5	3.4	56.7	5.4	1.4	45.3
75% Acephate SP 0.6 kg ai/ha	36.2	11.0	116.5	71.7	7.9	29.2
50% MIPC WP 0.3 kg ai/ha	39.6	4.0	161.2	16.5	5.4	24.2
40% BPMC WP 0.6 kg ai/ha	43.1	6.1	209.5	16.8	3.7	132.7
85% Carbaryl WP 0.6 kg ai/ha	41.2	28.9	205.7	185.3	49.7	192.6
50% CPMC WP 0.3 kg ai/ha	38.6	24.9	386.9	222.9	94.4	284.3*
CK	37.4	58.4	205.7	386.3	170.0	306.7*
25% Metalkamate EC 0.3 kg ai/ha	38.4	6.1	193.6	40.3	5.0	7.2
40% Hokbal EC 0.6 kg ai/ha	35.7	1.2	137.5	4.2	0.7	0.9
20% MIPC EC 0.3 kg ai/ha	40.1	1.9	207.1	13.5	1.2	3.5
55% Monocrotophos S. 0.33kg ai/ha	41.2	5.0	221.4	94.8	19.4	9.0
CK	36.4	37.1	390.3	347.9	134.7	60.8*

a/ DAT: Days after transplanting, DAA: Days after application.

*: Hopperburned.

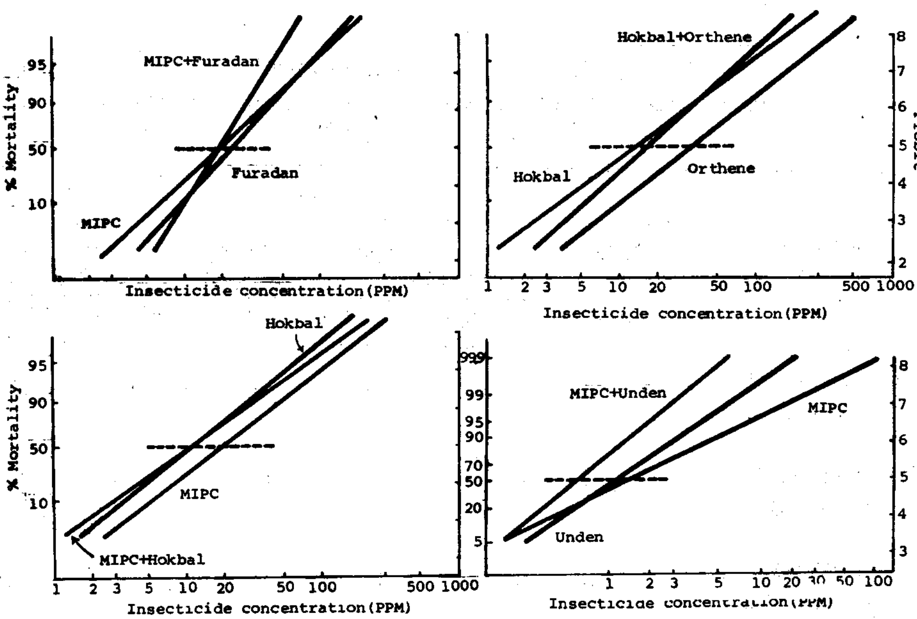

Fig. 2. Toxicity response of brown planthopper to various combinations of some commonly used insecticides (ku, et. al., 1977).

planthopper control. Heinrichs, et. al. (1977) reported that field studies with Perthane from 190 to 950 liters of spray solution obtained equally control of the brown planthopper. Liu (1979) revealed that the effectiveness of Hokbal and Carbofuran applied as canopy spray at rate of 1.2kg ai/ha. with 500 liters of spray solution were comparable to those sprayed toward the plant bases at rate of 0.6kg ai/ha, with 1000 liters of spray solution (Table 2).

Similar to wettable powdered and emulsified insecticides, dusts have rapid action on the brown planthopper, but have better insecticidal distribution to the plant bases than that of foliar spray with liquid insecticides. Due to this characterestics, control of the brown planthopper with dust decreased rapidly the population of the insect to a very low density few hours after treatment. Therefore, this formulation is very suitable to be used while the population of the insect is high (Toyoda and Yoshimura, 1967). The residual activities of dust formulated insecticides are also short, population of insect recovered from treatment 7–10 days after application (Table 5).

In Japan, Dust fromulated insecticides are generally applied with pipe duster which can be used to treat an extensive areas rapidly with easy handle. However, during the middle or later stage of plant growth, chemicals application with pipe duster fail to deposite an adequate amount of insecticide to the plant bases, (Toyoda and Yoshimura, 1967). In Taiwan, powered duster or hand-operated duster are widely used to apply dust. The insecticide can be deposited to the plant bases by placing the blowing-tuble of the duster into basal part of the plants. In term of work effecency, dusts application is 4–5 times faster than that of liquid foliar applications (Liu, 1979).

Table 3. Effect of certain insecticide mixture on the brown planthopper control
(Yen, et. al., 1979)

Chemicals	No. BPH/hill						
	1 day before appl. (59 DAT)	1st appl. (60 DAT)		2nd appl. (68 DAT)		3rd appl. (82 DAT)	
		63 DAT	68 DAT	71 DAT	78 DAT	85 DAT	92 DAT
MIPC WP+Carbofuran FW	14.4	3.7	10.0	5.4	7.5	3.6	6.0
MIPC WP+Hokbal EC	14.8	4.4	13.1	6.2	8.7	4.3	6.6
Acephate S. + Hokbal EC	18.0	4.3	10.5	5.1	7.7	3.6	6.8
Carbofuran FW	19.4	7.8	9.5	6.5	7.9	3.6	6.4
Hokbal EC	15.8	9.0	16.0	8.0	18.9	11.2	14.1
MIPC WP	18.9	11.7	221.3	11.8	18.3	19.2	36.7
Acephate S.	14.6	14.0	23.8	21.9	29.9	33.5	50.9
Undreated	14.7	62.2	88.6	293.3	389.3	637.8	660.4

* DAT: Days after transplanting.

