Resistance to *Nephotettix virescens*[1] in Rice Varieties[2]

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ABSTRACT

Greenhouse evaluations of 879 rice varieties and selections revealed that several are highly resistant to *Nephotettix virescens* (Distant). Resistant varieties generally were not preferred by adults and nymphs. Also, insects caged on these plants suffered high mortality. On highly resistant varieties, only 0.3% of the 1st instars reached the adult stage, whereas on susceptible varieties 76–90% became adults. Except for a few varieties on which different instars had different mortality rates, all instars had identical mortality rates on resistant varieties. Adults had 4 to 8 times longer life spans and laid about 15 times more eggs on susceptible than on resistant varieties. The population declined rapidly on resistant varieties, whereas it increased cumulatively on susceptible varieties.

The insect made more probing punctures in the most resistant varieties than in the susceptible varieties but did little feeding; consequently, resistant varieties were seldom damaged. Histological studies of the leaf blades of resistant and susceptible varieties revealed no mechanical barrier to the insect's feeding.

Nephotettix virescens (Distant) is one of the most destructive insect pests of rice throughout Asia (Nasu 1964, Pathak 1968) and damages rice by feeding on it and by transmitting viral diseases. It is the vector of yellow dwarf, tungro, penyakit merah, yellow-orange leaf, and leaf-yellowing viral diseases of rice (Ling 1968). Losses caused by direct feeding were particularly severe in central Vietnam and East Pakistan (Tao 1962, Alam 1964).

Use of insecticides is the only known method for protecting rice crops from damages caused by this insect. Recent studies at the International Rice Research Institute (IRRI), however, revealed that certain rice varieties have a very high level of resistance to the insect (Pathak et al. 1969). Reported herein are studies undertaken to identify additional sources of resistance in rice varieties to this insect, effect of resistant rice varieties on the insect, and factors responsible for varietal resistance.

MATERIALS AND METHODS.—*Rearing Test Insects.*—Insects were mass-reared from adults collected at the experimental farm of IRRI. They were examined for virulence by the seedling test method (Nasu and Suenaga 1961, Ling 1968). Virus-free insects were caged for multiplication on potted plants of 'Taichung Native 1,' a susceptible variety. Cages were 42×42×160 cm and had a wooden frame with glass panels on the front, back, and top and nylon cloth on the remaining 2 sides.

Insects of about the same age were obtained by caging ovipositing insects on plants for short periods. Insects were reared to desired instars from eggs laid on the plants.

Screening for Varietal Resistance.—Test varieties were grown in seed boxes in rows 20 cm long (ca. 1/2 width of the seedbox) spaced 10 cm apart. Each seed box contained 10 rows. One row was planted with the susceptible check variety Taichung Native 1, another with the resistant check variety 'Pankhari 203,' and the remaining 8 rows contained test varieties. All varieties were sown in 2 replications. One week after seeding, seed boxes were placed on a tray inside a 6.5×3.6×3-m screen cage within a greenhouse. Each row was thinned to 20 seedlings, and a large population of 2nd and 3rd instars was scattered uniformly on test plants. Water was maintained at a depth of 4–5 cm in the tray to keep humidity high and to protect plants from ants.

The number of insects present and plant damage were recorded for each variety at 5-day intervals until most plants of the susceptible check variety were killed. The following grades were used for recording plant damage: 0, no visible damage; 1, partial yellowing of the 1st leaf; 2, partial yellowing of the 1st and 2nd leaves; 3, pronounced yellowing and slight stunting; 4, signs of wilting and severe stunting; 5, plants killed.

The same procedure was used for retesting selected varieties. Studies on insect-host plant interrelationships were conducted by caging insects either on potted plants in a greenhouse or on seedlings growing in a nutrient culture inside 30×3 cm test tubes, kept in an incubator at 29±1 C, 14 hr daylight, and 70–100% RH.

Preferences of nymphs and adults for different varieties were studied in separate experiments. Preference of nymphs was tested by using the same procedure of the general screening tests, except that the population of nymphs on each variety was recorded every 2 days until 14 days after infestation.

To test the preference of adults, 10 plants of each variety were transplanted randomly in seed boxes at a spacing of 10×10 cm. At 30 days after transplanting, plants were thinned to contain 1 tiller plant, and a large population of 3-day-old adults was released on them. The number of adults present and the number of eggs laid on each plant were recorded.

