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Insect Pests of Rice in Korea

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Entomological work in Korea began about the time that the Central Agricultural Experiment Station was established at Suwon in 1905. From that time until the beginning of World War II, various projects were conducted on rice stem borers, leafhoppers, and planthoppers. The research activities were, however, seriously hampered during World War II and the Korean War in 1950. After the establishment of the United States Operation Mission projects in Korea, research activities were greatly encouraged. The present paper reviews recent research on rice entomology in Korea.

A number of government or private agencies are conducting research on rice insects. Their efforts are concentrated on solving problems associated with the rice stem borer, as the damage by this insect is far greater than that of any other pest attacking rice.

RICE INSECTS IN KOREA

A total of 98 species of insects have been reported as infesting rice plants in Korea. Of economic importance are:

Common Name	*Scientific Name*
Stem borer	*Chilo suppressalis*
Green rice leafhopper	*Nephotettix cincticeps*
Smaller brown planthopper	*Laodelphax striatellus*
White-back planthopper	*Sogatella furcifera*
Brown planthopper	*Nilaparvata lugens*
Zigzag-striped leafhopper	*Inazuma dorsalis*
Rice green caterpillar	*Naranga aenescens*
Grass leaf roller	*Cnaphalocrosis medinalis*
Rice leaf roller	*Susumia exigua*
Long-winged rice grasshopper	*Oxya velox*
Rice root worm	*Donacia provosti*
Rice phloeothrips	*Haplothrips oryzae*
Smaller rice leaf miner	*Hydrellia griseola*
Rice plant weevil	*Echinocnemus squameus*
Rice midge	*Chironomus oryzae*
Rice leaf beetle	*Lema oryzae*

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The paddy stem borer *Tryporyza incertulas* does not occur in Korea, and *Sogata furcifera* and *Nilaparvata lugens* occur only sporadically and are not major pests.

Most of the research conducted in recent years has been concerned with the rice stem borer. However, some has focused on the control of the leafhoppers. Research has been directed toward solving physiological and ecological problems—the efficacy of light traps, plant damage and crop losses, chemical control, varietal resistance, biological control, and forecasting the extent and severity of insect outbreaks.

PHYSIOLOGICAL AND ECOLOGICAL STUDIES

From 1946 to 1948, technicians of the Entomology Section, Central Agricultural Experiment Station, surveyed the insect population of rice paddies under different cultural practices (Anonymous, 1948). They reported 19 per cent more stem borers and rice plant weevils on plants grown on ridged rows than on plants grown in a paddy following the usual method.

Kim (1955) surveyed rice stem borer damage in the Taejon area resulting from different cultural practices. He noted that late-transplanted rice plants were less damaged than those transplanted earlier in the season. The average percentage of damaged stems was 10.4 for rice seedlings transplanted June 10, 6.0 for those transplanted June 25, and 1.8 for those transplanted July 10. He also reported that rice plants in irrigated paddies were less damaged than plots from which the irrigation water had been withdrawn.

Other workers at the Central Agricultural Experiment Station measured the *p*H of the digestive liquid of several species of lepidopterous larvae, including the rice stem borer, and compared it with the *p*H of macerated leaves from their host plants. They expected, but did not find, any correlation between the two (Anonymous, 1946b).

Kye and Park (1960) reported on the vitality of rice stem borer larvae. Five hundred mature larvae were collected in late fall from paddies located at Suwon, Nonsan, Posong, and Kimhae and kept under field conditions at Suwon. The percentage of larvae which lived through winter was as follows: Suwon, 56.2; Nonsan, 48.0; Posong, 42.8; and Kimhae, 42.6.

Park and Imm (1961) reported on the ecological differences of rice stem larvae from different localities. Their data showed a positive relationship to the average temperature for the respective localities, as indicated below:

Locality	*Date of 50 Per Cent Pupation*
Suwon	May 19
Nonsan	May 25
Posong	May 26
Kimhae	June 5

Bai *et al.* (1963a) reported on the location of matured stem borer larvae in the stem and stubble in late fall. They said that about 84 per cent of the larvae were found in the stem up to a distance of 25 cm above the ground, while the remaining 75 per cent were located between this point and the tip. Some larvae were found in the stem as high as 61 cm above the ground. These investigators also opined that overwintering stem sites for larvae may differ, depending largely on the specific location of the paddy area concerned.

Bai *et al.* (1963) reported on the flight distance of some rice stem borer moths, as shown below:

Flight Distance (m)	*Percentage of Marked Moths Caught*
100	1.3
200	2.2
300	1.2
400	0.3

He also reported that moths that had traveled more than 600 m were trapped.

LIGHT-TRAP STUDIES

Light traps have been used in rice insect surveys by the Central Agricultural Experi-

TABLE 35–1: Total Number of Rice Stem Borer Moths Trapped at Various Locations in Korea, 1958–63

Location	1958	1959	1960	1961	1962	1963
Chunchon[a]	—	788	803	936	906	1,047
Sosa[a]	—	1,419	1,762	2,239	1,180	647
Suwon	2,462	4,943	3,826	9,137	3,673	2,930
Chungju[a]	483	316	189	1,618	271	177
Taejon	—	—	—	16,147	2,419	1,700
Iri	2,572	4,202	5,970	7,241	2,491	2,233
Taegu[a]	—	977	2,137	2,024	413	100
Kwangju	1,356	2,244	2,966	1,380	1,821	1,379
Chinju	1,906	909	2,270	4,460	1,874	1,438
Average	1,756	1,975	2,490	5,020	1,672	1,295

[a] Kerosene lamps were used as the light source.

ment Station and provincial experiment stations since before World War II. The data obtained have been used as bases for forecasting rice stem borer occurrence.

The results are summarized in Table 35–1. The variation between stations for any year was large. An increase in the average number of moths from 1955 to 1961 in the data for the various stations in any one year also was noted. In fact, for the latter year, serious rice stem borer outbreaks were recorded at all locations except Chunchon and Kwangju.

In 1946, studies using light traps were made at the Central Agricultural Experiment Station, Suwon, on the activity of four species of rice insects (Anonymous, 1947a). The results are shown in Table 35–2. It is to be noted that while as many moths of *Chilo suppressalis* were collected between 10 and 11 P.M. as between 7 and 8 P.M., over 90 per cent of the remaining three species had been trapped by 10 P.M. With all insects, a larger number were trapped between 8 and 9 P.M. than during any other hour interval. A few stem borers as well as the occasional leafhopper (*Nephotettix bipunctatus*) were still flying after midnight, but flights of the other two insects had apparently stopped.

Rice insects are more attracted by a daylight fluorescent bulb than by a tungsten filament bulb. It was recorded that 72 per cent more rice stem borer moths, 362 per cent more green rice leafhoppers, and 132 per cent more green leafhoppers *Cicadella viridis* were collected per unit of time using a daylight bulb than were caught when a tungsten bulb was used (Anonymous, 1947a).