Table 4. The effect of various insecticidal application methods with a hand operated knapsack on controlling the brown planthopper (Liu, 1979)

Sit of applica-tion	Dosage	Volume (1/ha)	Azodrin		Hokbal		Furadan		Application time hrs/ha
			insect /hill	% b/ Control	insect /hill	% control	insect /hill	% control	
Above Canopy	Recom. D. a/	1000	32.8	49.8 b	45.2	59.9 b	6.9	88.3 b	6–12
Between Stems	Recom D.	1000	4.2	89.1 a	31.7	71.1 a	2.7	95.1 a	12
Above Canopy	Double D.	500	–	–	33.5	70.4 a	4.5	90.7 ab	6
CK	–	–	86.4	0	117.4	0	56.4	0	–

a/ Dosage recommended for BPH contrl are 0.6 kg ai/ha for Hokbal and Furadan and 0.33 kg ai/ha for Azodrin
b/ Investigation at 3 day after treatment.

Granular application have many advantages over foliar sprays and dusts. It is less laborious and rapid than foliar sprays and requires no equipment. Moreover, granules penetrate the dense canopy and reach the area where the brown planthopper feed.

Granules ususlly provide a longer control effect on the brown planthopper due to its longer residual activity. An experiment conducted in a similar field conditions for foliar spray and dusts as indicated in Table 2, Carbofuran and Propoxur controlled the brown planthopper for more than 20 days. Two applications of these chemicals were adequate to deppress the population of the insect lower than the levels of economic damage throughout a crop season (Table 6). However, control with Disyston and Diazinon were poor probably due to their short residual activity. Nagata (1978) indicated that the residual activity of Diazinon was shorter than 4 days even the dosage was increased to be at rate of 2.4kg ai/ha.

The effectiveness of gronules applied to paddy field is affected greatly by environment conditions. Toyoda (1970) indicated that when MIPC, BPMC and Diazinon applied to half-dried of wet soil without standing water, the control effect appeared more rapidly than that obtained from ordinary granular applications into paddy water (Fig 3). It was belived that this result was due to the effect of vaporization of the active ingredients

Table 5. The effect of dust applications on brown planthopper population (Cheng and Liu, 1978)

Chemical	Before appl.	No. BPH/hill: 1st appl. (72 DAT)a/ 3 DAA	10DAA	2nd appl. (82 DAT) 3 DAA	10 DAA	3rd appl. (87 DAT) 3 DAA	10 DAA
Propoxur 1 D. 0.8 kg ai/ha	28.4	1.9	29.8	4.8	–	0.6	145.0
Carbaryl 1.5 D. 0.75 kg ai/ha	20.1	7.2	189.1	56.3	–	4.1	275.0
Control	23.2	18.3	221.6	265.2	-	99.9	1148*
Ofunack-M 3.5D. 1.4 kg ai/ha	58.4	6.2	12.3	1.7	9.0	3.3	21.4
Propoxur 1 D. 0.8 kg ai/ha	63.2	5.1	6.8	1.3	6.4	4.9	15.3
Control	59.6	1.9	164.0	102.1	165.5	555.2	457.8*

a/ DAT: Days after transplanting, DAA: Days after application.
* Hopperburned

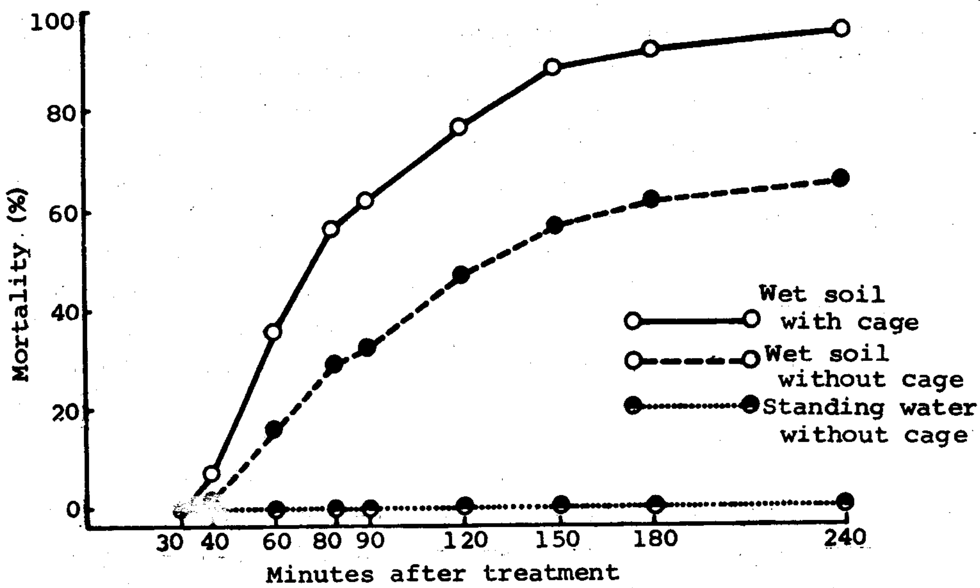

Fig 3. Effect of application of MIPC G in potted rice plants with or without standing water on control of the brown planthopper (Toyoda, 1970)

Table 6. Paddy-water application of granular insecticides at the rate of 1.8 kg ai/ha for brown planthopper control (Cheng and Liu, 1978)

Chemicals		No. BPH/hill				
		Before appl.	1st appl. 67 DAT a/		2nd appl. 86 DAT	
			7 DAA a/	20 DAA	7 DAA	20 DAA
3%	Carbofuran G.	31.2	1.4	3.3	3.8	0.7
5%	Propoxur G.	29.6	1.7	4.4	4.5	1.2
5%	Disyston G.	33.4	6.1	240.2	58.5	21.9
10%	Diazinon G.	30.7	19.6	399.4	138.9	64.2
	CK	29.3	45.7	467.4	150.0	205.4*

a/ DAT: Days after transplanting, DAA: Days after application.

* Hopperburned

in the granules. Similar results were also reported by Cheng (1974) as shown in Table 7, the population of the brown planthopper treated with Carbofuran, Propoxur and Dysiston decreased greater but recovered slower in the plots without standing water than those obtained from the plots with 5cm standing water.

