

PLANT PROTECTION

Both basic and applied research on the epidemiology of insects and diseases are studied. Life cycles of various insects such as rice brown planthopper, vegetable cutworms, insects of grapevine, etc. are extensively studied. The controlling measures by the application of insecticides and sex pheromones are also the major subjects of concern. In order to enforce an effective insect and disease control, a system for "forecasting insect and disease epidemics" is adopted and is operated based on the field observation and the analysis of meteorological data.

To ensure the safety of vegetables on the market, the vegetables are randomly sampled and analyzed for the amount of insecticide residues by both chemical and biological assays.

Insect Pest and Their Control

A. Rice Insects

a. Brown Planthopper (*Nilaparvata lugens*)

1. Life History of Brown Planthopper

This insect has 10 generations annually and lived over-winter as egg, nymph and adult but the population density of the insects in overwinter is very low.

It completed a generation about 21-58 days. Egg, and nymph stages lasted 6 to 11, and 15 to 36 days respectively. The egg mass was laid into the leaf sheath and was arranged into one straight row. The number of eggs contained in an egg-mass is about 8.8 in average, but may deposite as many as 30-176 eggs.

There were two types of brown planthopper; the short winged occurred during the plenty of normal diets and was unsuitable for flying, but their capacity of oviposition was larger than the long winged. The optimum temperature for the development of the insect was 25-28°C; temperature below 8°C or above 35°C was unsuitable for the development of the insects.

Depending on the variation of accumulative average temperature in over winter one can forecast the prevailing of the brown planthoppers. If the accumulative average temperature of over-winter is higher than 2100°C and then the outbreak of these insect pests may be forecasted in the next year.

2. Economic Methods for Brown Planthopper Control

Different pesticidal formulations and application methods were tested in the

field to select the most effective and economical control measure for the control of the brown planthopper on rice. Results showed that two applications of insecticidal dust, one at midbooting and the other at the uniform heading stage, gave the most profitable result. The application of a granule at mid-booting and a dust at the uniform heading stage also showed a high profit. Carbofuran G 3% when used under shallow water condition, gave a better result in terms of its efficacy and profit. However, application of granule before transplanting of rice seedlings would do nothing to either pest population or rice yield. And spraying usually gave lower profit.

3. Tank-Mixed Insecticides for Brown Planthopper Control

For the brown planthopper control on rice, preliminary results showed the formula consisting of MIPC at 1/3 recommended rate + ethyl parathion at 1/3 recommended rate + kerosene was more effective than that of MIPC at 1/2 recommended rate + ethyl parathion at 1/2 recommended rate. The former formula was similarly or more effective than each respective insecticide alone at conventional recommended rate. In the 1979 experiment, MIPC at recommended rate + kerosene was found to be the most economic and effective mixture, while MIPC at 1/2 recommended rate + Furadan at 1/2 recommended rate was as effective as Furadan alone at full recommended rate. Both of these mixtures, therefore, can be recommended to the farmers. In addition, MIPC at 1/2 recommended rate + carbaryl at recommended rate and MIPC at recommended rate + sun spray 7E oil were also satisfactory, and provided alternative formulae for tank-mixing when necessary.

4. Different Application Method for Brown Planthopper Control

Among the insecticides tested, dust formulated insecticides had fast knockdown effects than the liquid ones and caused higher mortality of the brown planthopper (BPH) as well. No distinct differences were observed between the effect of dust on BPH control by using hand-operated blower duster and powered duster. On the other hand, among liquid sprays, insecticide sprayed on the stems either by using hand-operated knapsack sprayer or mobile-type high-pressure mistsprayer with multiple-hand nozzles had 6.8 to 40% more effect for BPH control than those sprayed on leafcanopy. Differences in contact insecticides generally were greater than those systemic ones. Conventional application with a motorized mist blower machine generally had poor effect on BPH control. However, 10 to 32% more

effect than foliar sprays on the canopy was obtained when the machine was equipped with a curve blow-tube and fanshaped cover or with duck-mouthshaped cover in the tip of blow-tube to spray on the stems of rice. In term of work efficiency, powered-duster and mobile-type high pressure mistsprayer needed least application time to cover the crop and followed by motorized mist blower machine and hand-operated blower duster and hand-operated-knapsack sprayer.

5. Lower Dosage for Brown Planthopper and Green Rice Leafhopper Control

The field tests were conducted during 1977 and 1978. Comparisons were made for each chemical between efficacy of presently recommended dosage (PRD), 1/3 of PRD and 1/2 of PRD. Tainan 5 rice variety was used in all tests. The plot was 40m² in size and was arranged in randomized complete block design with 4 replication. Chemicals were applied by a knap-sack sprayer at 1200 l/ha.

The dosage currently recommended for the brown planthopper (BPH) control is 0.6 kg ai/ha for 40% Hokbal E. C., 50% Uden W. P., 40.64% Furadan F. and 75% Orthene sp. and 0.3 kg ai/ha for 20% MIPC E. C. Among the comparisons made, only 40% Hokbal E. C. and 40.64% Furadan F. showed non-significant difference when both were used at 0.6 and 0.4kg ai/ha. Hence, we recommended that the dosage of these two chemicals can be reduced from presently recommended dosage to 0.4 kg ai/ha for the BPH control.