DAMAGE CAUSED BY THE RICE STEM BORER IN KOREA

Chang and Chun (1958) and Chang, Chun, and Kye (1959, 1960) made extensive surveys of rice stem borer damage. For this purpose, 884 fields distributed among 52 countries in 8 provinces were examined. The results of this survey are shown in Table 35–3 and Figure 35–1.

The results indicate that rice in the southern plain area, represented by Cholla Pukto and Cholla Namdo Provinces, and considered a most productive rice region, was attacked more severely by first-generation borers than that cultivated in the mountainous region comprising Kangwondo and Chungchong Pukto provinces. The average percentage of damaged stems in this generation was 9.5.

In the second generation, Kyongsang Pukto rice fields were damaged more than those of Chungchong Pukto. The average percentage of damaged stems in the second generation was 4.6.

The over-all estimated crop loss caused by the stem borer was 7.1 per cent.

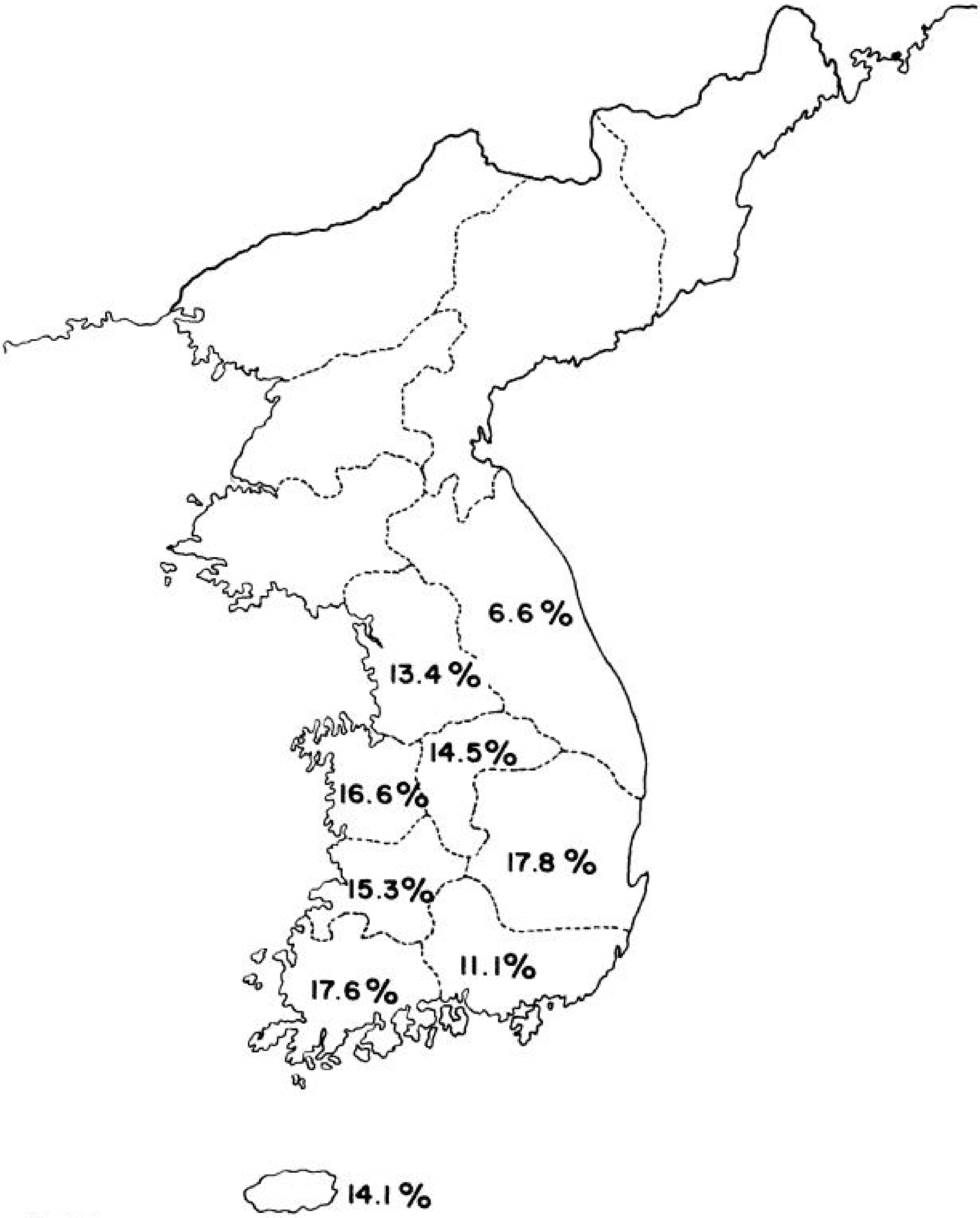

Fig. 35-1: Distribution of rice stem borer damage by provinces in Korea. (Chang and Chun (1958); and Chang, Chun and Kye (1959, 1960.)

TABLE 35-2: Effect of Time at Night on the Number and Percentage of Rice Insects Caught at Light Traps (August 19–September 1, 1946)

Insect	Hour at night												Total number of insects
	2000		2100		2200		2300		2400		After midnight		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Chilo suppressalis	6	15.8	16	42.1	7	18.4	6	15.8	2	5.3	1	2.6	38
Naranga aenescens	11	10.4	72	67.3	15	14.0	8	7.5	1	1.0	0	0.0	107
Nephotettix cincticeps	2,259	36.6	2,729	44.2	984	16.0	137	2.2	40	0.7	27	0.4	6,116
Cicadella viridis	148	42.8	89	25.7	86	24.9	14	4.0	7	2.6	0	0.0	46

Kangwondo Province had the least amount of stem damage and the smallest crop losses. The reason is not clear, but an explanation might be the greater environmental resistance of paddy rice grown in mountainous regions than that grown in plain areas. Kyongsang Namdo, which has a plain area, showed a lower percentage of damaged stems than any other province except Kangwondo. The percentage of damaged rice stems was exactly the same here for both generations.

In general, the number of moths appearing in the second generation is only one-third to one-half that of the first generation. The difference might be explained by the presence of more natural enemies of the stem borer during the lifetime of the second generation.

Estimated crop losses shown in Table 35–3 were calculated using a method proposed by the Japanese Ministry of Agriculture and Forestry (Anonymous, 1957).

CHEMICAL CONTROL

Rice insect control studies in Korea have been carried out largely against the rice stem borer and with the use of insecticides. γ-dol, sumithion, dipterex, EPN, diazinon, dimecron, and BHC have been recommended in that order and distributed to farmers through agricultural cooperatives. All of these insecticides have been used widely for the past few years.

The following section discusses some of the most important insect control experiments.

The Rice Stem Borer

Fumigation of Rice Stems. Technicians (Anonymous, 1946c) tested the effect of fumigants on rice stem borer larvae living within the rice stem. One hundred damaged stems per plot were used in closed boxes. Results showed that fumigation with carbon disulfide for 12 hours or with chloropicrin for 24 hours at 18–22 C at the rate of 1 lb. each for 1,000 cu ft sufficed to kill all larvae.