To study the longevity of adults and the average number of eggs laid per female on different varieties, a pair of adults was caged on individual plants grown in a culture solution in a 40×250-mm test tube. Insect mortality was recorded every day. Every 4 days, plants were replaced with healthy plants of the same variety. The eggs laid on these discarded plants were counted by dissecting the plants under a binocular microscope.

Feeding by N. virescens *on Resistant and Susceptible Varieties.*—The amount of feeding on different varieties was assessed by the change in the insects' body weights and by the quantity of honeydew excreted. Specimens of *N. virescens* were kept without food for 2 hr, weighed, caged for 4 hr on the 15-day-old seedlings growing in hydroponics in 30×170-mm

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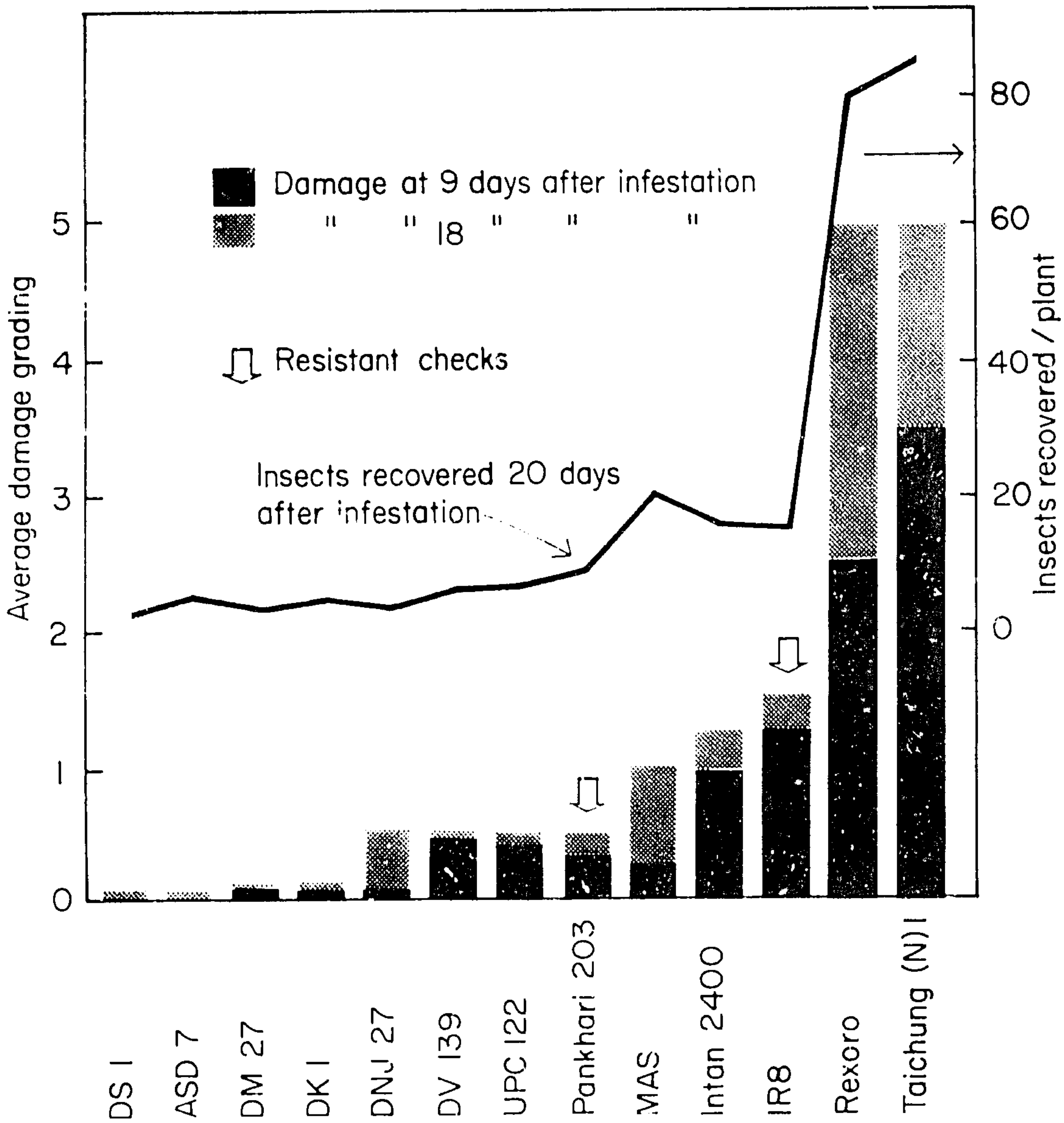