In case of the rice green leafhopper control, the dosage currently recommended is 0.6 kg ai/ha for 40% kilval S., 75% Orthene S. P. and 50% Tamaron L. C., and 0.33 kg ai/ha for Azodrin S. Results showed that the dosage of Azodrin and Tamaron can be reduced to 0.25 and 0.4 kg ai/ha, respectively, for the green rice leafhopper control while its population is low.

6. Control Timing of Planthopper and Leafhopper

The optimal frequency and best timing for chemical control of planthoppers and leafhoppers (mainly *Laodelphax striatellus*, *Sogatella furcifera* and *Nephotettix cincticeps*) were studied in the first rice crop of 1978 to 1980. Single application each at the initial booting, heading and doughy grain stage as well as 2 and 3 applications at 2 or 3 stages were compared in terms of the net profit gained. The control at the heading was more critical than either at the initial booting or the doughy grain stage. However, the highest net profit was gained when 3 applications were made at 3 consecutive stages. When 2 applications were planned, both at the

heading and the doughy grain stage would give better result. We would like to recommend that in the first cropping season when the hopper number reached 5 per net sweep at the initial heading (ca. 55-60 days after transplanting) a chemical application should be initiated. Another application during late booting to heading stage was indispensable. Whenever the hopper number reached 10-20 per net sweep at the milking to doughy grain stage one more spray was recommended.

7. Technique and Effectiveness of Ultra-low-volume Application

Viscosities of eight ULV grade pesticides, i. e., 95% Sumithion, 96% Malathion, 95% Ambithion, 93% Elsan, 60% Azodrin, 50% Hinosan, 60% Lebaycid and 3% Kasumin, were examined. Preparations containing more than 90% active ingredient in a liquid form were found four times more viscous than those containing 50-60% active ingredient. The viscosity of a chemical was inversely related to temperature. The flow-rate of a liquid preparation, emitting from a motorized mistblower with an orifice restrictor installed in between the nozzle and spray-gun, was also inversely related to its viscosity. By the ULV ground spray application method described, an effective range of 7-8 meters and a droplet spectrum of 40-90 microns were achieved when the spray gun was held horizontally or pointed upward at 10 degrees. If an operator carrying a mistblower advances at a pace of 36-50 meters per minute during spraying, tests showed that he would be able to cover one hectare in about 25-35 minutes.

8. Resistance of Brown Planthopper to Commonly Used Insecticides

Among the nine areas surveyed, brown planthoppers of Huatang strain was found resistant to MIPC, MTMC, Hokbal and Azodrin. Puyen, Taichung and Tachia strains were resistant to MTMC. The brown planthoppers of Puyen and Taichung strains were shown to be highly tolerant to MIPC and Azodrin, respectively. There is a conspicuous correlation among the resistance levels of these commonly used insecticides occurred in the field populations of brown planthoppers in central Taiwan, they may have the multiresistance to these insecticides.

Vertical polyacrylamide slab gel electrophoresis was used in the study of the esterases activity of the strains collected from various locations. There was positive correlation between the esterases activity and the resistance level of brown planthoppers to these insecticides. The esterases activity is considered to be an important factor in the appearance of the resistances.

9. Current Status of Brown Planthopper (*Nilaparvata lugens* Stal) Resistance to Four Commonly Used Insecticides in Central Taiwan

Intensive application of insecticides has produced instances of brown planthopper resistance to these four insecticides. As large quantity and wide kinds of insecticides were used for rice insect pest control, results obtained so far indicated that relatively even population of brown planthopper has developed resistance to a great variety of chemicals. By using the dosage-mortality line or some portion of it such as LD₅₀, LD₉₀ and the slope etc., we had been able to establish a quantitative measure by which a change in susceptibility to the test chemicals were determined. The brown planthopper were collected from rice paddies in central Taiwan. Higher LD₅₀ value for each strain than those susceptible data in 1981 was shown. A year later as the results obtained in 1982, however, a general trend of higher resistant level than those data reported in 1981 was found, indicating that brown planthopper can survive well under heavy selection pressure of insecticides. The occurrence of resistance in rice brown planthopper population as collected in 1982 were found in substantial increase in comparison with data obtained in 1981, especially Huatan, Puyen, Hsensi and Chutang strain to Isoprocarb, Tali and Chutang to MTMC, Tungshih and Tali to Hokbal, Tungshih and Hsensi to Monocrotophos. According to resistance factor, Tachia to Isoprocarb and Hokbal has the trend of reduction, Huatan to MTMC, Tachia, Puyen, Chutang, and Yuchu to Monocrotophos have the same phenomenon and the other strains have the trend of increase.

b. Green Rice Leafhopper (*Nephotettix cincticeps*)

1. Life History of Green Rice Leafhopper

The average life cycle of this insect is usually completed in about 70 to 80 days in summer months and about 120 to 130 days in winter months. In general, the pre-oviposition period averaged 6 to 7 days in summer months, 10 to 12 days in the fall and an average of 16 to 18 days in winter months. Eggs were laid as a mass under the inside cortex of the rice leaf sheath, but in less frequent cases, females deposited the egg masses half exposed outside the leaf sheath. Usually a insect deposits as many as 22-314 eggs. Egg, nymph and adult stages lasted 5 to 15, 14 to 32, and 27 to 30 days respectively.

2. Resistance of Green Rice Leafhopper to Commonly Used Insecticides

Among the areas surveyed, green rice leafhopper of PY strain was found resistant to monocrotophos, TC strain was also resistant to malathion, while strain Hs was highly tolerant to monocrotophos.