Evaluation of Different Insecticides. Kye and Lee (1960) conducted a field experiment at Suwon using diazinon E, dipterex E, EPN E, endrin E, and dieldrin E. The light trap was used to attract moths to the experimental plots for three nights during the peak period of moth emergence. A randomized complete block design with three replications was used. Each plot was 10 *pyongs*[2] in size. Chemicals were sprayed 15 days and 10 days after moth appearance in the first and second generations, respectively. The treatments for the first-generation borer were delayed because of many continuous rainy days.

Some of the results are shown in Table 35–4. Dipterex 400× proved best, followed by diazinon 300×, dipterex 500×, 700×, and 800×. Endrin 300×, EPN 800×, and dieldrin 300× were least effective.

Kim and Bang (1961) tested the effect of mixed chemicals in the fields at Suwon. Light traps were used again for five nights

[2] 1 *pyong* = approximately 36 sq ft.

TABLE 35-3: Damage to Rice Plants Caused by the Rice Stem Borer and the Resulting Effect on Crop Yields (Chang and Chun, 1958; Chang, Chun and Kye, 1959, 1960)

Province	Genera-tion	Average per cent of: Dam-aged stems	Crop loss
Kyunggido	First	9.0	4.5
	Second	4.4	2.2
	Total	13.4	6.7
Chungchong Pukto	First	11.2	5.7
	Second	3.3	1.7
	Total	14.5	7.4
Chungchong Namdo	First	10.8	5.4
	Second	5.8	2.8
	Total	16.6	8.2
Cholla Pukto	First	11.6	5.9
	Second	3.7	1.8
	Total	15.3	7.7
Cholla Namdo	First	11.6	5.6
	Second	6.0	3.0
	Total	17.6	8.6
Kyongsang Pukto	First	12.4	6.2
	Second	5.4	2.7
	Total	17.8	8.9
Kyongsang Namdo	First	5.6	2.8
	Second	5.5	2.8
	Total	11.1	5.6
Kangwondo	First	3.7	1.9
	Second	2.9	1.4
	Total	6.6	3.3
Average all provinces	First	9.5	4.8
	Second	4.6	2.3
	Total	14.1	7.1

during the peak period of moth emergence. The moths were of the early-emergence type, so that the plots were treated considerably later than the usual recommended date, being 29 and 22 days after the peak of moth emergence in the first and second generations, respectively. Each plot was 8.3 *pyongs* in size. A randomized complete block design with three replications was used.

The results (Table 35-5) indicate that because of the delayed application of chemicals, no significant differences were obtained between chemicals in the first generation or even between the treated plots and the check, except PM E in the second generation.

Bai, Paik and Bai (1963) conducted field experiments with 11 chemicals. These were sprayed 13 days after the peak of moth emergence for the first generation. Each plot was 10 *pyongs* in size. In both generations, calcium serenate was sprayed to control rice blast. For the first- and second-generation experiments, the plants were sprayed with parathion EC 50 per cent (1,500×) to control insects other than the stem borer in the first and second generations. The results are shown in Table 35-6. There was no significant difference between chemicals for controlling the rice stem borer in the first generation, except for dimecron and diazinon. In the second-generation experiment, the chemicals did not significantly differ in controlling the borer, but imidan, malathion, lebaycid, and dimecron resulted in the best yields. Diazinon was least effective.

Bai and Paik (1962) reported a large-scale field experiment for the control of first- and second-generation stem borers, using five insecticides. Chemicals were sprayed on each plot of 10 hectares set 100 m apart. This was done on June 27 and July 1. The data (Table 35-7) indicate that all insecticides used controlled the rice stem borer effectively, but of these, lebaycid proved the most effective.

Timing of Application. Kim and Kye (1961) studied timing insecticides in fields at Suwon. The experiments were so designed that the effects of the first generation could be separated from those of the second generation. One plot was sprayed with dipterex 50 per cent EC at a dilution rate of 1/600 at five-day intervals, beginning on June 14. This application was directed at the larvae of the first generation. At the end of this period of treatment, the entire plot was sprayed with diazinon 25 per cent EC at a dilution rate of 1/300 to protect it from attack by second-generation borers. Another plot was sprayed with the same dipterex formulation and concentration was directed against the second generation. Application was made at five-day intervals, beginning on August 10. Previously this plot had been sprayed with dipterex to prevent damage by first-generation borers. In this

TABLE 35-4: Effect of Various Insecticides on the Control of Second-Generation Rice Stem Borers (Kye and Lee, 1960)

Chemical	Dilution	No. of stems examined	No. of healthy stems	Ratio	Weight of sound grain	Ratio
Diazinon E 25%	700×	608	97.2	109	337.4	108
Diazinon E 25%	500×	600	97.2	109	344.9	110
Diazinon E 25%	300×	626	97.7	109	338.4	108
Dipterex E 50%	800×	680	97.2	109	334.3	107
Dipterex E 50%	600×	599	97.4	109	350.7	112
Dipterex E 50%	400×	618	98.3	110	348.4	111
EPN E 45%	2,400×	619	94.8	107	337.4	108
EPN E 45%	1,600×	616	95.8	107	339.8	108
EPN E 45%	800×	649	96.0	107	343.4	110
Endrin E 19.5%	600×	638	94.5	107	332.9	106
Endrin E 19.5%	300×	590	96.3	108	333.4	106
Dieldrin E 15.5%	300×	583	93.8	105	322.2	103
Check		642	89.5	100	313.3	100
LSD 5%			1.39			
1%			1.89			

TABLE 35-5: Effect of Mixed Chemicals on Control of the Rice Stem Borer (Kim and Bang, 1961)

	First generation						Second generation					
Chemical	Dilution	No. of stems examined	Percentage of damaged stems	Ratio	Weight of sound grain	Ratio	Dilution	No. of stems examined	Percentage of damaged stems	Ratio	Weight of sound grain	Ratio
Lebaycid E 50%	600×	665.3	0.72	17	398.6	105	600×	584.0	0.35	20	380.7	106
Lebaycid E 50%	1,000×	711.3	0.77	18	376.9	103	900×	581.0	0.58	34	262.2	101
Lebaycid E 50%	1,500×	671.3	0.88	21	368.9	97						
Lebaycid dust 3%	3 kg per 10 a	662.0	0.65	15	387.0	102	4 kg per 10 a	588.3	0.76	44	359.7	100
PM E (parathion EC 25%, malathion EC 25%)	700×	693.7	0.45	10	392.3	113	700×	552.0	0.12	7	365.0	102
PMD E (parathion EC 15.4%, malathion EC 7.0%, DDT EC 20%)	700×	752.0	0.45	10	411.1	110	500×	534.7	0.51	30	390.3	109
Diazinon E 40%	800×	685.7	0.92	21	384.1	101						
Dipterex E 50%	800×	689.7	9.80	19	383.7	101	600×	546.3	1.11	65	356.9	100
Check		700.0	4.29	100	382.4	100		565.0	1.71	100	358.4	100
LSD 1%			1.25						1.45			
5%			1.81						2.19			