FIG. 1.—Survival of and damage by 100 *N. virescens* 2nd instars on 20-day-old seedlings of different varieties of rice. Avg of 10 replications.

test tubes, then weighed again. For honeydew studies, 3-day-old females were used. These first were kept without food for 2 hr and then placed on individual plants in groups of 5 inside conical cages of mylar sheet. Filter paper placed at the bottom of this cage absorbed the honeydew excreted by the insects. There were 10 replications of each variety. The filter paper was removed 18 hr after the plants were infested, and the honeydew on it was assessed by either dipping the filter paper in ninhydrin, which stained the honeydew spots pinkish yellow, or by measuring the total sugar and amino acid contents of the honeydew colorimetrically.

Feeding behavior of the insect was studied on different varieties to determine the cause of restricted feeding on resistant varieties. The number and distribution of feeding marks on a variety were determined by caging a newly emerged female for 24 hr on the 2nd leaf of a 10-day-old seedling. Then the leaf was dipped in a 1% erythrosine solution which stained the feeding marks (Naito 1964). The termination of the stylet sheaths in the plant tissues was studied with microtomic sections 15μ thick (Sass 1958, Jensen 1962) of the feeding sites on 20-day-old plants. FAA solution was used for fixing, butyl alcohol for dehydrating, and safranin and fast green for staining these sections.

RESULTS AND DISCUSSION.—*Differences in Varietal Resistance*.—A total of 879 varieties was tested for resistance to *N. virescens*. In most experiments, several varieties were distinctly damaged ca. 1 week after infestation, and susceptible check and other susceptible varieties were killed within 2 weeks. Generally, insects preferred susceptible varieties but migrated

Table 1.—Preference among selected rice varieties and damage caused on them by *N. virescens* nymphs[a], IRRI. 1969.

Variety	Insects (no. seedling) Day after infestations		Plant damage[b]
	3	9	
DV 139	0.5	0.9	1.0
'IR 110-136-3'	.6	.2	0.5
'HR 107'	.5	.7	1.0
'MAS'	.5	1.2	1.0
'Betong'	.7	1.1	1.0
'Khama 49 2'	.7	.5	1.0
Intan 2400	.7	.8	1.0
'ADT 11'	.7	.7	.5
'ASD 9'	.9	.3	1.0
DS 1	.4	.8	1.0
UPC 122	1.1	.8	1.0
'Lemkan-mi-thow-gao'	1.2	.8	1.0
Pankhari 203	1.2	.9	1.0
DK 1	1.2	.4	1.0
ADT 27	1.4	1.8	1.0
'TKM 6'	1.5	.9	2.0
'Peta'	1.5	.2	2.0
'DM 77'	1.5	2.7	1.5
'DV 29'	1.6	.4	1.0
'Ptb 19'	1.7	.5	1.0
ASD 7	1.7	.2	1.0
DM 27	1.7	1.5	1.0
IR8	1.7	.5	1.5
'Kalimakri 391'	1.7	2.3	1.5
'Sukali'	1.8	.5	1.0
'DNJ 27'	1.8	.2	1.0
'Bir-co-se-mao'	2.2	.5	1.0
'Szu-Miao'	2.4	2.3	1.5
'S53-6463'	4.0	2.3	5.0
Rexoro	5.2	[c]	5.0
'DD 106'	5.5	[c]	5.0
'Mudgo'	5.7	1.5	2.5
Taichung Native 1	11.0	2.2	1.0

[a] Avg of 2 replications, each consisting of 20 seedlings variety.
[b] See text for explanation of grades.
[c] Plants were killed.

to other varieties after susceptible lines were damaged severely. Usually, however, the insect population declined rapidly after susceptible varieties were killed.