The green rice leafhopper strains from PY was found to be highly tolerant to vamidothion and carbaryl. The small correlation among the resistance levels of these commonly used insecticides in the field populations of green rice leafhopper in central Taiwan implies that they may have multiresistance to these insecticides.

Vertical polyacrylamide slab gel electrophoresis was used in the study of the esterase activity of the strains collected from various locations. There was positive correlation between the esterase activity and the resistance level of green rice leafhopper to these insecticides. The esterase activity is considered to be an important factor in the appearance of resistance.

c. Rice Stem Borer (*Chilo suppressalis*)

1. Life History of Rice Stem Borer

The rice stem borers multiply 5 generations annually. The length of each generation was influenced by the variation of the climatic conditions.

The first crop damaged by the insects was more severe than the second one.

The rice stem borers overwintered in the larvae stage in rice residues. The overwintering larvae survived until the spring of the next year, and then transformed into pupae, and moth. Longevity of adult estimated around 2 to 7 days. And deposited as many as 80 to 143 eggs. Egg, larval, pupal stages lasted 4 to 15, 42 to 118, and 3 to 16 days respectively.

d. Rice Leaf Folder (*Chaphalocrocis medinalis*)

1. Life History of Rice Leaf Folder and Varietal Resistance of Rice Plants to the Insect

Rice leaf folder completed 8 generations at Taichung area. It took about 96 days and 30 days to complete one generation in the winter and summer seasons, respectively. The larva molted 4 times and the developmental durations of the 1st and the 5th stages were usually longer than other stages. The number of eggs laid varied from generation to generation. One single female moth could produce 19-70 eggs in average under greenhouse conditions, while more eggs could be produced by

the moth collected from the field. It appeared to have 8 peaks of moths annually. The first major peak (the third generation) appeared in June and the second major peak (the sixth generation) appeared in November. The larvae of these two generations were, mainly responsible for the damages done on the 1st and 2nd crops of the rice plants, respectively. At the end of second crop, the larvae or moths of 7th generation migrated to the adjoining rice fields and continued to multiply for one more generation on the weeds or regrowing ratoon rice during the winter season. Some moths of the 7th generation which developed with a slower pace could appear during January to February.

Forty-two entries including most of the commercial rice varieties were tested for their resistance to rice leaf folders in the fields. No resistant variety was found throughout the trial and there seemed to have no difference in resistance between the indica and the japonica types of rice plants.

e. Others

1. The Assessment of Rice Yield Loss due to the Damage of *Pomacea lineata*

The rice plants are most susceptible to the damage of *Pomacea lineata* at young seedling stage right after transplanting. The damage level depended on the size and number of snails. The highest damage percentage was observed at the 14th and 24th days after transplanting for the 2nd crop, 1985 and the 1st crop, 1986, respectively. The yield losses were 71.2, 47.4 and 22.3% when 50 large snails or the same number of middle snails or small snails were released, respectively, in the 2nd crop, 1985; while the corresponding percentages were 19.9, 2.8 and 1.8% in the 1st crop, 1986.

The yield reduction resulted from the damage of *P. lineata* were 50.4, and 26.4% by 50 large snails and 20 large snails, respectively; while the yield loss of other treatments have no significant difference in the 2nd crop, 1985. In the 1st crop, 1986, the yield reduction were 14.7, 8.2 and 6.7% by 50 large snails, 20 large snail and 50 middle snails, respectively. In general, the yield reduction and damage level are found more serious in the 2nd crop than in the 1st crop.

According to the cost/benefit analysis, when one large snail or 2 middle snails or 5 small snails are found in one square meter paddy field, respectively, some control measures are considered necessary.

B. Upland Crop Insects

1. Life History of Sorghum Aphid and Varietal Resistance of Grain Sorghum to the Insect

The sorghum aphid, *Melanaphis sacchari* (Zehntner), is one of the major pests of grain sorghum in the central Taiwan.

High population of the aphid ubiquitously occurs in the booting and the heading stages of the host plant. It reduces the quality and yield of the grain sorghum severely. Both temperature and rainfall are the influential factors on the prevailing of the aphid, especially the effect of the latter factor is remarkable. This aphid develops 51 to 61 generations annually. The longevity of adult estimated around 14-37 days. It deposits as many as 45-89 nymphs. Nymphal stage lasts 4.3 to 12.4 days.

The resistance of sorghum to aphid was estimated for 95 varieties of the sorghum. The results revealed that 5 different groups existed in the tested 53 varieties. They consisted of 3 resistant, 10 moderately resistant, 21 moderately susceptible, 17 susceptible and 2 highly susceptible varieties in R-line.

C. Orchard Insects

1. Morphology and Life History of Red Coffee Stem-borer

Red coffee stem-borer (*Zeuzera coffeae* Nietner) is one of the most important pests of grape-vine in Taiwan. A newly hatched larva at first penetrates into young twig of grape. Later, it removes to larger limb or trunk with its larval development. The infested twig is characterized with the symptom of excreta of larva from a penetrated hole. A damaged twig becomes fragile and easy to be broken off from just beneath a hole. Furthermore, sudden leaf withering on twig ubiquitously occur. In the case of seriously damaged plant, the grape-vine entirely killed. A mature larva pupates in the larval burrow. Before emergence of adult, a pupa escapes to the outside of a burrow, and splits down pupal skin to backward. It has 2 generations annually. Periods of adults emergence fall on during April to June and August to October. Longevity of adult estimated around 2-6 days. And deposits as many as 190-1134 eggs. Egg, larva, pupal stages lasted 9 to 30, 73 to 205 and 19 to 36 days respectively.