Table 7. Differences between the effectiveness of granules as applied into paddy water and on wet soil surface for control of the brown planthopper (Cheng, 1974)

Treatments	Water levels	No.BPH/hill				
		Before treatment	3 DAT	10 DAT	20 DAT	30 DAT
Carbofuran 3G 1 kg ai/ha	5cm standing water	103.1	14.4	3.6	18.5	218.1
	wet soil	104.6	11.1	3.3	13.1	154.2
Propoxur 5G 1.8 kg ai/ha	5cm standing water	146.4	34.3	37.2	229.0	871.0
	wet soil	133.5	6.9	14.0	48.1	188.7
Disyston 5G 1.8 kg ai/ha	5cm standing wter	194.5	195.0	68.9	826.9	*
	wet soil	137.8	29.4	57.5	1388.9	*
Control	5cm standing water	192.2	188.2	200.5	1498.6	*
	wet soil	126.9	135.7	199.9	1119.0	*

DAT : Days after treatment.
* : Hopperburned

In a rice paddy model ecosystem studies, Wong and Lee (1979) found that in the plots without surface water for 10 days after chemical application, the residue of Carbofuran either in rice plant or paddy soil at 43 days after treatment were much higher than that chemical detected at 18 days after application in the plots with standing water. In additions, IRRI (1979) reported that Carbofuran was degraded much more slowly when applied to flooded soil than when applied to paddy water. Appearently, maintenance of stanting water is not necessary when granules are applied for controlling brown planthopper. Furthermore, persistance of granules are also affect by the PH value of paddy water and microbes. It was reported that Carbofuran degradation rate related directly to initial paddy water or soil PH : the higher the PH, the greater the insecticide loss (IRRI, 1978; Getzin, 1973). Repeated application of Diazinon and Carbofuran in paddy field induced rapid hydrolysis of the insecticides due to direct or indirect microbial degradation (Sethunathan and Pathak, 1972; IRRI, 1978).

Placement of insecticide, in rootzone of rice plant within few days after transplanting were effective for controlling the brown planthopper and several other rice insect pests for more than 40 days (IRRI, 1972; 1973; 1976; 1977; Heinrichs, 1979; Choi, et. al., 1975; and Halteran Sama, 1976). In some cases, one application of insecticide in the rootzone has provided insect control and yields equal to or superior to 4 broadcast or foliar applications in a crop season (Heinrichs, et. al., 1978) (Table 8). Since the insecticide is applied shortly after transplanting, this application technique is very practical in the areas where pest problems are severe early in the crop season. However, insect pest such as brown planthopper is usually severe after flowering stage of plant growth, control with this method seems not much advantage as compare with granules broadcasting at proper time, about 60 days after transplanting (Table 9). Except Carbofuran, the following insecticides, FMC 27289, BPMC; Bendiocaxb, FMC 35001 and Miral were also effective for controlling the brown planthopper when applied into the rootzone (Heinrichs, et. al., 1978; Choi, 1976).

Soil incorporation and seedling boxes treatment may be considered as a modified type of insecticidal rootzone application. These application methods are much easier than those applied with a liquid band applicator or inserted the encapsuled or mudballed insecticide into each hill by hands. Although these two techniques are not quite as effective as placing the insecticide in each hill, but it would much easier to be accepted by farmers. Heinrichs (1979) reported that the population of the brown planthopper in paddy field incorportated with insecticide before transplanting generally builded up slowly in a crop and reached their peak near harvest time in locations where the brown planthopper infestation began early in the crop season and migration from adjacent fields did not occur.

PROPER TIMING FOR INSECTICIDE APPLICATION

Proper timing of insecticide application for the brown planthopper control at least may discuss from three aspects, depending on the basis of consideration : (1). biology of

Table 8. Rice pest control as influenced by method, rate, and frequency of insecticide application. Variety IR22. IRRI, 1977 dry season. (Heinrichs, et. al., 1978)

Treatment[1/]	Rate (kg ai/ha)	Whorl maggot damage[2/] 29 DT	Dead hearts (%) 60 DT	Virus (%) 60 DT	Brown planthopper 10 linear meters 61 DT	Brown planthopper 10 linear meters 78 DT	Hopperburn (%) 92 DT	Grain[3/] yield (t/ha)
Carbofuran (SI) 1x	1.0	1	1.5bc	0.2a	135a	1584a	14ab	3.7a
Carbofuran (SI) 1x	2.0	0	0.6a	0.0a	144a	2329a	16ab	3.6a
Carbofuran (Rz) 1x	1.0	3	2.0c	0.2a	189a	3461a	00a	3.2a
Carbofuran (Rz) 1x	2.0	2	0.7ab	0.6ab	245a	2802a	12ab	3.5a
Carbofuran (B) 6x	1.0	4	1.0ab	0.9ab	293a	5098ab	13ab	3.5a
Carbofuran (B) 4x	1.0	5	0.8ab	1.1ab	261a	1744ab	4a	3.3a
Carbofuran (B) 4x	2.0	4	0.5a	0.8ab	181a	3500a	25ab	3.5a
Carbofuran (F) 4x	0.5	7	1.2abc	1.4ab	121b	29965c	97	1.9bc
Control	–	9	4.9d	12.5c	264a	4812ab	8ab	1.6c

a/ SI – Soul Incorporation; Rz – Root zone applictiaon with liquid and applicator; B – Broadcasting every 20 days;
F – Foliar spraying every 20 days.

2/ Based on a scale of 0–9 : 0 – no damage; 9–50% of leaves damaged.

3/ In a colun, means followed by a common letter are not significantly different at 5% level (DMRT).

Table 9. Effect of rootzone applications on control of the brown planthopper (Cheng, et. al., 1977)

Treatments	Rate (kg ai/ha)	Brown planthopper/hill 50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	Grain Yield kg/ha
				Taichung area			
Rootzone (Carbofuran 4F) x 1 + Spray (MIPC) at 95 DAT	(1.5 x 1) + (0.3 x 1)	0.8	2.1	2.3	20.5	56.7	5,431
Carbofuran 3G (B) x 1 at 61 DAT	1.5x1	1.5	11.7	3.0	14.5	24.1	4,083
Carbofruan 3G (B) x 3 every 20 days	1.5x4	0	0.2	0.1	1.9	5.0	5,277
Control	–	1.6	11.8	19.3	121.4	174.8	3,097
				Chiayi area			
Rootzone (Carbofuran 4F) x 1 + Spray (Carbofuran) at 74 DAT	(1.5 x 1) + (0.6x1)	3.6	7.3	42.4	14.1	5.0	4,917
Carbofuran 3G (B) x 1 at 54 DAT	1.5 x 1	7.6	1.0	1.1	9.5	1.8	5,140
Carbofuran 3G (B) x 3 every 20 days	1.5 x 3	0.4	0.1	0.5	4.2	0.3	5,505
Control	–	7.0	44.8	108.2	308.3	155a/	2,399

a/ Hopperburned.

the insect, (2). the stages of rice plant and (3). population levels of the insect.