In these tests, 111 varieties were moderately to highly resistant. In retesting experiments, ca. 30 were found to be highly resistant. These varieties were further evaluated by caging 100 2nd instars on individual plants. Ten 30-day-old plants of each variety were used. The 1st symptom of plant damage was retardation of growth, followed by yellowing of lower leaves, and finally by drying of the whole plant. On varieties 'IR8,' 'Intan 2400,' Taichung Native, 1 and 'Rexoro,' yellowing of lower leaves occurred by 6 days after infestation, but no damage was apparent on other varieties. In subsequent observations, damage on Taichung Native 1 and Rexoro increased considerably, and these varieties were killed by 18 days after infestation, whereas IR8 and Intan 2400 suffered only moderate damage. Other varieties were damaged only slightly (Fig. 1). Survival of insects on these varieties varied from ca. 80% on Rexoro and Taichung Native 1 to less than 5% on 'DS 1,' 'ASD 7,' 'DM 27,' and 'DK 1.' In general, damage to different varieties depended on the number of insects that survived on them.

Differences in the nymphs' preference for different varieties were most evident at 3 days after infestation, when up to 22 times more insects were recorded on susceptible than on resistant varieties (Table 1). Subsequently, as preferred varieties were damaged, the insects migrated to the less preferred varieties, but many varieties remained comparatively insect free and suffered little damage. Also, after susceptible

Table 2.—Preference and oviposition by *N. virescens* adults on selected rice varieties, IRRI. 1969.

Variety	Insects[a] (no. plant)		Eggs (No. plant)
	Male	Female	
DNJ 27	70	80	120
DV 139	90	80	130
ASD 7	80	90	125
ADT 27	80	90	165
DK 1	125	120	105
MAS	125	120	120
Intan 2400	100	125	165
Pankhari 203	110	155	118
IR8	110	160	110
Szu-Miao	75	275	150
Taichung Native 1	280	670	175
Rexoro	110	925	140

[a] Based on 12 different observations.

Table 3.—Survival of 1st instar *N. virescens* on selected rice varieties[a], IRRI. 1969.

Variety	Survival (%), days after caging		
	2	10	22
HR 107	3	0	0
DNJ 27	3	0	0
DM 27	4	0	0
DS 1	4	0	0
ASD 7	4	0	0
DK 1	6	0	0
IR8	6	0	0
ADT 27	7	0	0
Khama 49 2	8	3	0
DM 77	9	0	0
Kalimakri 391	11	0	0
DV 139	11	0	0
DV 29	11	8	5
'Khama 49 8'	11	0	0
MAS	13	0	0
Betong	18	0	0
Lemkan-mi-thow-gao	18	2	0
Peta	19	5	0
PTB 19	20	16	5
Intan 2400	22	0	0
ASD 9	23	10	6
'IR 110-136-3'	29	16	6
UPC 122	32	1	1
Bir-co-se-mao	33	5	1
'Su-vai 20'	38	1	1
'Sukali'	38	18	15
Pankhari 203	55	15	7
TKM 6	93	75	55
Rexoro	92	89	58
DD 106	95	88	60
'S53-6462'	96	90	85
Mudgo	97	88	65
Su-Miao	98	95	75
Taichung Native 1	100	93	93

[a] Avg of 8 replications. Each replication consisted of caging 10 1st instars on an individual plant of a variety.

Table 4.—Survival of *N. virescens* nymphs on 15-day-old seedlings of selected resistant and susceptible rice varieties,[a] IRRI. 1969.

Variety	Survival (%), instar 1st	2nd	3rd	4th	5th	Mean
	Resistant varieties					
DS 1	0.0	1.3	0.2	0.0	0.0	0.3
DM 27	.5	3.3	.0	.0	.5	.9
DK 1	.5	1.3	.0	.5	2.0	.9
DNJ 27	.5	1.3	3.0	.5	5.3	2.1
ASD 7	4.7	3.3	12.0	8.0	.5	5.7
Pankhari 203	4.7	11.3	3.3	4.0	1.3	4.9
UPC 122	5.3	6.0	4.7	2.7	.5	3.8
IR 8	9.3	8.0	5.0	5.3	3.3	6.2
MAS	12.0	11.3	8.0	6.7	2.7	8.1
Intan 2400	12.7	14.0	12.7	3.3	.5	8.6
	Susceptible varieties					
Rexoro	96.0	96.7	98.0	95.3	91.0	96.0
Taichung Native 1	97.3	94.7	96.7	96.0	98.0	96.5

[a] Avg of 150 nymphs at each instar on each variety. Observations were made 3 and 4 days after caging of each instar.

varieties were killed, the population of *N. virescens* declined rapidly. Thus, besides not being preferred, resistant varieties adversely affected the leafhopper population.