TABLE 35-6: Effect of Various Insecticides on Control of the Rice Stem Borer (Bai, Paik and Bai, 1963)

	First generation						Second generation					
Chemicals	ml used (cc)	No. of stems examined	Percentage of damaged stems	Ratio	Weight of sound grain	Ratio	ml used (cc)	No. of stems examined	Percentage of damaged stems	Ratio	Weight of sound grain	Ratio
Folithion E	90	9,752	0.48	12.0	367.1	115.0	180	9,507	0.60	28.3	399.5	119.4
Sumithion E	90	10,023	0.69	17.3	361.0	113.1	180	10,203	0.56	26.4	415.9	124.3
Dimecron WP	90	9,754	0.51	12.8	363.4	113.8	180	9,072	0.49	23.1	416.4	124.1
Lebaycid E	90	9,811	0.20	5.0	389.3	121.9	180	10,081	0.44	20.8	419.4	125.3
Dol G	3 kg	11,196	0.30	7.5	376.4	117.9	6 kg	10,007	0.43	20.3	400.5	119.7
Malathion E	112.5	10,492	0.39	9.8	391.2	122.5	225	11,307	0.44	20.8	427.2	127.2
Cidial E	90	10,880	0.43	10.8	367.5	115.1	180	9,883	0.43	20.3	409.0	122.2
Tedron EC	180.5	10,866	0.57	14.3	368.0	115.3	361	11,136	0.45	21.2	409.6	122.4
Diazinon E	112.5	10,040	0.96	24.0	357.3	11.9	25	10,903	0.71	33.5	376.1	112.3
EPN E	100	10,602	0.53	13.3	378.0	118.4	200	10,593	0.53	25.0	396.1	118.3
Imidan WP	90	—	—	—	—	—	180	11,312	0.50	23.6	454.4	135.8
Check	—	11,196	3.99	100.0	319.3	100.0	—	10,681	2.12	100.0	334.7	100.0

TABLE 35-7: Effect of Various Insecticides on Control of the Rice Stem Borer (Bai and Paik, 1962)

		Percentage of damaged stems			
Insecticide used	Dilution	First generation	Second generation	Total	Ratio
EPN EC 45%	1,500×	0.35	0.12	0.47	10
Dipterex SP 80%	700×	0.22	0.24	0.46	10
Lebaycid EC 50%	1,000×	0.08	0.09	0.17	4
PM EC 50%	1,000×	0.33	0.22	0.55	12
MB EC 20%	400×	0.37	0.25	0.62	13
Check	—	3.18	1.52	4.70	100

way, the damage caused by the borers of the two generations could be segregated. Each plot was 10 *pyongs* in size. A randomized block method with three replications was used. Some results are shown in Table 35–8. The best time for application was 19 days after the peak of moth flight in the first generation and 17 days in the case of the second generation. The peaks of moth flight in this year were June 1 and August 3.

Paik and Choi (1962) conducted an experiment to determine the effectiveness of several insecticides and the correct timing of their application for rice stem borer control. The results (Table 35–9) indicate that diazinon, lebaycid, endrin, and folidol sprayed at 14 days before hatching showed good residual effect, whereas dipterex proved to have a shorter residual effect. All the insecticides tested were effective at 4 to 7 days after hatching and 5 to 10 days after boring into the stem. In the second generation, treatments at 21 days before hatching were effective in the following order: detron = folidol > γ-dol > endrin > dimecron. Detron from 21 days before hatching to 7 days after boring and endrin and dimecron from 14 days before hatching to 7 days after boring gave good control.

Large-scale Application. From 1958 to 1962, a series of large-scale field tests with insecticides was attempted. Some of the results are summarized below.

Chang, Chun and Kye (1959) sprayed twice with folidol, E 605, 46.7 per cent, 2,000×, 15 and 25 days after transplanting

TABLE 35–8: Experiment on the Timing of Application of Insecticides (Kim and Kye, 1961)

First generation			Second generation		
Date of treatment	Ave. no. of damaged stems	Ratio	Date of treatment	Ave. no. of damaged stems	Ratio
June 14	6.4	70	Aug. 10	1.4	55
19	3.2	35	15	1.5	57
24	5.4	59	20	1.1	42
29	5.7	62	25	0.6	23
July 4	5.7	63	30	1.4	53
9	5.9	65	Check	2.6	100
Check	9.1	100			

fields of 10.8 hectares at Anyong near Suwon. The results (Table 35–10) indicate that the degree of damage diminishes toward the center of the plot.

Kye and Lee (1960) reported a similar experiment. Rice fields of 18 hectares at Anyong near Suwon were sprayed twice, at 15 days and 21 days after the peak of moth flight in the first generation, with dipterex, E 50 per cent, 700×, and no control measures were taken in the second generation. The results (Table 35–11) show that the damaged stems gradually increased outward toward the borderline of the plot from the center.

Water-surface Application. Kim and Bang (1961) reported on the effect of γ-dol applied to the irrigation water surface for controlling rice stem borers at Suwon. Each plot was 51.6 sq m. A randomized block design with three replications was used. γ-dol and fine mesh γ-BHC were dispensed on the water surface, and other chemicals were sprayed on June 28. The peak of moth flight was June 11 in this year. The results (Table 35–12) indicate that γ-dol and γ-BHC applied on the water surface were equally effective or a little better than foliar sprays. They also reported on the correct timing of application of γ-dol through outdoor experiments with potted rice plants. On July 11 each pot was treated with γ-dol on the water surface at the rate of 2 kg per 10 a. The depth of water was kept at 5–6 cm during this experiment. The results (Table 35–13) indicate that plots treated with γ-BHC on the water surface 4

TABLE 35–9: Effect of Various Insecticides on Control of the Rice Stem Borer (Paik and Choi, 1962)

Insecticide	Application	Second-generation borers Treated no. of days before hatching			Treated no. of days after boring into the stem	
		21	14	7	2	7
		No. of borers	No. of borers	No. of borers	No. of borers	No. of borers
Endrin	Foliar	58	0	0	4	0
Detron	Foliar	0	0	0	0	0
Folidol	Foliar	0	0	0	0	0
Dimecron	Foliar	113	0	0	0	0
γ-dol	Water surface	20	58	37	39	60
Check	—	115	222	133	112	137
		First-generation borers				
		14	7	4	5	10
Endrin	Foliar	32	14	26	1	3
Folidol	Foliar	37	66	34	1	1
Diazinon	Foliar	17	86	45	8	3
Dipterex	Foliar	121	38	50	0	1
Lebaycid	Foliar	31	42	66	1	0
Check	—	144	148	154	66	86

LSD = 20.5 (between insecticides)

TABLE 35–10: Effect of Large-scale Application of Insecticide on Rice Stem Borer Damage (Chang, Chun, and Kye, 1959)

Distance from the center of the plot (m)	First generation		Second generation	
	Ave. no. of stems examined	Percentage of damaged stems	Ave. no. of stems examined	Percentage of damaged stems
Center	374	7.0	333	2.7
25	349	6.9	297	6.1
50	328	5.8	295	5.8
75	335	7.2	279	6.1
100	358	6.1	287	4.9
125	356	11.0	317	10.1
150	328	12.5	286	10.5

to 11 days after oviposition (from 3 days before to 4 days after the hatching date) showed no white panicles.