D. Vegetable Insects

1. Injury and Seasonal Occurrence of Melon Fly

Cue-lure + DDVP (20:1), methyl eugenol (poisoned) and Cue-lure + methyl eugenol (1:1, poisoned) were used for monitoring the population density of melon fly, *Dacus cucurbitae* Coq. The results showed that the population density in bitter

gourd field was the highest; the pear field in Puli was the least one; the population density was the highest on November in 1982 at different crop. Temperature and rainfall may regulate the population of the melon fly. The efficacy of Cue-lure + methyl eugenol was the best based on its attraction. Sponge gourd damaged in Nantou was the severest, averaging 39.4% while bottle gourd damaged in Hsihu was the lightest, averaging 5.2%.

2. Chemical Control of Diamond Back Moth

Among the three different concentration of chemicals at 0.1, 0.05 and 0.025%, the best mortality was shown by 24% Phosdrin E. C. but this kind of insecticide is more toxic to human being than others and can not be used in two weeks before the harvesting of vegetables. The chemicals DDT and Phosdrin ranked second and 25% Nerion E. C., the third. So far the results of 50% DDVP E. C. and 25% DDT E. C. were more effective at high concentration than at low one. The parathion and metasstox which were highly toxic to human being were less effective in the control of diamond back moth than malathion which had low toxicity. So the resistance of diamond-back moth to insecticides differed with compositions of insecticides.

3. Economic and Safe Application of Insecticides for the Control of Diamond Back Moth, *Plutella xylostella* L.

This experiment was carried out in the vegetable field of central Taiwan to compare the economic and safe application of insecticides and control costs for diamond back moth, *Plutella xylostella* L.

Results showed that the dosage of economic and safe application in the common field with the same control efficacy was 441 gm to 1588 gm per 0.1 ha, and the control cost was NT\$ 396 to 1588 per 0.1 ha, respectively.

This suggested that the farmers tended to use the mixtures of pesticides at the concentrations higher than the recommended rate and disregard the necessity of economic and safe application of insecticides, therefore, some education must be strengthened.

E. Flower Insects

1. Insect Pests of Chrysanthemum and Their Control

The surveys in several years indicated that among the more than 10 different insect pests on chrysanthemum, aphids, thrips and mites occurred most frequently. Lepidopterous insect pests, though occurring only sporadically, brought much trouble. Higher populations of sucking-type insect pests were mainly found in dry seasons due to the inhibitory action of continuous rain on population density. This suppressive action was less apparent to the chewing-type insects pests. The ununiformity of culturing period of chrysanthemum made the effort of timing of control difficult, which generally must vary with planting time. In general, 1 to 2 sprays are necessary during early stage of the plant. According to need, 1 to 2 sprays at an interval of 7 to 10 days can be made before blooming. The most critical stage for exporting chrysanthemum is between budding and time of cutting. In this stage 3 to 5 sprays at an interval of 3-5 days was absolutely necessary. Screened from more than 20 insecticides are 6 insecticides including 25.3% EC mevinphos for aphids, 2 for thrips, and 5 including 50%WP Plictran for mites. Significant reduction of efficacy of some insecticides had been noticed in the field and this may indicate the development of resistance of insects due to continuous application of insecticides for many years.

F. Safety Use of Chemicals

1. The Residue of Dursban in Five Vegetables and Corn Plants

Dursban is one of the currently used effective insecticide for the control of insects in vegetables and corn borer. This experiment adopted both biological test and chemical analysis methods to study the residue of Dursban in the corn leaves. The results showed that the changing tendency of the Dursban residue obtained from both methods were similar. However chemical analysis method is more sensitive. It detected 0.17 ppm of Dursban residue in the corn leaves 14 days after the spray. Biological test showed that the flies were killed up to the 8th day after the spray, and it was estimated to have 0.51 ppm residue according to the conversion factor.

It seemed that the biological method had the advantages of simple and practicality. Further tests with the biological method found that the Dursban residue in the five vegetables, Pak-choi, Chinese kale, field mustard, water convolvulus, and Pait sai on the 6th day after spray were 0.51 ppm, meeting the less than 0.5 ppm permissible residue requirement. Therefore, it is safe to the human body if the application of Dursban is stopped 6 days before the harvesting of the above five vegetables for the market.

Plant Pathology

A. Rice Diseases

a. Rice Blast

1. Epidemiology of Rice Blast

Rice blast usually started 33-36 days after transplanting of japonica varieties in first crop of rice. The maximum percent of infection was usually noted about 57 days after transplanting. The occurrence of blast on indica varieties was usually a little late and the percent of infection was lower. The percent of infection of leaf blast was higher in 1979 than in 1980 based on tested varieties. It was possible that average temperatures during disease initiation were lower in 1979 than in 1980. On the contrary the average relative humidity during disease initiation were higher in 1980 than in 1979. It seems that disease initiation was mainly controlled by temperature rather than relative humidity. Dew period may affect the percent of infection, especially during disease severe stage.

The percent of panicle blast was the highest on Tainan 5 and Taichung Sen 3 was the lowest. The percent of panicle blast was higher in 1979 than in 1980. It was possibly due to the fact that the raining days were longer during heading stage, and the average temperature was lower in 1979. The occurrence of panicle blast was somewhat correlated with ligule blast.