Adult *N. virescens* differed in preference for various varieties as early as 3 hrs after infestation. These differences were greater in later observations. As for the nymphs, adults also preferred susceptible varieties to resistant ones (Table 2). Adults showed identical varietal preferences, but the male tended to be less consistent in its host preference.

In spite of the distinct differences in the insects' preference for different varieties, preference for a variety and the number of eggs it laid on it were not correlated ($r = 0.0327$ $< 5\%$). Several resistant varieties received as many eggs as the susceptible varieties. This fact is not consistent with the general behavior of most insects (most insects lay fewer eggs on nonpreferred hosts (Pathak 1970)), but it shows that

Table 5.—Longevity and oviposition of *N. virescens* on some resistant and susceptible rice varieties, IRRI. 1969.[a]

Variety	Life span (days) Male	Female	Eggs (mean)
	Resistant		
DV 139	2.6	2.7	6.8
DS 1	2.9	2.2	11.5
ADS 7	3.8	3.7	12.8
DK 1	3.4	4.0	13.3
Pankhari 203	3.6	3.8	13.8
DM 27	3.7	3.8	14.3
DNJ 27	4.0	3.8	16.8
IR8	2.6	2.7	19.3
	Susceptible		
Taichung Native 1	18.3	17.0	276.5
Rexoro	15.6	19.0	301.8
LSD 5%	4.2	3.1	124.9

[a] Avg of 30 insects on each variety.

Table 6.—Population developed in 32 days from 5 pairs of 1-day-old *N. virescens* adults on selected rice varieties, IRRI. March 1969.

Variety	Insects recovered, no. plant Adult	Nymph	Total	Plant damage[a]
	Resistant			
DS 1	0.0	0.0	0.0	0.1
DK 1	.1	.3	.4	.1
DM 27	1.9	1.1	3.0	.1
ASD 7	.7	9.8	10.5	.2
UPC 122	.4	11.9	12.3	.2
ADT 27	1.4	12.6	14.0	.2
DV 139	2.7	15.8	18.5	.2
DNJ 27	2.6	21.8	24.4	.5
Pankhari 203	7.2	29.9	31.7	.5
IR8	29.5	15.1	44.6	1.0
Intan 2400	5.2	48.0	53.2	1.0
Lemkan-mi-thow-gao	5.8	69.3	74.0	1.0
MAS	6.4	68.3	74.7	1.0
	Susceptible			
Szu-Miao	24.2	267.8	292.0	5.0
Taichung Native 1	148.4	143.7	292.1	4.0
Rexoro	161.2	141.2	302.3	4.0
LSD 5%	19.14	27.07	32.99	

[a] See text for explanation of the grades.

the insects readily oviposited during the short periods that they settled on the resistant varieties. Resistant varieties were not damaged greatly, since the insects did no sustained feeding on them.

Survival of N. virescens *on Resistant and Susceptible Varieties.*—At 2 days after 1st instars were caged on 35-day old plants, ca. 90% of the nymphs died on most of the resistant varieties, whereas less than 10% died on susceptible varieties (Table 3). At 22 days after being caged, 90% of the caged nymphs had become adults on the susceptible check variety Taichung Native 1, whereas few survived on resistant varieties. Besides higher mortality, nymphs developed slower on resistant than on susceptible varieties; this was evident in a longer nymphal period on resistant than on susceptible varieties. Also, all instars suffered high mortality on all resistant varieties (Table 4). There were some differences in their mortality on a few resistant varieties which indicated differences in the nature of their resistance. However, additional data are required for definite conclusion.

Adults had a much longer average lifespan on susceptible than on resistant varieties (Table 5). On resistant varieties, highest mortality of the insects usually occurred during the 1st 2 days after caging, whereas little mortality occurred on susceptible varieties. The adults had similar life spans on each variety.