In Japan and Korea, where the brown planthopper immigrates annually, early generation have little overlap and control is rather easy. Uebayashi and Osaki (1968) studies the susceptibility to several insecticides of the brown planthopper at various stages; they ranked the adult male to be more susceptible than the adult famale, which was more susceptible than nymphs of the 4th or 5th instars. The young nymphs are probably the most sensitive to insecticide while eggs are the most tolerance due to they are laid inside the tissure of leafsheath and most insecticide do not have ovicidal activities. In such conditions, spray program aiming at maximum nymphal period but in avoidance of egg-laying period would get better control of the brown planthopper.

Based on the population grown in the field, Hirao (1972) reported that the suitable timing of insecticide application was considerated to be at the nymphal stage of third generation (2nd generation nymph of immigrants). In additions, Kisimoto (1977, 1975) revealed that suitable timing of chemical application should base on the population of immigrants, when a mass immigration was detected (particularly when more than 150 *N. lugens* were trapped in a water trap), the application of insecticide should be timed for nymphs of the first generation before they emerged and laid eggs (about 20 to 25 days after the immigration); when 50 to 100 planthopper were caught in a water trap and the brachypterous females of 1st generation was more than 30 to 50 per 100 hills, then the insecticide should be applied to kill late-nymphs of 2nd generation. Studies in Korea indicated that proper timing for control of the brown planthopper was depending on dates of immigration, insecticide application was scheduled about 5 weeks after immigration (Lee and Park, 1977; Heinrichs, 1979). Control in later seasons are often little effective owing to overlapping generation and survival of eggs from insecticide. Such experience is clearly illustrated by the study of Nagata, et. al. (1973). They indicated that when the insecticide was applied to meet the begining of 3rd or 4th adult period, one application with MIPC fine granular was enough to depress the planthopper population density sufficiently through the crop season and a high yield was obtained (Fig 4). However, when control were taken during the peak or the end of adult period, population of the insect recovered early due to survived eggs and caused heavy infestation.

The brown planthopper is active through the year round in tropics because of continous and staggered plantings of rice plants, timing is much more difficult. However, studies at the International Rice Research Institute in Philippines (IRRI, 1973) indicated that only the application at maximum nymphal density in each generation provided good control, spray at other periods have poor effective because the insecticids did not remain effective long enough to kill the newly hatching nymphs (Fig 5). In studies on the relation between date of peak of light trap catches of the brown planthopper and date of peak of nymphal population within a field, Heinrich, et. al. (1978) revealed that peak catches in a kerosene light trap occurred about 10–12 days before peak nymphal population were observed in the field.

In Taiwan, the brown planthopper is active through the year round, but the population density is quite low during winter season due to low temperature and poor conditions

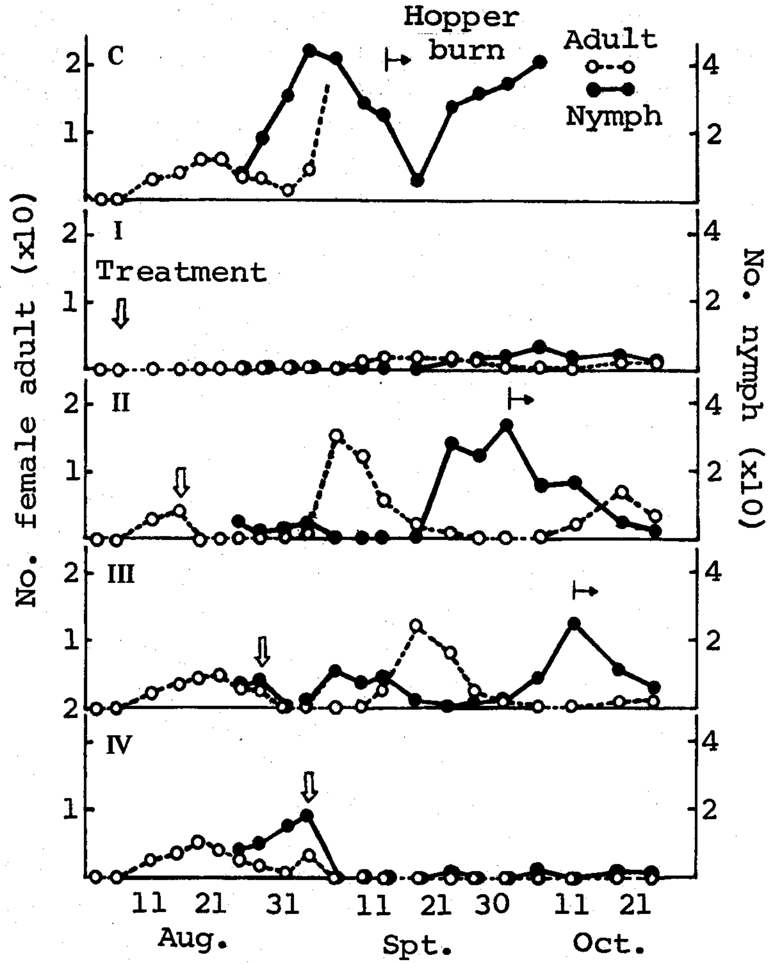

Fig. 4. Density of adult and nymph of N. lugens in relation to timing of insecticide application (MIPC FG, 4kg/10a) (Nagata, et al. 1973)

C: Untreatment,
I. The beginning of the 3rd adult period
II. The peak of the 3rd adult period
III. The end of the 3rd adult period
IV. The beginning of the 4th adult period

of host plant (rice ratoons). During first rice crop season (from January to June), the planthopper is low and control is usually not necessary in most rice cultivated areas. Some localities especially in southern part of this island, however, the population density occasionally can build up to the levels enough to cause hopperburn during ripping stage of rice plant. In such localities, application of insecticide during milky to dough grain stages of plant growth, about at the maximum nymphal stage of a generation before outbreak