Conidia are always collected from air before lesions are observed. However the number of conidia collected was very low, only 10 conidia were collected every 5 days.

b. Rice Virus

1. Comparative Transmission of Rice Yellow Dwarf

The yellow dwarf of rice was transmitted experimentally by *Nephotettix impicticeps* Ishihara, besides there are the two known vectors *N. cincticeps* and *N. apicalis*. In comparative experiments, *N. cincticeps* and *N. impicticeps* were equally efficient in transmitting the disease with a transmission rate of 70.7% for *N. cincticeps* and 77.4% for *N. impicticeps* following an acquisition period of 24 hours. These rates were considerably higher than that obtained with *N. apicalis* which was 51.9%.

There were no differences in the length of incubation period of the yellow dwarf agent in three *Nephotettix* species. In *N. cincticeps*, it was from 24 to 34 days, and mostly 26 to 28 days; in *N. apicalis*, from 24 to 38 days, and mostly 28 to 30 days; and in *N. impicticeps*, from 24 to 38 days, and mostly 26 to 30 days. Apparently, the leafhoppers retained the infectivity until their death.

2. Effect of Yellow Dwarf Disease on Agronomic Characters of Rice Plant

Two commercial rice varieties, Tainan 5 and Taichung 186 were inoculated with yellow dwarf disease by viruliferous leafhoppers, *Nephotettix cincticeps* Uhler at different plant ages.

In the field, rice plants of Tainan 5 inoculated at 10, 20, 30, and 50 days after sowing had a longer incubation period, more tillers and panicles, heavier thousand grain weight and less yield losses than those inoculated at greenhouse. The plants in greenhouse inoculated at 10, 20, 30, and 50 days after sowing, the yield reduction was 100, 98, 96, and 27 percent, respectively, while in the field, for the comparable ages, it was 93, 81, 54, and 4 percent, respectively.

Rice plants of Tainan 5 inoculated at the stages of seedling, tillering, panicle initiation and heading showed the yield reduction of 55, 22, 9, and 4 percent in the first crop, and 93, 54, 4 and 1 percent in the second crop, respectively.

3. Varietal Resistance of Rice Plant to Yellow Dwarf

Seedling screening test indicated that optimal temperature for inoculation was 20 to 30°C, in which 40 to 51% of the inoculated seedlings developed symptoms. At 15°C, only 22% of the tested seedlings were infected. The seedling test also indicated that illumination during inoculation feeding has no significant effect on the transmission ability of the insect vector.

All test varieties of japonica type were found susceptible to yellow dwarf. Of 1858 indica varieties, 52 displayed an infection level below 10 percent and 72 varieties between 10.1 to 20 percent. The most resistant variety of this group, Firooz-1 which was introduced from Iran was found completely free from infection in 23 separate seedling tests conducted in different seasons and in 3 separate field tests in different years. Other varieties including Kabara (Sierra Leone), C4-63A (Thailand), Blue-bell (Malawi), Faya (Malawi), IR1487-194-5-3-2 (Philippines), 4bs-6-1 (Iran), B581A6-545 (Philippines), 153IR-22 (SI) (Sierra Leone), MTU 1 (India), IR Early 773 (Philippines), IR994-102-2-3-2 (Philippines) and the wild rice *O. nivara* (IRRI collection no. 101512 and 101524) were also highly resistant to yellow dwarf.

When tested in the greenhouse on 15 yellow dwarf-resistant and 5 vector resistant rice varieties, *Nephotettix cincticeps* Uhler, vector of rice yellow dwarf (RYD), showed non-preference toward the highly yellow dwarf-resistant varieties of Firooz-1, Kabara and C4-63A. However, there was preference toward some of the disease resistant varieties such as Ilan-chu-tsu A and Dee-chueh-chu-tsu. The vector-

resistant varieties reacted either as susceptible to yellow dwarf, as in the case of Te-tep and Koasenyu 12, or as moderately susceptible, as in the case of H 105 and MTU 1. Under the field conditions, all these varieties were resistant to the disease. Therefore, there appeared a lack of correlation between resistance to RYD and to its vector.

By artificial inoculation at the seedling stage, the 15 RYD-resistant varieties produced yellow dwarf infection in 0-12% of tested plants, as judged by symptoms observable before ratooning and 0-15% on ratooning. The comparative figures for the 5 RYD-susceptible varieties are 32-62% and 33.3-63.3%, respectively. In the field tests conducted during the second crop of 1975, yellow dwarf symptoms appeared at the booting stage, with an incubation period of 83 days or longer on those resistant varieties. Most of the infected plants showed symptoms only on ratooning and their yield seemed to be very little affected. Of the susceptible variety group, TN 1, Tainan 5 and IR 26 had an incubation period of about 50 days.

Firooz-1 is a rice variety which has been shown to produce no visible symptoms with yellow dwarf. However, from inoculated plants, yellow dwarf could be recovered in a low percentage of the test insects which had fed on the upper leaves of the test plants previously receiving yellow dwarf inoculation.