Fifteen to 20 times more eggs were laid on susceptible than on the resistant varieties. This result is in contrast to that shown in Table 2. Apparently, when caged on both susceptible and resistant varieties, insects oviposited on resistant varieties, but when caged on resistant varieties only, oviposition was restricted. Furthermore, there was a positive correlation ($r = 0.9937$) between longevity of the females and the number of eggs laid on a variety.

Data on survival of *N. virescens* and on oviposition show that the insect may not be able to maintain

Table 7.—Gain in body weight[a] of *N. virescens* caged 4 hr on selected rice varieties.

Variety	Gain in body weight (mg/insect) Min.	Max.	Mean
	Resistant		
DM 27	0.22	0.32	0.28
DNJ 27	.20	.36	.29
DV 139	.22	.34	.30
DK 1	.24	.38	.33
DS 1	.32	.36	.35
ASD 7	.32	.38	.35
IR 8	.30	.48	.37
	Susceptible		
Taichung Native 1	.36	.48	.43
Rexoro	.36	.56	.48
LSD 5%			.04

[a] Insects were kept without food 2 hr before being caged on these plants.

populations on some resistant varieties. Results of caging 5 pairs of newly emerged adults on resistant and on susceptible varieties showed that 30 days after infestation no living insects were on the variety DS 1. Most other resistant varieties had few insects, whereas susceptible varieties had many (Table 6). Also, susceptible varieties were damaged severely, whereas resistant varieties showed little damage.

On all varieties, insects gained weight, indicating that they fed even on highly resistant varieties. They gained significantly more weight on susceptible varieties than on all of the resistant varieties (Table 7). The insects gained significantly more weight on IR8 than several other resistant varieties. This fact may explain the reason IR8 plants show some damage when caged with the insect. But after several days of caging, the insects suffered high mortality, indicating that IR8 had an antibiosis effect on the green leafhopper. These results differ from the finding that a planthopper, *Nilaparvata lugens* (Stål), generally lost weight when caged on resistant rice varieties (Sogawa and Pathak 1970).

Less honeydew was excreted by insects caged on resistant than on susceptible varieties. On susceptible varieties Taichung Native 1 and Rexoro, excreted honeydew contained 20-30 times more amino acids or total organic matter than that on most of the resistant varieties (Table 8). Also, quantities of excreted honeydew show that the insects did more feeding than on other resistant varieties.

There were 1.5-4 times more feeding punctures on resistant than on susceptible varieties (Table 9). Probably the insects made more exploratory punctures in resistant varieties to locate feeding sites than they did in susceptible varieties. In both resistant and susceptible varieties, the proboscis was inserted mostly through parenchymatous cells. Although more feeding punctures were made near fiber cells in susceptible than in resistant varieties, the stylets terminated mostly in the vascular bundles irrespective of the sites of penetrations. Larger percentages of stylet sheaths terminated in the vascular bundles in susceptible than in resistant varieties. This did not appear to be a major factor of resistance, since even in the most resistant varieties, 71% of the stylet insertions reached vascular bundles, and the insects made more punctures in resistant than in susceptible varieties (Table 9).

A positive correlation (r = 0.748, P = 5%) was recorded between the thickness of leaf blades (in the nonvascular bundle area) and the percentages of stylet sheaths terminating in vascular bundles. The resistant varieties DK 1, DM 27, 'DV 139', and 'ADT 27' had thinner leaf blades than the other varieties. However, distances between vascular bundles of different varieties and termination of the stylet sheaths in them were not correlated. Stylet sheaths were long enough to reach vascular bundles from any point of insertion in the leaf blade. Usually the stylets seemed to reach the vascular bundles with the 1st puncture, but occasionally, feeding tracts were 2 or 3 branched, indicating that the proboscis was reoriented to reach phloem tissues. Thus, it is concluded that resistance to the green leafhopper in these varieties is not due

Table 8.—Analysis of honeydews excreted by 5 female *N. virescens* on different rice varieties,[a] IRRI, 1969.