Paik and Choi in 1964 tested the effect of six chemicals applied to the water surface to control the stem borer. Emulsions were used, except in the case of diazinon G and γ-dol. Actual ingredient per 10 a was 120 g for all insecticides used. The results (Table 35–14) show that diazinon G and γ-dol are more effective than the others.

Economics of Insecticide Application. Bai, Paik, and Bai (1963) carried out an experiment to compare the efficacy of 11 insecticides on controlling rice stem borers at Kimhae, Kyongsang Namdo Province. The results (Figs. 35–2, 35–3, and 35–4) indicate that lebaycid showed excellent control of rice stem borers in both generations, and dimecron, malatera, and γ-dol also showed better control than EPN, diazinon, and sumithion, which are widely used by farmers. An economic analysis of the results obtained (net profit per 10 a) showed that lebaycid also yielded the highest profit, with dimecron, malatera, and γ-dol following in that order. In proportion to the changes in the price of chemicals, the net profit fluctuates (Fig. 35–3), as it also does in response to changes in the price of rice (Fig. 35–4). These figures illustrated that the income of farmers is influenced more by changes in the price of rice than by changes in the price of chemicals.

Leafhoppers

The Central Agricultural Experiment Station tested the effect of DDT on *Nephotettix*

TABLE 35–11: Effect of Large-scale Application of Insecticide on Rice Stem Borer Damage (Kye and Lee, 1960)

	Distance from the center (m)						
	Center	50	100	150	200	250	Check
No. of hills examined	120	270	900	1,110	1,020	4,140	270
Damaged stems, first generation	16	17	16	17	18	29	41
Damaged stems, second generation	9	11	15	17	19	27	30

TABLE 35–12: Effect of γ-dol Applied to the Water Surface on the Control of the Rice Stem Borer (Kim and Bang, 1961)

Chemical	Ave. no. of damaged leaf sheaths	Ratio	Ave. no. of white panicles	Ratio	No. of larvae		
					Alive	Dead	Total
Fine mesh γ-BHC 6%	7.0	18.3	0.0	0.0	0	0	0
γ-dol 6%	7.0	17.5	0.3	1.3	1	1	2
Dipterex EC 50%	7.7	19.1	0.7	2.6	0	0	0
Sumithion EC 50%	8.7	21.6	0.7	2.6	0	1	1
Dimecron WP 50%	8.0	20.6	0.7	2.6	5	1	6
Endrin EC 19.5%	10.7	26.6	1.3	5.1	5	0	5
ACC 18,133 granule	7.7	19.1	1.0	3.9	0	4	4
Check	40.0	100.0	25.7	100.0	62	6	68

TABLE 35-13: Experiment on the Timing of Water-Surface Application of γ-BHC (Kim and Bang, 1961)

Days from oviposition to treatment	No. of stems examined	Per cent damage: Sheaths	Per cent damage: White panicles
20	75	78.2	31.1
19	77	75.3	16.9
17	75	76.6	10.7
16	79	67.0	10.1
15	77	49.4	7.8
14-13	62	45.2	4.8
12	66	34.8	3.0
11	67	24.1	0.0
10	92	9.8	0.0
9	88	9.2	0.0
8	64	9.4	0.0
6	72	5.9	0.0
4	65	3.1	0.0

bipunctatus after 100 treated leafhoppers were liberated in caged pots planted with rice plants (Anonymous, 1949). Ninety per cent of the leafhoppers were killed with 0.05 per cent DDT wettable-powder spray.

Kye and Bang (1959) tested several insecticides on *N. bipunctatus*. Fifty leafhoppers per plot were liberated on potted rice plants caged in the screen and sprayed with chemicals. Malathion EC, 50 per cent (2,000), folidol EC, 46.7 per cent (3,000), diazinon EC, 50 per cent (700), EPN WP, 25 per cent (2,500), dipterex EC, 50 per cent (700), and endrin WP, 50 per cent (500) were used. Of these, diazinon, malathion, and endrin showed good control. Kim and Kye (1961) tested nine chemicals on *N. bipunctatus*. These were sprayed on the potted rice plants, and 20 to 30 leafhoppers were liberated in each plot daily for seven days after treatment. Lebaycid, sevin, DM, PP 175, diazinon, and malathion were used. Sevin WP (0.05 per cent) showed the best control for seven days. Where the plots received treatment for only one day, lebaycid, sevin, and PP 175 showed good control. Sevin seems to be the best insecticide for controlling leafhoppers.

Oxya Velox

Grasshoppers dipped in solutions of different concentrations of DDT were made to live on rice plants treated with the same concentration. The lowest concentration tested (0.05 per cent DDT WP) killed more than 86 per cent of the grasshoppers (Anonymous, 1949).

TABLE 35-14: Effect of Insecticides Applied to the Water Surface on the Control of the Rice Stem Borer, 1964 (Paik and Choi, 1964)

Insecticide	Treated no. of days before hatching: 9	Treated no. of days before hatching: 5	Treatment on day of hatching	Treated no. of days after hatching: 5	Treated no. of days after hatching: 9
	Per cent mortality	*Per cent mortality*	*Per cent mortality*	*Per cent mortality*	*Per cent mortality*
Cidial	9.7	3.1	58.1	8.2	10.0
Sumithion	32.3	69.6	55.6	57.2	50.0
EM	61.3*	39.5	67.9	63.3	23.4
EPN	9.7	36.4	82.7	59.2	56.6
Diazinon G	74.6	94.0	92.6	87.8	80.0
γ-dol G	83.9	75.8	43.3	81.6	60.0

*Some spiders were found in this plot.