4. Yellow Dwarf Determined by Time of Symptom Appearance

The yield losses due to rice yellow dwarf were significantly influenced by the time of symptom appearance. In Tainan 5 grown as single plant per hill, yield reduction was 80, 46, 30 and 14% in the first crop when symptoms began to appear at booting, heading, dough ripening and maturing stages, respectively. In the second crop, yield reduction was 99, 89, 53, 39, 24, 19 and 8%, when symptoms first appeared at tillering, booting, heading, full heading, dough ripening, yellow maturing, and maturing stages. In general, yield loss was reduced when symptoms appeared after full heading stage. The percentage of yield reduction could be estimated by the following equations: $Y=777.0593-12.2015X+0.04855X^2$ for the first crop and $Y=37.26395+4.96484X-0.11142X^2+0.00058X^3$, for the second crop, while X represents the plant age at symptom appearance (days after transplanting), Y represents percent yield reduction.

5. Age Distribution of Green Rice Leafhoppers and Remaining RYD-Diseased Plants During Overwintering Period

A survey of age distribution of rice green leafhoppers *Nephotettix* spp. was made

from September, 1975 to February, 1976 at 47 locations in Taichung area. While surveying on the remaining of RYD-diseased ratoon stubble rice plants, samples were taken at four locations where yellow dwarf incidences have usually been high.

In September, 1976, and January and February, 1977, the overwintering population of rice green leafhoppers was 64.51, 67.49 and 84.35 percent adults; 18.75, 12.38 and 8.31 percent of 1-3 instar nymph; and 16.74, 20.23 and 7.34 percent of 4-5 instar nymph respectively. However, in the cooler month, the rate of propagation tended to be lower than the warm period. There were 3.7-6.7 and 0.8-13.3 percent of the surveyed ratoon stubble infected by RYD-disease in December and January during the year of 1975-1976. Apparently, the diseased ratoon stubble was reduced during the cooler month.

The preceding results indicated that the insect vector not only multiplied in the winter season but also acquired the diseased agent from the RYD-diseased ratoon stubble and then transmitted the disease of the following year.

6. Epidemiology of Rice Yellow Dwarf

Active individuals of the rice green leafhoppers, *Nephotettix* spp. that carry rice yellow dwarf (RYD) was found all year round in the field collections. Two peaks are observed each year. The first one was in February-March with 26-29% being active transmitters. They became the main source of inoculum for the first rice crop. The second peak appeared in July-August with 10-36% as active transmitters which transmitted the disease to the second rice crop.

The green leafhoppers that survived in the winter season and carrying the causal agent (an MLO) played a very important role in the spread of RYD. The surviving nymphs of the 7th generation which acquired MLO from the diseased plants in November became the primary source of inoculum in next January and February. On the other hand, the offspring of some adults of the 7th generation may also acquire MLO from diseased ratoons and then transmit it in March and April. However, due to a low population of RYD-diseased ratoons in the cool season, the latter might not constitute an important way of spreading the disease.

Seven species of Gramineous weeds may act as hosts of RYD by artificial inoculation under greenhouse conditions. They are *Leptochloa chinensis*, *Imperata cylindrica*, *Leexsia hexandra*, *Alopecurus aequalis*, *Digitaria setigera*, *Paspalum conjugatum* and *D. Fauriei*. However, the symptoms on these weeds were rarely seen in the field and they might not act as important hosts of MLO in the disease spread.

Infection with RYD mainly occurred in the seedling stage or shortly after transplanting either in the 1st or 2nd crop. Because of low vector population and low

temperature in the early part of the first crop, the disease incidence was usually low and the symptoms appeared only after June, thus the disease exerted little effect on the yield of the first rice crop.

7. Rice Transitory Yellowing Virus and Insect Vector

Rice transitory yellowing virus (RTYV) had an apparent harmful effect on its leafhopper vector, *Nephotettix cincticeps* (Uhler). The average nymphal period of the leafhoppers was 23 days and 21 days for the transmitters and the non-transmitters, respectively, and there were more nymphs of transmitters causing premature death. The average life span of the males and the females that transmitted virus was 18 and 20.8 days, whereas the males and females of non-transmitters lived 21.9 and 26.7 days, respectively. The evidence for the difference in longevity is significant statistically. The deposited egg number of the insects of virus transmitters reduced 35-38% as compared to non-transmitters. However, there was no evidence exhibiting any difference of the hatching percentage of the eggs deposited by transmitters and non-transmitters.

The progeny (F1) of viruliferous insects was more active to acquire the RTYV (55-58%) than the virus-free insects (21-28%). This suggested that the transmission ability was genetically controlled.

8. Factors Affecting Transmission of Rice Transitory Yellowing Virus

Both *Nephotettix cincticeps* and *N. nigropictus* were able to acquire rice transitory yellowing virus at the temperature range of 10-35°C. Efficiency of virus acquisition increased with the increase in temperature, though at 35°C the mortality of the tested insects was high. On daily transfers of viruliferous *N. cincticeps* to healthy plants, a higher transmission rate was obtained at 25 and 30°C, at which there were more skipplings in virus transmission. Keeping the test insects at same temperature throughout the virus acquisition, incubation and inoculation processes, transmission was obtained at 17°C with an incubation period of 48-66 days, but no transmission at 15 and 16°C. There was a marked effect of virus source plants on RTYV transmission. More insects became viruliferous after they had fed on the leaves with severe symptoms (28.4%) or on the diseased plants of susceptible varieties (20.1-34.6%) than those fed on the leaves in rice plants recovered from symptoms (3.3%) or on resistant varieties (9.0-13.3%). Green rice leafhoppers showed a negative preference to RTYV diseased plants on which 7% of the tested insects

landed as compared to 18% landing on healthy plants and 75% of plants infected with yellow dwarf nymphs of *N. cincticeps* were more efficient in transmitting RTYV than adults. Males of this insect were slightly more efficient than females as virus vector, but there was no such efficiency difference in *N. nigropictus*.

