crotophos, Lannate, UC-30045, UC-34096, and VCS-506.

The location of the tests did not affect results. In Florida, population pressure can be extreme resulting in 100% damaged plants in untreated checks. Materials and rates which prevented damage in one area of Florida gave comparable results in the other area with similar population pressure.

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Ability of *Nephotettix apicalis*[1] to Transmit the Rice Tungro Virus[2]

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ABSTRACT

The transmission of tungro disease of rice in the Philippines and of similar diseases in other countries by *Nephotettix impicticeps* Ishihara is now generally accepted. On the other hand, the transmission of the disease by *N. apicalis* (Motschulsky) has not yet been established, with contradictory results being reported in the literature. To help settle the problem, a taxonomic-transmission study was made and the results are presented in this paper.

N. apicalis was found to be capable of transmitting the rice tungro virus. However, the percentage of active transmitters varied among the insects collected from different localities or even from the same locality. A higher percentage of positive transmission was obtained by testing the insects daily after an acquisition feeding for 5 days and after providing them with daily reacquisition feedings.

The virus-vector interaction of *N. apicalis* did not differ fundamentally from that of *N. impicticeps*. The virus did not persist in the vector. However, *N. apicalis* was less able to transmit the tungro virus than *N. impicticeps* because the percentage of active transmitters, virus retention period, and number of disease-transmitting days of the former species were significantly lower than those of the latter.

The morphological features of the active transmitters of *N. apicalis* such as location of tegminal spots, length of aedeagus, arrangement of teeth on aedeagus, and number of teeth did not differ significantly from those of the nonactive transmitters.

The transmission of rice tungro and of similar diseases by *Nephotettix impicticeps* Ishihara has been demonstrated by investigators in different rice-growing countries such as India (tungro—John 1968; leaf yellowing—Raychaudhuri et al. 1967), Indonesia (tungro—Rivera et al. 1968), Malaysia (penyakit merah—Ou et al. 1965, Singh 1969), Pakistan (tungro—Nuque and Miah 1969), Philippines (tungro—Ling 1966, Rivera and Ou 1965), and Thailand (tungro—Lamey et al. 1967; yellow-orange leaf—Wathanakul and Weerapat 1969).

The transmission of the disease by *N. apicalis* (Motschulsky), on the other hand, has not yet been settled, with contradictory results being reported in the literature even from the same country. Positive transmission of the disease by *N. apicalis* has been reported by several investigators (Fajardo et al. 1964, Rivera and Ling,[4] Wathanakul et al. 1968, Wathanakul and Weerapat 1969). However, similar attempts by others have failed (John 1968, Lamey et al. 1967, Ling 1968, Raychaudhuri et al. 1967, Singh 1969). Since the general morphology of *N. apicalis* appears similar to that of *N. impicticeps* and both species are widely distributed in the tropical region (Nasu 1969), a taxonomic-transmission study has been suggested by some workers to help settle the problem. This paper reports the results obtained from one such study.

MATERIALS AND METHODS.—*N. apicalis* insects were collected from different localities in the Philippines or from the same locality but at different dates. After acquisition feeding on tungro-diseased plants, the male adults were tested individually for their infectivity by a method described earlier (Ling 1966). The external morphological features of individual insects were examined after inoculation feeding, and the genitalia of the insects were dissected after soaking in 10% KOH solution. The aedeagus was examined under a high-power microscope.

In some cases, the insects were allowed a daily reacquisition feeding, i.e., after acquisition feeding, the insects were used for transmission tests conducted daily from 8 AM to 5 PM and confined individually on diseased leaves in test tubes until the succeeding test.

The transmissive ability of *N. apicalis* was compared with that of *N. impicticeps* reared on caged rice plants.

RESULTS.—*Morphological Features.*—The morphological features of the male *N. apicalis* adults ex-

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[4] C. T. Rivera and K. C. Ling. Transmission of rice tungro virus by a new vector, *Nephotettex apicalis*. Paper presented at the 5th Annual Meeting of the Philippine Phytopathological Society, Davao, Philippines. May 10–12, 1968.

amined generally agreed with previous descriptions (Ishihara 1964, Ishihara and Kawase 1968, Nielson 1968), especially in regard to the presence of a submarginal black band on the vertex. However, there were deviations in the number and arrangement of teeth or spines on the aedeagus. The teeth were generally arranged in 2 rows but, in some cases, 1–4 teeth were arranged irregularly or almost linearly on one side or on both sides of these 2 main rows (Fig. 1). Furthermore, the arrangement of the teeth on the 2 main rows was not always symmetrical or equinumeral (Fig. 2). The actual number of teeth observed ranged from 10 to 23 with a maximum frequency of 14 to 17; this was not in agreement with the other records of 7 pairs (Ishihara 1964) or 7 to 9 pairs (Nielson 1968).