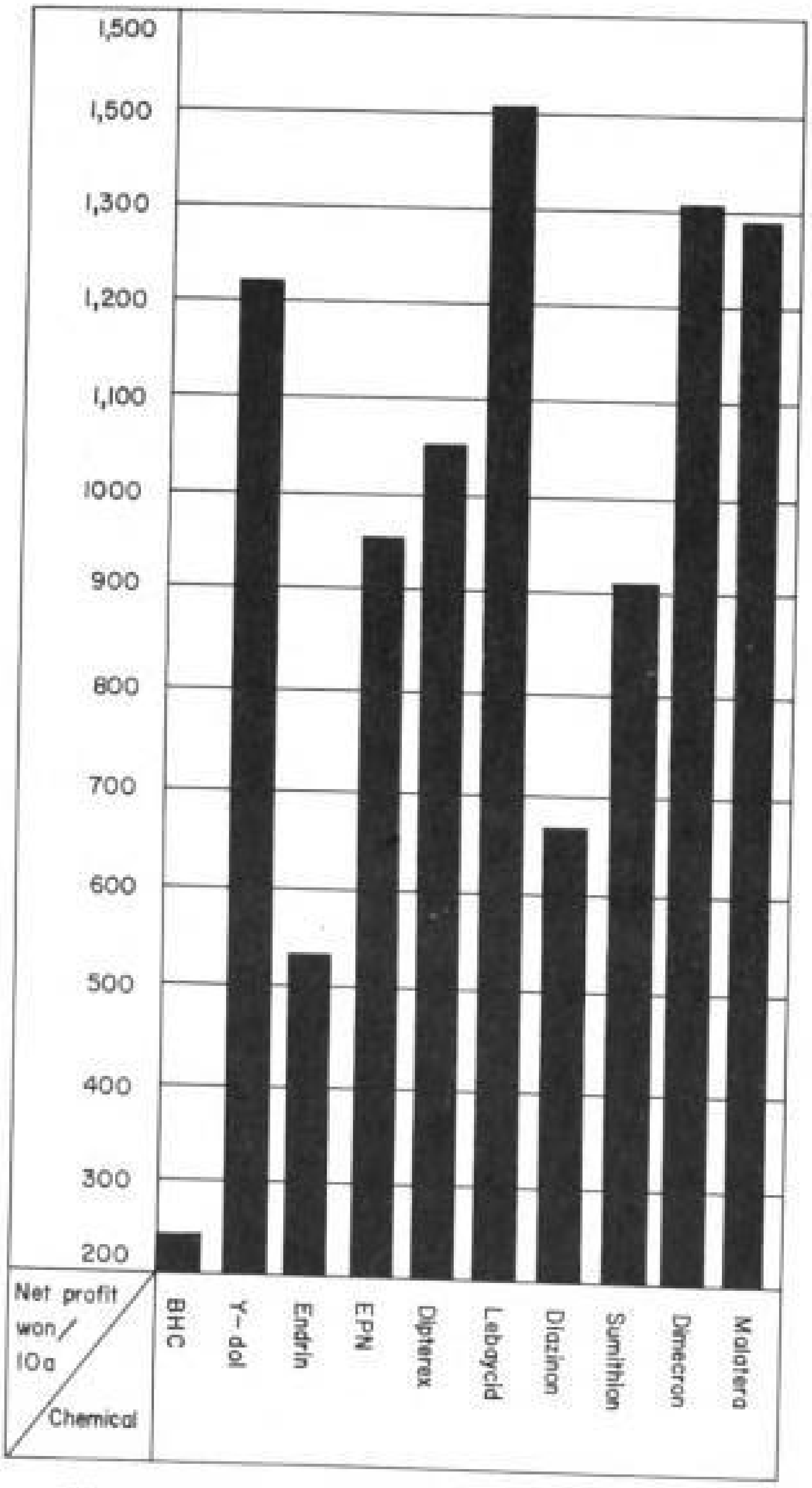

Fig. 35-2: Comparison of net profit by chemicals. (Bai, Paik and Bai, 1963.)

BIOLOGICAL CONTROL OF THE RICE STEM BORER

The use of egg parasites of the rice stem borer, such as *Trichogramma japonicus* and *Phanurus beneficiens*, has been recommended by many entomologists as a natural control measure. However, the actual role of these parasites in checking borer populations has not been well evaluated.

As early as 1946, egg parasites of the rice stem borer were investigated at Suwon (Anonymous, 1946d). Of 18 egg masses collected from rice plants at Chonan, all had been attacked to some degree by the parasite *Phanurus beneficiens*. Of a total 1,496 individual eggs, 966, or 45.5 per cent, had been parasitized. Additional studies of borer egg masses at Suwon were made from June 4 to August 29. In these experiments, 83 egg masses and 4,607 individual eggs were examined. A total of 80.3 per cent of the egg masses had been attacked and 62 per cent of the eggs destroyed by the parasite.

Another test carried out at Suwon showed that 46.1 to 49.5 per cent of the stem borer eggs were parasitized by *T. japonicum* only (Anonymous, 1947b).

Yoon (1958) reported that the parasitic percentage for rice stem borer eggs of the first generation in the Kwanju area was 46. This compares with a 50–60 percentage during the prewar period. He indicated that

TABLE 35-15: Effect of Parasites of Egg Masses from First- and Second-Generation Rice Stem Borers (Chun and Kye, 1959)

Generation	Activity	Date: May 29	May 30	June 5	June 8	June 12	June 13	Total	Mean
First	Egg masses examined	48	10	6	11	43	13	131	21.8
	Per cent parasitized	12.5	20.0	16.7	18.7	9.3	15.4		15.4

Generation	Activity	Date: August 10	August 11	August 12	August 14	Total	Mean
Second	Egg masses examined	35	27	39	2	103	25.8
	Per cent parasitized	91.7	48.2	59.0	100.0		74.7