The *Nephotettix* leafhoppers collected from 16 locations on the island of Taiwan were all capable to act as RTYV transmission, regardless of whether the disease incidence has been recorded for the locations, or not.

9. Effects of Rice Transitory Yellowing Virus on Yield and Yield Components

In the field conditions, infection with RTYV rarely caused the death of rice plants. However, there was a positive relationship between the degree of yield reduction and the length of heading delay. For both cultivars inoculation at 40 to 60 DAS caused the longest heading delay in the 1st crop, but in the 2nd crop this occurred at 5-35 DAS for TN 5 and at 5-25 DAS for TCS 3.

In a field test with the number of inoculated plants varying from 0, 1, 3 and 5 plants per hill for 5-plant hills, the yield losses increased with the increase in number of plants that were inoculated with RTYV before transplanting.

Under field conditions, the number of plants infected naturally with RTYV was increased as the planting density increased. The percentages of infected hills were 1.5, 2.8 and 3.0% for hills of 1, 4 and 7 plants, respectively, in the 1st crop of 1977; while the corresponding percentages were 40.1, 61.3 and 73% in the 2nd crop. The yield loss was reduced in the 1st crop as the planting density per hill was increased, but no such difference was observed in the 2nd crop.

10. Factors Affecting Transmission of Rice Wilted Stunt

The threshold temperature for the brown planthopper (BHP), *Nilaparvata lugens* to complete the incubation period of rice wilted stunt virus (RWSV) was about 12°C, at which an incubation period of 37.1 days in average was observed. On hourly transfers of viruliferous insects to healthy plants, none of the 15 tested viruliferous insects transmitted the virus at 8°C. Fasting before acquisition feeding significantly increased the transmission ability of the insect. The nymphs were found more efficient to transmit RWSV and had a shorter incubation period than adults. More insects became viruliferous when they fed on leaves (23%) than on stem (16%) or root (14%) of the same diseased plant. There were 4, 27, 24, and 15 percent of the insects became viruliferous when they were allowed to feed on

diseased plants at 10, 30, 60 and 120 days, respectively, after symptom appearance. In comparing two different methods of virus acquisition, no significant difference of the tested insects became transmitter following a natural acquisition feeding on diseased plants and by insect injection with the crude sap of the plants. However, a longer incubation period and a higher mortality of the insects were observed with the injection method.

11. Rice Ragged Stunt and Wilted Stunt Disease and Growth of Rice Plant

Rice ragged stunt (RRS) was first found in the paddy field of Chiayi in 1978. It caused stunting of plants with leaves slightly darker in color than normal and brittle in feeling; the leaves became twisted and ragged. A few veinswellings were found on the lower surface of leaf blades and outer surface of leaf sheaths. Nodal branches were produced on old plants on which the panicles, if any, had mostly unfilled grains. The latent period for symptoms was 8-10 days in summer but extended to more than one month in winter. The brown planthopper, *Nilaparvata lugens* Stal, transmitted the virus with an average latent period of 9.6 days (5-14 days). About 22% (15.2-30.4) of the vector insects were active transmitters. Both male and female were capable of transmitting the virus. The minimal acquisition feeding period was 2 hr, whereas that for inoculation was 1 hr. Efficiency of virus acquisition increased with an increased temperature.

Other six rice insects in Homoptera failed to transmit RRSV. Neither was transmission obtained by soil, seeds or mechanical means.

Rice wilted stunt (RWS) has a significant influence on rice yield reduction. The major yield components such as panicle number, length of panicle, percent of filled grains and weight of one thousand grains of the diseased plant had decreased in proportion to the increase of the age of the rice plant from the time of infection. During the field trials made in the second crop season, infection with RWS resulted in 94, 78, 58 and 39% yield reduction for Tainan 5 when inoculated at 30, 40, 50 and 60 days after germination. Infection with RWS resulted in 96, 59 and 42% yield loss for Taichung Sen 3 when inoculated at 30, 40 and 50 days after germination. With these varieties, there was no yield at all when inoculation were made before 30 days after germination. At the time of transplanting, 1 and 3 plants per hill (planted 5 plants) were inoculated. This caused about 22 to 52% yield reduction.

12. Three Symptomologic Types of Rice Virus Diseases Related to Grassy Stunt

Three rice diseases with virus like symptoms were collected from central Taiwan. The diseases were designated as wilted stunt, grassy stunt B, and grassy stunt Y. Their causal agents were all transmitted by the rice brown planthopper *Nilaparvata lugens* in a persistent manner, with incubation periods in the vector ranging from 3 to 23 days. Symptomatically, wilted stunt was distinct in that it caused extreme plant stunting and was often lethal to rice plants, especially in the winter months. Both grassy stunt B and grassy stunt Y also caused stunting, but they were not lethal to the tested plants. All three disease types stimulated tillering in some rice cultivars in summer; only grassy stunt B had this effect in winter. On the basis of vector-relationships and enhancement of host tillering, these three diseases were tentatively identified as virus diseases related to rice grassy stunt.