The samples of *N. impicticeps* insects showed a similar deviation in the number and arrangement of teeth (Fig. 3). The number of teeth observed varied from 4 to 10 with a maximum frequency of 7 to 8 instead of the earlier reported 4 pairs (Ishihara 1964) or 3 to 4 pairs (Nielson 1968).

Based on the morphology of the *N. apicalis* and *N. impicticeps* insects examined, the following key is proposed for separating these 2 species:

Aedeagus without elongated paraphyses and hardly constricted below paraphyses. Style straight.

1. Vertex with a submarginal black band. Tegminal spots often present and confluent along the claval suture. Aedeagus with a total of 10 to 23, mostly 14 to 17 teeth. .... ***N. apicalis***
2. Vertex without a submarginal black band. Tegminal spots present or absent; if present, not confluent along the claval suture. Aedeagus with a total of 4 to 10, mostly 7 to 8 teeth. .... ***N. impicticeps***

Transmission of the Tungro Virus.—Forty-seven out of 733 insects from 10 samples collected from different localities in the Philippines or from the same locality but at different dates transmitted the rice tungro virus after an acquisition feeding of 4 to 5 days. The percentages of active transmitters of the 10 collections were 0, 0.96, 2.00, 2.68, 2.86, 5.00, 8.33, 10.00, 10.00, and 27.17. The variation existed not only among the samples collected from different localities but also among those collected from the same locality.

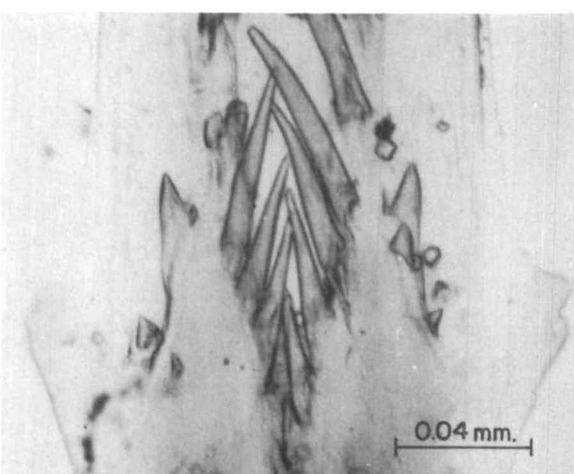

FIG. 1.—Portion of aedeagus of *N. apicalis* showing teeth on each side of the 2 main rows of teeth.

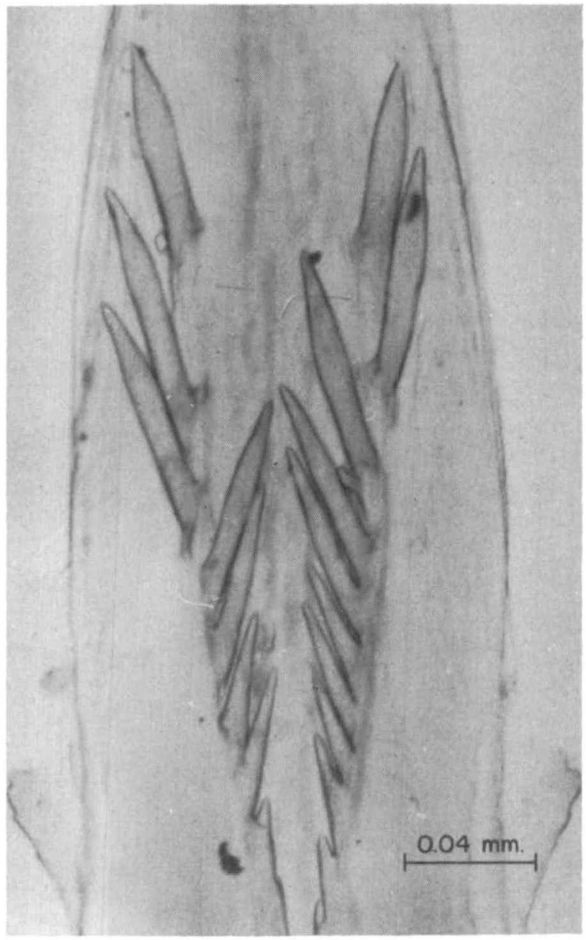

FIG. 2.—Portion of aedeagus of *N. apicalis* showing asymmetrical arrangement of teeth.