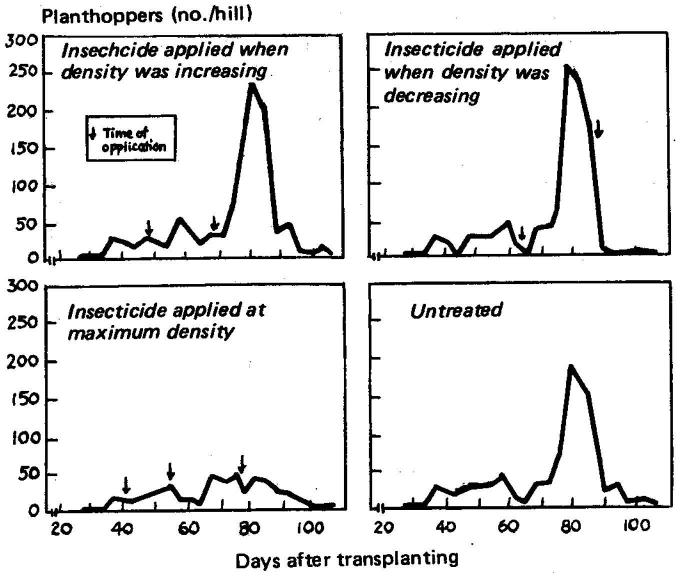

Fig. 5 Density of brown planthopper nymphs on IR20 in relation to timing of insecticide (MIPC at 0.04%) application. IRRI, 1972 wet season. (IRRI, 1973)

of the planthopper is recomended (Cheng, 1978). The brown planthopper in 2nd rice crop (July to November) is much severe than that of 1st rice crop. Since adults and nymphs can act as an immigrant, the generation of the brown planthopper overlap with each other especially in later part of the crop season. Control of the brown planthopper are usually based on the growing stage of rice plant, from which the generation and stages of the insect can be expectant roughly. In most cases, population density is low within 30 days after transplanting. Thereafter, it increase gradually and the population peak (nymphal stage of 3rd generation) appear during milky to dough grain stages of rice plant. Chemical application is suggested to time the maximum nymphal stage of 2nd generation during booting stage of rice plant. Proper control at this stage with Carbofuran depress the population sufficiently through the crop season and gave a yield equal to that obtained with three applications and double that in the control plot (Cheng et. al., 1977) (Table 9). Moreover, Liu and Chang (1980) investigated further the proper timing and frequency of spray on the population of the brown planthopper and net profit of the control. They indicated that one spray at any of following stages : late-tillering (coincide with 3rd to 4th instar nymphal stage of 1st generation), Mid-booting (2nd to 3rd instar nymphal stage of 2nd generation) Heading and dough grain stages (the beginning to late nymphal stage of 3rd generation) was not adequate to control the planthopper sufficiently throughout a crop season (Fig 6). However, Among them. One spray at mid-booting stage obtainded the highest grain yield which did not differ significautly with those received two to three applications, including one at mid-booting stage (Table 10). Two applications with one at late tillering and another at mid-booting stage had better effeciency than

Table 10. Effect of spray application at different stages of rice for the brown planthopper control on the yield and net profit (Liu and Chang, 1978)

Code	Date of application (DAT)*	Frequency	Yield (kg/ha)	Cost (NT$/ha)	Net profit (NT$/ha)
A	40	1	4395.6 bc	800	15095.3
B	55	1	4853.5 ab	900	20261.2
C	74	1	4501.4 b	1000	17112.0
D	90	1	4416.0 b	1000	15229.9
E	40 + 55	2	4975.6 a	1700	20865.3
F	40 + 74	2	4751.7 ab	1800	18190.5
G	55 + 74	2	4944.9 a	1900	20312.3
H	40 + 55 + 74	3	5280.8 a	2700	23376.3
I	55 + 74 + 90	3	5230.0 a	2900	22590.9
J	40 + 55 + 74 + 90	4	5250.3 a	3700	22024.4
K	Check	0	3013.4 d	0	

*DAT = Days after transplanting

those spray at other stages. The highest net return profit of control obtained from a 3 consective sprays with one to meet the late-tillering stage, and the others to meet booting and heading stage, respectively. However, scheduled this spray type into a control program is not necessary, because the population growth pattern differ greatly year to year and population change after application is also different depending on the chemical and application techniques used. The report from IRRI (1978) also indicated that the most effective was one-spray application at 61 days after transplanting, which coincided with the time that most planthoppers were 3rd and 4th instar nymph of 2nd generation. The importance of control planthopper at this period were because (1) 2nd generation is a key generation which was closely related with the poulation density of the planthopper of 3rd generation when hopperburn occurred usually, (2) rice plant at this stage was the most sensitive to the attack of the planthopper (Cheng, 1979; Chen and Cheng, 1978).

As mentioned above, control of the brown planthopper at maximum nymphal stage or late stages of nymph of the insect population could reduce the population density for a longer period. However, in tropics the insect population increase rapidly, if the control action is taken until that stage, rice plants may have been suffered from damage of the insect to a certain extent. In order to determine the levels of population density were economic for control, a series experiments with varies insecticides were conducted at Chiayi Agricultural Experiment Station in Taiwan. The result of one such experiment is shown in Fig 7. It is worth to note that control of a population density of the brown