13. Cell Inclusions Associated with Wilted Stunt Disease

In rice tissues from plants affected with a new, *Nilaparvata lugens*-vectored disease, known as wilted stunt, a particular type of inclusions was found in the nucleus and cytoplasm of both phloem and mesophyll cells. This appeared to be the first record of such inclusion type relative to a viral disease in rice.

14. Control of Rice Virus Diseases by Granular Chemicals in Seedling Boxes

Three chemicals, viz., 4% Padan G., 3% Furadan G. and 5% Disyston G. were tested to prevent the incidence of the rice virus diseases.

The low incidence of the rice transitory yellowing and the wilted stunt was found in our tested field; Nevertheless, after the treatment of Padan G. at 50 g/box, and 3% Furadan G. at 100 g/box or 125 g/box, the infection rates of the transitory yellowing resulting from these applications were four times as low as that of control, that is, 0.44%, 0.55%, and 0.47%, respectively, while those of the wilted stunt were 0.28%, 0.56% and 0.51%, respectively.

The incidence of the rice yellow dwarf which is caused by MLOs and transmitted by the rice green leafhopper was extremely high in this experiment. The infection rates were 12.33%, 11.47%, and 10.00% by the same dosages as indicated above. These rates were only 3 times less than that of control (33.73%).

The results indicated that application of granular chemicals in seedling boxes before transplanting was not only economical and safe, but also may reduce the infection rate of rice virus diseases transmitted by insect vectors, and therefore increases the rice yield.

B. Upland Crop Diseases

1. Resistance of Wheat and Triticale to Rust and Powdery Mildew

Studies on the resistance of 542 varieties of wheat and triticale to rust and powdery mildew were carried out in the field. On the basis of eight reaction types to rust, the number of wheat varieties as classified into immune, hypersensitive, highly resistant, resistant, moderately resistant, moderately susceptible, susceptible, and highly susceptible were 375, 17, 34, 14, 13, 4, 8 and 17, whereas of the triticale were 15, 4, 1, 1, 11, 14, 11 and 3, respectively.

Based on five reaction types to powdery mildew, the number of wheat varieties as classified into immune, highly resistant, moderately resistant, moderately susceptible, and highly susceptible, were 124, 239, 108, 10 and 1, respectively. All of the triticale lines/varieties were immune to powdery mildew.

C. Orchard Diseases

1. Chemical Control of Loquat Pink Disease

Forty-three fungicides were incorporated in PDA plates for testing the growth of *Corticium salmonicolor*, the causal agent of loquat pink disease. Eight kinds of fungicides named Rovral M 50% WP 750X, Benlate 50% WP 3000X, Topsin-M 70% WP 1000X, Mertect 40% EC 500X, Delan C 56% WP 500X, Cuprosan 311 super D 72.5% WP 500X, Bavistin 50% WP 1500X and Benlate-C 60% WP 500X, were found to inhibit fungal mycelial growth and were released to control loquat pink disease in the field. Investigation on spore density of *Corticium salmonicolor* in Tungshih and Hsinshih by spore trap showed that spore density increased from middle February so that it was suggested to start fungicidal spray on February or March for controlling loquat pink disease. Fungicide treatments in the field showed that Rovral M 50% WP 750X and Cuprosan 311 super D 72.5% WP 500X, were the two best fungicides for controlling loquat pink disease.

D. Vegetable Diseases

1. Bitter Gourd Wilt Physiological, Thermal Death Range of Pathogen

Fusarium oxysporum f. sp. *momordicae* was the causal organism of bitter gourd wilt. This pathogen grew best on PDA under 24°C, water potential from -1 to -10 bars, arabinose and galactose as the best carbon source, glycine and glutamic acid as suitable nitrogen source.

Temperatures in 35-60°C for different time periods were lethal to *F. oxysporum* f. sp. *momordicae*. At 45° and 50°C, the exposure time for a LD₅₀ were 100 and 40 minutes respectively. Propagules density of fungi was greatly reduced in field soils solarized for the necessary time period. The exposure time and temperatures necessary to kill this fungi were useful for evaluating the progress of soil solarization under field conditions.

E. Sugarcane Diseases

1. Mild Mosaic and Severe Mosaic of Edible Sugarance

This field experiment was conducted at Puli to compare the influence of mild mosaic and severe mosaic of edible sugaranes, collected from 4 Hsiens of Nantou, Yunlin, Chiayi and Tainan on the stalk growth and sucrose content.

The result showed no significant difference between the two types of mosaic regarding the mean length and circle length of sixth internode, the mean total length of fifth, sixth and seventh internodes and the mean weight of ten stalks. However, there was difference among locations.

The mean content of sucrose showed that there was significant difference at 1% level between two types of mosaic or among locations.

2. Control of Edible Sugarcane Mosaic Virus

The hot-water treatments showed that edible sugarcane mosaic virus was not inactivated by 7-min. treatments at daily intervals at temperatures of 55, 56, 57 and 57°C, respectively, or 55, 57, 57 and 57°C, respectively, or 50, 52, 54, and 56°C, respectively for four days. Neither did by 10-min. treatments at daily intervals at temperature of 54°C for four days, nor by 10.5-min. treatments at temperatures of 55°C and 56°C for two days.

However, the mosaic virus-free edible sugarcane seedling was obtained by apical meristem culture in which an excised apical dome (1-2mm) was cultured on modified Murashige and Skoog medium supplemented with active carobon (300mg/l).