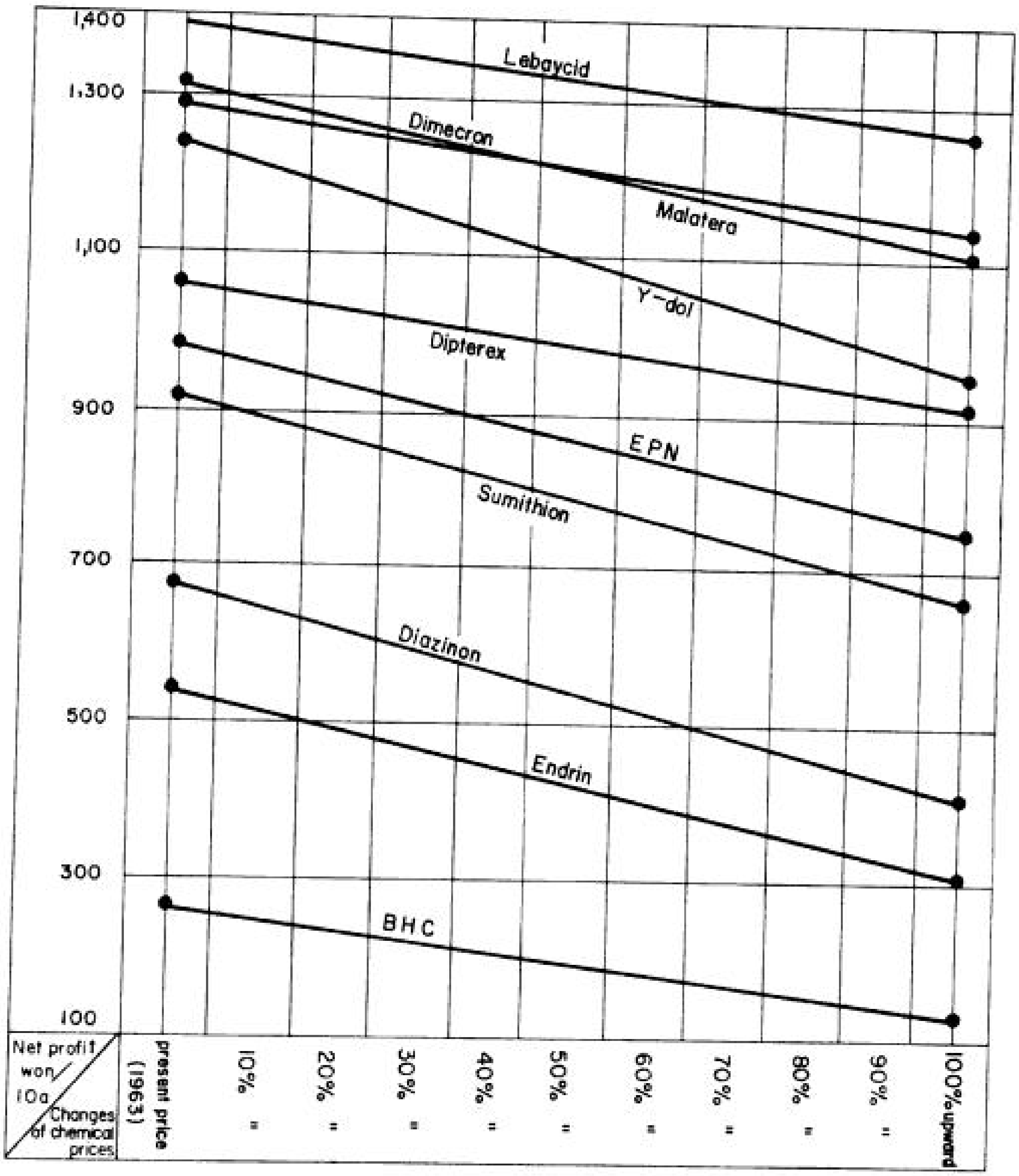

Fig. 35-3: Comparison of net profit by chemicals from chemical price changes. (Bai, Paik and Bai, 1963.)

this low figure might be attributed to the extensive use of effective insecticides, which also are toxic to parasites.

Chun and Kye (1959) investigated parasites attacking eggs of the first- and second-generation stem borers at Suwon. Both *Trichogramma* and *Phanurus* parasites were included. Table 35-15 presents the data showing the joint effect of these parasites. *Trichogramma* was much more effective than *Phanurus*.

FORECASTING THE OCCURRENCE OF THE RICE STEM BORER

To predict the number of rice stem borer moths in the second generation, Paik (1960), from studies made in the Taejon area, proposed the following formula based on data obtained from 1934 to 1941:

$$Y = 365.2 + 4.25X$$

where Y is the number of moths in the second generation and X, the number of

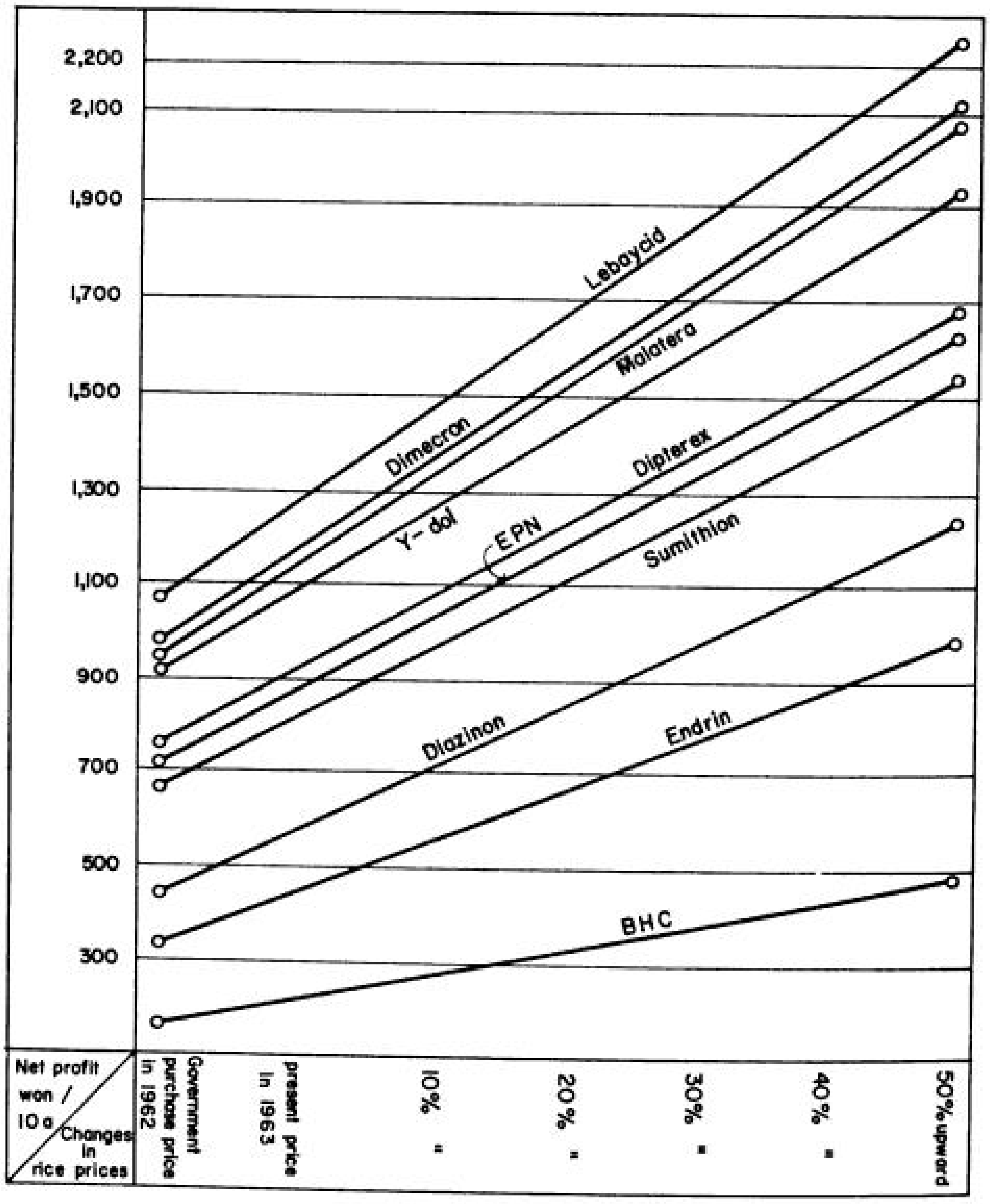

Fig. 35-4: Net profit by chemicals from changes in price of rice. (Bai, Paik and Bai, 1963.)

moths in the first generation as determined during the first five days of July.

The predicted and actual number of moths in the second generation from 1958 to 1963 were as follows:

Year	*No. of Moths during the First 5 Days of July (X)*	*Predicted No. of Moths in the Second Generation (X)*	*Actual No. of Moths in the Second Generation*
1958	2	365	555
1959	64	628	411
1960	45	547	61
1961	209	1,244	4,255
1962	98	772	512
1963	47	556	557
Average	77	685	1,058

Because too few years were observed, the results obtained did not coincide with the actual data.

Kye and Lee (1961) also proposed a number of formulas based on data recently accumulated at Suwon. The goals were to predict the first date of moth emergence in the first generation, the peak of moth emergence in the first and second generations, and the number of moths in the first and second generations.

Some of the formulas are tabulated below.