When insects were tested daily for 4 consecutive days after an acquisition feeding of 5 days and after being provided with daily reacquisition feedings, the percentages of active transmitters were 14.77 and 45.00 for 2 collections of 88 and 100 insects, respectively.

Transmissive Ability.—The percentage of active transmitters of 352 *N. apicalis* insects tested was significantly lower than that of 372 *N. impicticeps* insects tested under the same conditions whether or not there were daily reacquisition feedings (Table 1). Nevertheless, the percentage of active transmitters of both species increased significantly when daily reacquisition feedings were provided.

The percentage of infective *N. apicalis* insects did not always increase proportionally with the duration of the acquisition feeding period. The increase depended on the activity of the insects. For instance, when a colony with a very low percentage of active transmitters was used, the percentage of infective insects remained similar even if the acquisition feeding period varied from 1 to 4 days. However, a higher percentage of infective insects was often obtained from an acquisition feeding period of 4 to 5 days than from that of 1 day.

FIG. 3.—Portions of aedeagus of *N. impicticeps* showing arrangement of teeth.

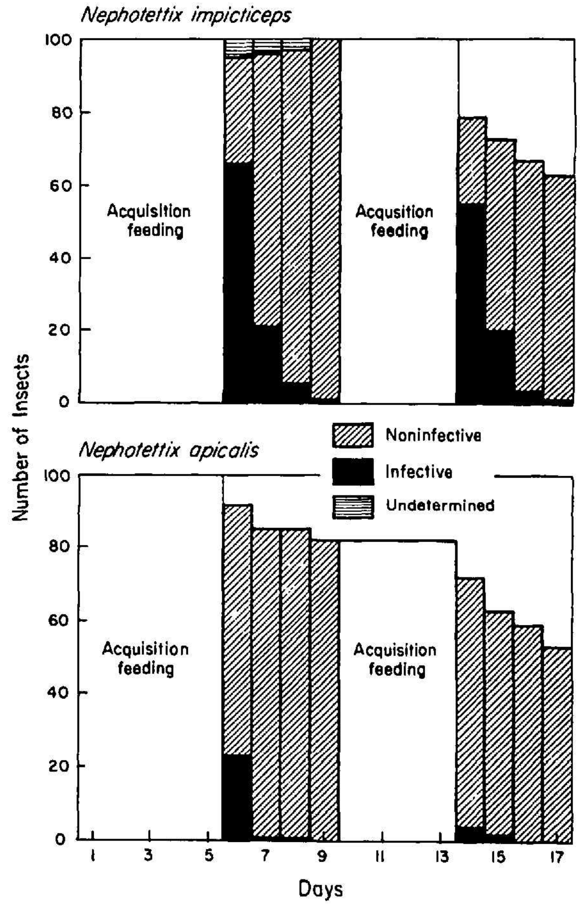

FIG. 4.—Daily serial transmission of rice tungro virus by *N. impicticeps* and *N. apicalis.*

Daily serial transmission tests showed that the percentage of infective insects of both species decreased gradually with time following the termination of acquisition feeding (Fig. 4). Once the insect lost their infectivity, they remained noninfective until their death unless given access to another virus source. The longest virus retention period of *N. apicalis* (3 days) was shorter than that of *N. impicticeps.* Both species could become re-infective after reacquisition feeding. In some cases, the previously noninfective insects became infective after the 2nd acquisition feeding.

Table 1.—Comparison of the average percentage of active transmitters between *Nephotettix impicticeps* and *N. apicalis.*

Species	Percentage of infective insects (tested for 4 consecutive days): Acquisition feeding of 4 to 5 days	Supplemented with daily reacquisition feeding	LSD 5%
N. impicticeps	69.40	83.67	11.09
N. apicalis	17.39	30.13	11.67
LSD 5%	9.46	12.84	

The average number of disease-transmitting days, i.e., the number of days in which the insects transmitted the disease during a given period in days, were 1.06 and 1.38 for *N. apicalis* and *N. impicticeps,* respectively. With daily reacquisition feedings, the average number of disease-transmitting days were 1.28 and 2.70 during a period of 4 consecutive days for *N. apicalis* and *N. impicticeps,* respectively. The differences between the 2 species were highly significant (Fig. 5).

Morphological Features of Active Transmitters.—The tegminal spots of *N. apicalis* may or may not be confluent along the claval suture. Of 75 active transmitters examined, 88.0, 2.7, and 9.3% were classified under 2 spots confluent along the suture, 1 spot confluent along the suture, and no spot confluent along the suture, respectively. The corresponding figures for 106 nonactive transmitters were 86.8, 3.8, and 9.4%.