Variety	Spectrophotometer absorbance for Organic matters[b]	Amino acids[c]	Sugars[b]
	Resistant		
DS 1	0.07	0.17	3.22
ASD 7	.08	.11	2.76
DNJ 27	.08	.19	3.25
UPC 122	.09	.12	2.81
DM 27	.09	.39	2.21
DV 139	.10	.66	3.05
Pankhari 203	.10	.73	2.66
DK 1	.11	.76	3.18
Intan 2400	.13	.98	5.96
ADT 27	.16	1.01	5.27
MAS	.28	1.01	3.84
IR8	.56	3.20	6.22
	Susceptible		
Taichung Native 1	3.39	4.43	14.24
Rexoro	4.52	5.42	18.36
LSD 5%	.22	.32	1.16

[a] Avg of 8 replications.
[b] Absorbance at 625 mμ.
[c] Absorbance at 500 mμ.

Table 9.—Number of feeding punctures made by *N. virescens* adults on the leaf blades of selected resistant and susceptible rice varieties,[a] IRRI, 1969.

Variety	Punctures/insect per hour Min	Max	Mean
DM 27	4.7	12.0	8.4
DV 139	2.5	10.8	6.4
DS 1	2.8	6.5	5.5
DK 1	2.7	8.0	5.3
ASD 7	3.2	7.2	5.4
DNJ 27	2.3	7.7	3.8
IR8	1.8	6.0	3.5
Taichung Native 1 (Susceptible)	2.0	3.5	2.5
Rexoro (Susceptible)	1.8	2.5	1.9
LSD 5%			2.3

[a] Avg of 10 replications. Insects were caged individually on a seedling 6 hr.

to mechanical factors that interfere with the feeding of the insects. However, the insects did little feeding on resistant varieties, indicating that they either lacked phagostimulants or possessed feeding deterrents. Such factors apparently were absent in resistant variety IR8 on which the insects did more feeding than on other resistant varieties, but they still suffered high mortality. This fact indicated that IR8 plants either possessed materials toxic to the *N. virescens* or lacked nutrients vital for the survival of this insect.

REFERENCES CITED

Alam, M. Z. 1964. Insect pests of rice in East Pakistan, p. 643-55. *In* Proceedings of a symposium on the major insect pests of the rice plant, September 1964. Int. Rice. Res. Inst., Los Baños, Philippines. Johns Hopkins Press, Baltimore. 729 p.

Jensen, W. A. 1962. Botanical Histochemistry: Principles and Practice. W. H. Freeman, San Francisco. 405 p.

Ling, K. C. 1968. Virus Diseases of Rice Plant. Int. Rice Res. Inst., Los Baños, Philippines. 52 p.

Naito, A. 1964. Method for examination on the feeding marks of leafhopper and planthoppers and its application. Jap. Plant. Prot. 18: 482-4.

Nasu, S. 1964. Taxonomy, distribution, host range, life cycle and control of rice leafhopper. p. 493-523. *In* Proceedings of a symposium on major insect pests of the rice plant, September 1964. Int. Rice Res. Inst., Los Baños, Philippines. Johns Hopkins Press, Baltimore. 729 p.

Nasu, S., and H. Suenaga. 1961. A testing method for detection of insects infected virus disease of rice plant. [In Japanese.] Kyushu Agric. Res. 22: 213-5.

Pathak, M. D. 1968. Ecology of common insect pests of rice. Annu. Rev. Entomol. 13: 257-94.

1970. Genetics of plants in pest management, p. 138-57. *In* R. L. and F. E. Guthrie [ed.] Concepts of Pest Management. N. C. State Univ., Raleigh. 242 p.

Pathak, M. D., C. H. Cheng, and M. E. Fortuno. 1969. Resistance to *Nephotettix impicticeps* and *Nilaparvata lugens* in varieties of rice. Nature (London) 223: 502-4.

Sass, J. E. 1958. Botanical Microtechnique. 3rd ed. Iowa State Univ. Press, Ames. 228 p.

Sogawa, K., and M. D. Pathak. 1970. Mechanisms of brown planthopper resistance in Mudgo variety of rice (Hemiptera: Delphacidae). Appl. Entomol. Zool. 5: 145-58.

Tao, C. H. 1962. Preliminary report on the investigation of rice leafhoppers and planthoppers and their control measures at Chiayi, Taiwan in 1962. Plant Prot. Bull. (Taiwan) 5: 42-50.

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