Factors	*Regression Formula*	*Years Observed*	*Correlation Coefficient*	*Remarks*
First date of moth emergence in the first generation and hours of sunshine in March.	$Y = 46.4 - 0.2X$	7	−0.982	Apr. 30 = 0
Peak of moth emergence in the first generation and hours of sunshine in May.	$Y = 26.2 - 0.08X$	8	−0.805	May 31 = 0
Peak of moth emergence in the second generation and mean minimum temperature for May.	$Y = 60 - 4X$	9	−0.907	July 31 = 0
Number of moths in the first generation and mean relative humidity during the last 10 days of December.	$Y = 11{,}451 - 126X$	7	−0.919	
Number of moths in the first and second generations.	$Y = 122.4 + 0.2X$	8	+0.910	

The results obtained did not coincide with the actual data. This might be explained by the relatively small number of years considered.

Workers at the Entomology Section, Institue of Plant Environment, Office of Rural Development, predicted the date of peak moth flight in 1963. The differences between predicted and actual date for the first generation varied from 0 to 16 days (Table 35–16). The predicted date for the second generation was more accurate than that for the first, varying only from 0 to 3 days from the actual date. The lack of accuracy in prediction could be attributed to the use of kerosene lamps at Kanwondo, Kyongsang Pukto, and Cholla Namdo or to inappropriate location of the light traps. For instance, in the case of Kyongsang Pukto, the light trap was stationed at a place where the area planted to rice was not more than a hectare.

VARIETAL RESISTANCE

Of the few studies made on the resistance of rice varieties to the stem borer, one will be reviewed in this paper. It was made in 1946 at Suwon (Anonymous, 1946e). A total of 220 plants from 17 varieties grown together in the field were carefully examined for stem damage caused by first- and second-

TABLE 35–16: Dates of Peaks of Moth Appearance, 1965

	First generation		Second generation	
	Predicted date	Actual date	Predicted date	Actual date
Kangwondo*	June 6	May 21	Aug. 10	Aug. 13
Kyungido (Suwon)	June 12	June 12	Aug. 12	Aug. 10
Chungchong Pukto*	June 13	June 15	Aug. 12	Aug. 15
Chungchong Namdo	June 15	June 15	Aug. 14	Aug. 15
Kyongsang Pukto*	June 19	June 13	Aug. 17	Aug. 17
Kyongsang Namdo	June 25	June 28	Aug. 20	Aug. 20
Cholla Pukto	June 18	June 16	Aug. 15	Aug. 16
Cholla Namdo*	June 22	June 15	Aug. 18	Aug. 18

* Kerosene lamps were used as the light source.

generation stem borers. At the end of the experiment, a macerated suspension of straw, representing each variety was tested for *p*H. The results of these tests are shown in Table 35–17.

For the first generation, the most severely damaged variety appears first in the table and the one least damaged, last. Approximately the same number of stems were examined for each variety. The variety Rikuu 137 headed the list with 48 damaged stems, while Chosaeng Kogyando had no damaged stems. The other varieties ranged between these two.

Stems attacked by the first-generation borers were removed before the second-generation larvae attacked the plants. This was necessary in order to prevent counting the same stems twice. Some varieties showed about the same degree of resistance to both generations of stem borers and some did not. For example, Chosaeng Kogyando was undamaged by the first-generation borers, but was severely damaged by those of the second generation. In contrast, Poongok, which had 33 damaged stems by the first-generation borer, had only 5 damaged stems by the second generation. A few varieties, such as Sukwang and Eunkoo 6, were resistant to both generations of borer.

At first, it was thought that borer damage to the stems might be correlated with the *p*H of the stem tissue. However, the data did not indicate any such relationship.

DISCUSSION

The rice stem borer and *Nephotettix cincticeps* occur every year in considerable numbers in Korea and cause damage. Direct damage by *N. cincticeps* is usually not so severe, except when serious outbreaks occur. Because of the lack of technicians, the Entomology Section of the Office of Rural Development is concentrating only on the most urgent problems, such as measures for controlling the rice stem borer. However, the importance of research on the leafhoppers should also be realized. The rice stunt disease transmitted by *N. cincticeps* and *Inazuma dorsalis* and the rice stripe disease transmitted by *Laodelphax striatellus* are becoming more serious each year. *I. dorsalis* was found at Iri, Chola Pukto Province, in 1959 by Paik and now seems to have spread all over the country. More research, therefore, should be carried out with leafhoppers and planthoppers, especially on the physiological and ecological aspects.

To obtain accurate light-trap data at provincial experiment stations, workers should be trained to identify trapped insects. A survey of damage by leafhoppers and planthoppers also should be made.

Many chemical control studies have been made in Korea, but as previously mentioned, they have been concentrated on the rice stem borer. It is suggested that such research be conducted at the provincial experiment sta-

TABLE 35–17: Comparative Resistance of Rice Varieties to the Rice Stem Borer, 1946

Variety	No. of stems damaged by: First-generation borer	Second-generation borer	Total	pH of stem tissue
Rikuu 137	48	53	101	5.7
Namsun 13	42	12	54	6.0
Poongok	33	5	38	5.6
Rikuu 132	32	23	55	5.7
Chosaeng Eunbang	29	5	34	5.7
Sukchun Chungeun	26	10	36	5.9
Aekook 20	25	25	50	5.8
Chojo	22	63	85	5.7
Eunkoo 11	17	6	23	5.7
Eunkoo 5	14	14	28	5.3
Tamageum	6	3	9	5.8
Yungkwang	6	4	10	5.8
Paltal	4	40	44	5.8
Ilchin	7	5	12	5.7
Sukwang	5	2	7	5.6
Eunkoo 6	1	2	3	5.6
Chosaeng Kogyando	0	34	34	5.7

tions in cooperation with the Entomology Section of the Office of Rural Development. In this way, the section can broaden its research activities. From available results, a number of insecticides have proved to be effective against the rice stem borer. Chemicals now used widely are almost the same as those used in Japan.

Previously, insecticides were applied using a sprayer. Now, however, new methods of application, such as the water-surface application of γ-dol and diazinon G, also have proved effective. The use of other insecticides in this manner should be investigated. Results of such experiments will be of great value to farmers, who usually are not able to purchase expensive spraying machines.

An extensive survey of the natural enemies of insect pests of rice is advisable. Subsequently, the promising natural enemies should be evaluated individually for biological control. Forecasting stem borer occurrence has been done solely on the basis of light-trap results. In order for this work to improve, statistical and better experimental methods should be used. The latter are especially important, since the extent of stem borer occurrence is affected considerably by chemical control.

Varietal resistance to the stem borer and the rice stripe disease was indicated, but one can hardly expect to control the diseases economically by using resistant varieties in Korea. With the rice stripe diseases, however, many resistant varieties among those recommended can be found.

DISCUSSION

Woon Hah Paik, *Korea*

Comment

M. D. Pathak (*Philippines*): Low larval mortality when γ-BHC was applied on the day of larval hatching might have resulted from the 72 hours' time required by the plants to pick up an adequate amount of toxicant.

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