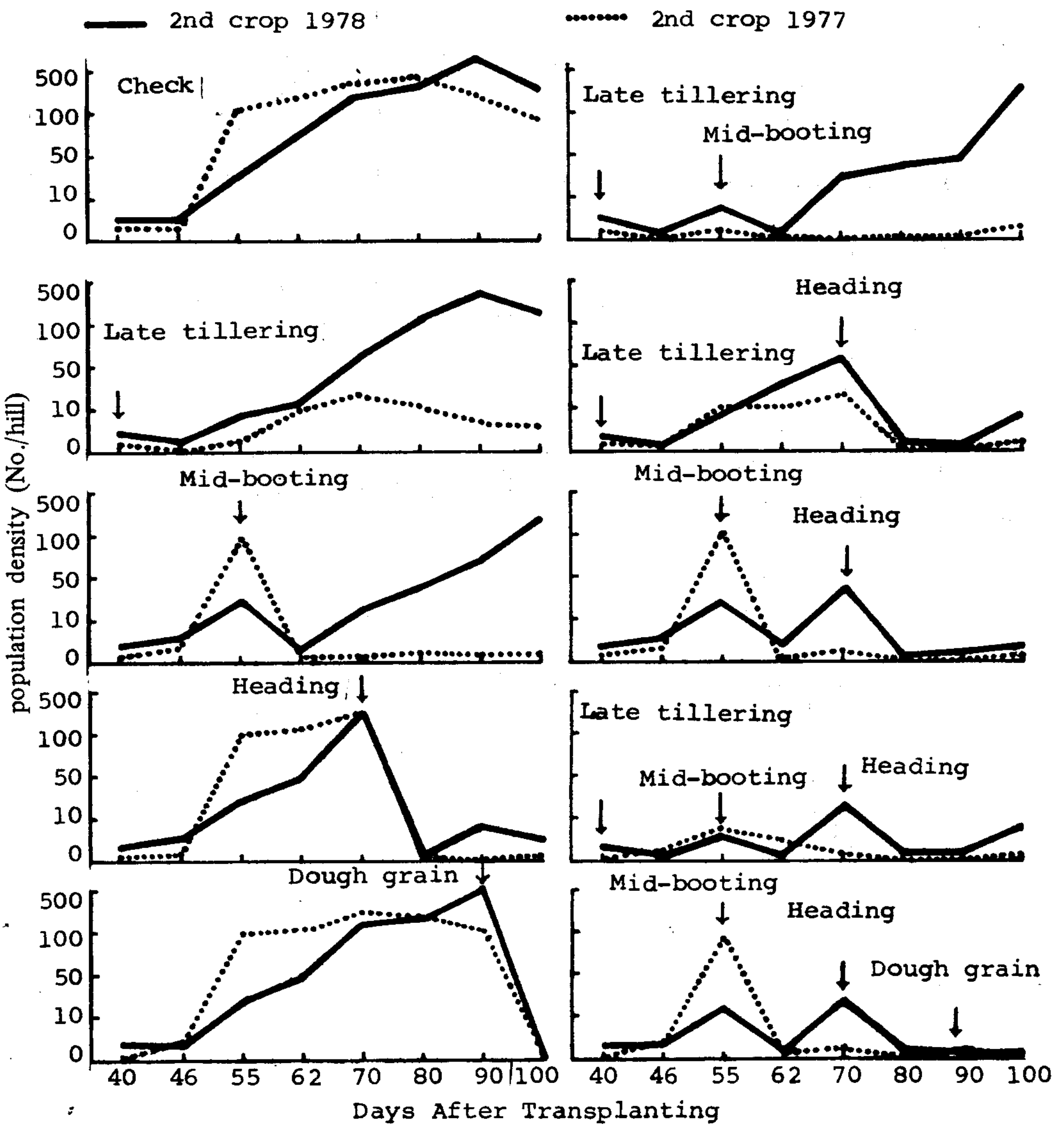

Fig. 6. Density of nymphs of *N. lugens* on Tainan 5 in relation to timing of insecticide application (Acephate at 0.6 kg ai/ha in 1977 and carbofuran + MIPC at 0.75 kg ai/ha in 1978) (Liu and Chang, 1978)

planthopper below an indicated level is difficult as field survey is taken at intervals of a week. This is evident particully during egg hatching period. The figure showed clearly that 3–4 sprays started from nymphal stage of 1st generation are usually required to depress the population density below the levels of 5 planthopper per hill throughout a crop season and 3 sprays with one spray at nymphal stage of 2nd generation and 2 sprays during nymphal stage of 3rd gereration were required to control the population below the levels of 10 planthopper per hill. Sprays at a higher population density could reduce applications, but yield production and net returns were lower remarkably than those treated

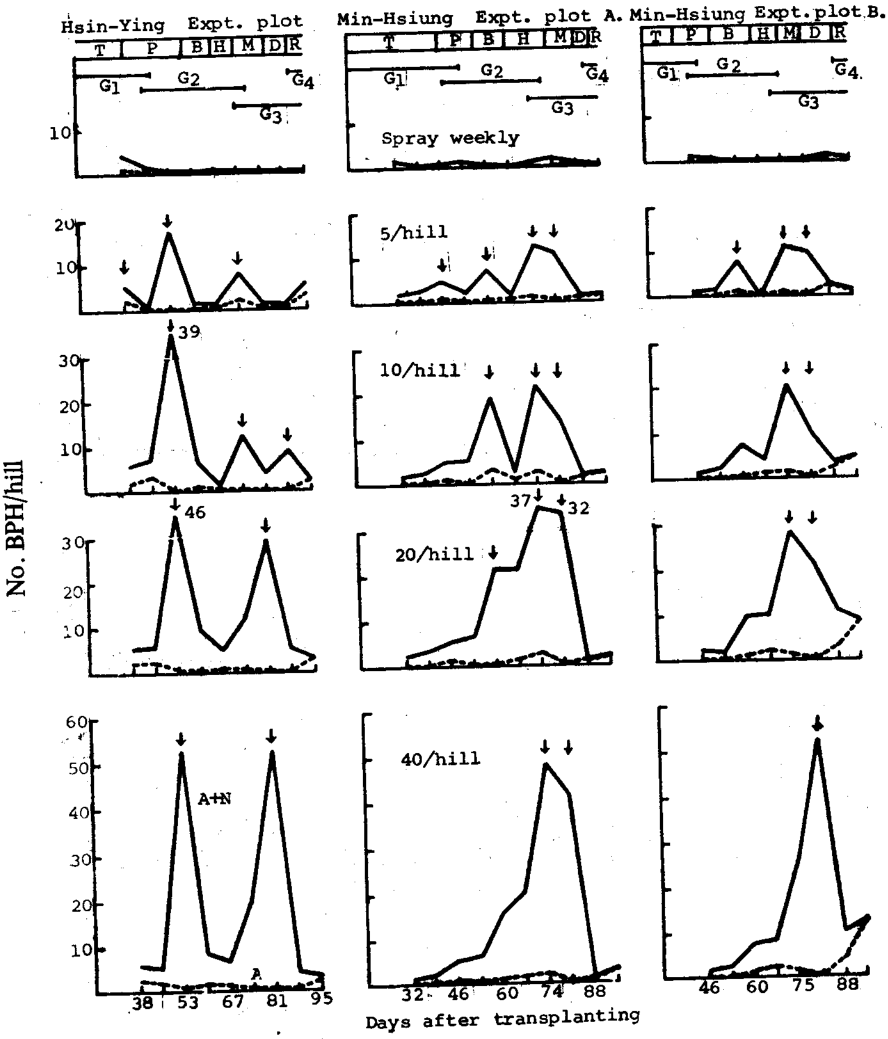

Fig. 7. Effect of control of the brown planthopper at various population levels on population dynamic of the insect (Cheng, 1978).

while the insect population density over than 5 or 10 insects per hill (Table 11). Therefore, in consideration of the profit of the brown planthopper control, action of chemical application is impossible to wait up to maximum nymphal stage or late nymphal stage of each generation. This became true particularly during later stage of plant growth, when the generations of the borwn planthopper are overlap with each other and all stages of the insect are widly distributed in paddy field (Cheng, 1978; 1979). In comparison of economic value of control with different application methods to depress the population of the brown planthopper below the levels of 10 insect per hill, Liu (1979) and Liu (1980 unpublished data) revealed that applications of granules, such as Carbofuran, Propoxur or MIPC into paddy water did'nt have any advantage over those treated with foliar ap-

Table 11. Brown planthopper control at various population density in different localities in relation to grain yield of Tainan 5 and net return. Chiayi AES, 1978, 2nd crop

Treatments A (insect/hill)	No. of applica-tion	Grain yield kg/ha	Yield loss (%)	Net return	
				Guarantee price	Market price
		Min-Hsinug A			
Spray weekly[c]	10	5296a	0.	50,014.0	31,568.0
5/hill	4.25	5078b	4.21	53,807.0	36,034.0
10/hill	3.25	4800c	9.37	51,690.0	34,890.0
20/hill	3	4640cd	12.39	50,120.0	33,880.0
40/hill	2	4467d	15.65	49,210.5	33,576.0
		Min-Hsiung B			
Srpay weekly[c]	8	5803a	0	59,694.5	39,384.0
5/hill	3.75	5611a	3.31	61,226.5	41,588.0
10/hill	2.5	5140b	11.43	56,910.0	38,920.0
20/hill	1.5	4843bc	16.54	54,374.5	37,424.0
40/hill	1	4622c	20.35	52,273.0	36,096.0
		Hsin-Ying			
Spray weekly[c]	9	4345a	0	34,307.5	19,100.0
5/hill	4	4040b	7.0	39,500.0	25,360.0
10/hill	3	3860bc	11.16	39,170.0	25,660.0
20/hill	2.5	3714c	14.52	38,361.0	23,080.0
40/hill	2	3320d	23.59	34,700.0	23,080.0

a. Treated with 40% Hokbal EC. 1.51/ha at Min-Hsiung A, 50% MIPC WP. 1.2kg/ha at Min-Hsiung B and 40.64% Furadan FW. 1.51/ah at Hsin-Ying while the number of nsiect per hill over indicaetd population levels.

b. net return: Value of rough rice minus the cost of insecticide and its application. Cost for one application at Min-Hsiung A: N.T. $1080/ha, Min-Hsiung B: 880/ha and Hsin-Ying: 1740/ha. Guarantee price for rice: NT$11.5/kg, and lowest market rice price: 8/kg.

c. Spray started while the density of the brown planthopper reached 1 insect/hill.

plications in terms of percentage of control or net return profit. Based on their results, application of dust formulated insecticides, such as Propoxur, Ofunak-M, provided the best effeciency.

INTERACTION OF INSECTICIDES WITH RESISTANT HOST PLANT

Recently, the brown planthopper resistant varieties are widely grown in the Philippines and Indonesia (Heinrichs, 1978; Harahap, et. al., 1977). From several experiment, it revealed that the population development of the brown planthopper on resistant varieties were very slow, in many cases with less than 10 insects per hill throughout the crop season

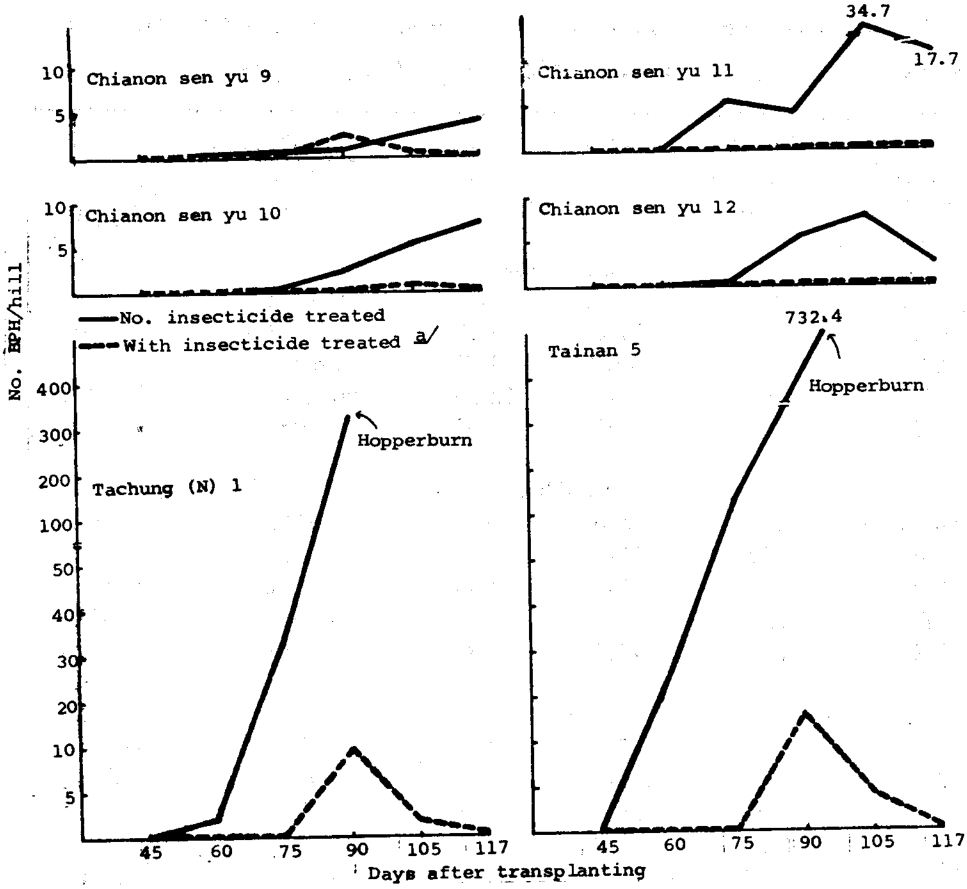

Fig. 8. The difference in brown planthopper population development on some rice selections between insecticidal treated and untreated plots. 2nd crop. 1972. (Cheng, 1975).

(Fig 8). In such case, chemical application on resistant varieties did not have any advantage to the grain yield, but it increased grain yield for more than 50 percent on susceptible ones (Cheng, 1975). Similar results were also observed at Indonesia and Philippines. In Indonesia where the brown planthopper was severe during 1974 to 1976 probably due to continous cropping throughout the year and staggered rice cropping. Under such conditions, the population of the brown planthopper on susceptible variety was difficult to be ckeck down by repeated insecticidal application, but the population density on resistant varieties were low and there was little difference between the densities on treated and untreated plots (Fig 9) (Mochida, 1977). Similar experiences were also recorded in the International Rice Research Institute in Philippines (IRRI, 1975). In this case, while resistant varieties sustained little damage, the susceptible varieties IR8, IR20, IR22, IR24, Taichung Native 1 and Rexoro suffered from hopperburn and produced virtually no rice, both on the plots treated with Diazinon and on the unprotected polts. Moreover, the low yield of suceptible varieties grown on plots periodically protected with

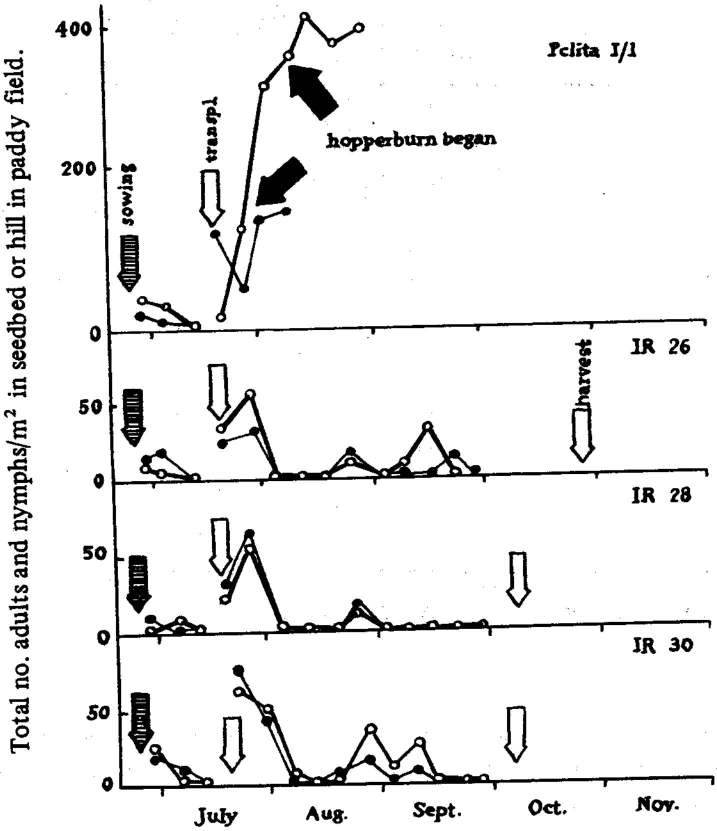

Fig. 9. The occurrence of the brown planthopper on four high yielding rice cultivars at Kutoharjo (Kendal, C. Java) in the dry season of 1975. (Mochida, et al. 1977)

Carbofuran indicated that the chemical alone could not adequately control the brown planthopper during a severe outbreaks of the insect (Pathak, 1976) (Table 12). From these experience, it indicate clearly that chemical application can be greatly reduced through the introduce of resistant varieties. Thus, the integrated use of resistant varieties and insecticide would provide not only a more effective and more economic way for the brown planthopper control, but also provide a more favorable conditions for the natural enemies.

CONCLUSION

At present, chemical is used as a primary weapon against the brown planthopper in most Asian countries, and it will continously act as an important role in controlling the insect pest in the near future. Based on experience, it has been will realized that ineffec-

Table 12. Yields of selected rice varieties when grown with and without insecticide protection during a severe brown planthopper outbreak (IRRI, 1975)

Vriaety	Yields (kg/ha)		Control
	Carbofuran*	Diazinon*	
IR 26	8260 a	6716 a	7203 a
IR 1514A = E 597–2	6072 b	4720 b	5732 b
IR 8	1824 d	0 c	0 c
IR 20	4230 c	0 c	918 c
IR 22	1450 de	0 c	146 c
IR 24	1620 d	0 c	364 c
Taichyng Native 1	2166 d	0 c	0 c
Rexoror	505 e	0 c	0 c

* Applied to the paddy water at 2 kg/ha a.i. every 20 days.

tive of chemical control of the brown planthopper is mainly due to failure of sprays to reach the plant bases where the planthopper feed and lack of residual effects to kill hatching nymphs. In order to solve these problem, more practical and effective application methods must be developed which allow the insecticide to contact the insect feeding at the bases of the plant. On the other hand, determination of proper timing of insecticide application either based on the pest biology or plant stage is essential to overcome the shortage of residual effects of insecticides and to minimize the frequency of chemical application. It must be keep in mind that the method developed should be practical and economic for famers' employment.

Many workers have reminded that insecticide have not been a panacea. In many cases, chemical alone is not adequate to control the brown planthopper sufficiently. Integrated use of insecticide with other control method, such as resistant varieties have demonstrated high effective and economic of the brown planthopper control. By using this approach, chemical application can be greatly reduced which would provide a more farvorable conditions for the pest's natural enemies to survive in paddy field.

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褐飛蝨葯劑防治，特別論及處理後之棲羣動態

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褐飛蝨爲亞洲地區水稻之主要害蟲。由於該蟲產卵於葉鞘組織內，成蟲及若蟲均取食於稻株基部，殺蟲藥劑難於充分佈及，而一般使用於該蟲防治之藥劑的殘毒甚短，因此由於新孵化之若蟲而使其棲群密度於藥劑撒佈後之短期內即呈快速回升。藥劑性質，施藥技術以及防治時期爲影響防治效果之重要因素。粒狀殺蟲劑一般較其他劑型藥劑具較長之殘餘毒效。而施用粒劑於水稻根際又較一般撒佈方法更具續效。撒佈粒劑於潮濕田面對飛蝨之殺蟲效果較一般撒佈於保持灌溉水之田間具較速之殺蟲效果並具較長之防治期。使用噴佈類殺蟲葯劑時，噴佈殺蟲劑於稻株基部較其噴佈於葉面者可增加10至30％之防治效果。噴佈粉劑，尤其在水稻生育後期，對褐飛蝨之防治較噴佈液態劑者爲優。但無論粉劑或液態噴佈劑之殘效均短，需連續兩次噴佈才能充份地抑制褐飛蝨棲群之快速回升。一般而言，當褐飛蝨棲群大部爲若蟲，而其棲群密度到達經濟爲害基準，即平均每叢水稻 5 ～10隻時即行施葯可獲最佳及最經濟之防治結果。而栽培抗蟲品種，於需要時再施用殺蟲藥劑，非但可減少葯劑之使用，並可保持田間害蟲天敵更佳之生存場所。