The aedeagus was 0.41–0.67 mm long with an average of 0.51 for 73 active transmitters and 0.45 to 0.62 mm with an average of 0.52 for 100 nonactive transmitters. The difference between active and nonactive transmitters was not statistically significant.

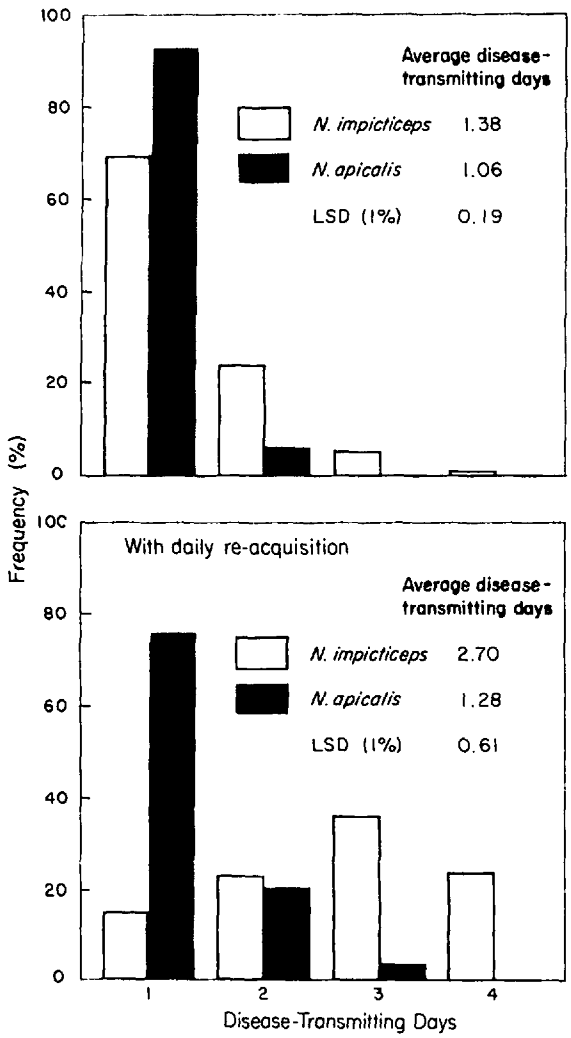

FIG. 5.—Comparison of disease-transmitting days of tungro virus between *N. impicticeps* and *N. apicalis*.

The majority of the insects, regardless of whether they were active or nonactive transmitters, belonged to the category in which the teeth were arranged asymmetrically. There were no striking differences between the active and the nonactive transmitters in regard to the arrangement of teeth on the aedeagus. The 73 active transmitters had 10 to 22 teeth with an average of 15.6, while the 98 nonactive transmitters had 12 to 23 teeth with an average of 16.2. The difference was not statistically significant.

None of the above morphological features could be used for separating the active transmitters from the nonactive ones.

DISCUSSION.—The following general characteristics of the tungro virus were similar in *N. apicalis* and in *N. impicticeps:* (1) the insects lose their infectivity gradually with time after the termination of acquisition feeding; (2) prolonging the acquisition feeding period increases the percentage of infective insects; (3) daily reacquisition feeding increases not only the percentage of infective insects but also the number of disease-transmitting days; (4) once the insects lose the infectivity, they remain noninfective until death; and (5) the insects can regain their infectivity by renewed feeding on virus sources. Consequently, the virus-vector interaction of *N. apicalis* does not differ fundamentally from that of *N. impicticeps.* The available evidence seems to establish that the tungro virus does not persist in *N. apicalis* although the absence of a definite incubation period of the virus in the vector and the loss of infectivity resulting from the molting of the vector have not been demonstrated due to the poor ability of *N. apicalis* to transmit the virus. The nonpersistence of the tungro virus in *N. impicticeps* is now generally accepted by research workers in various countries (John 1968, Lamey et al. 1967, Ling 1966, Nuque and Miah 1969, Rivera and Ou 1967, Rivera et al. 1968, Wathanakul et al. 1968).

The ability of *N. apicalis* to transmit the tungro virus is less than that of *N. impicticeps* because the percentage of infective insects with or without daily reacquisition feeding, the length of the virus retention period in the vector, and the number of disease-transmitting days of the former species are significantly lower than those of the latter.

N. apicalis can transmit the tungro virus. A probable reason for the negative results reported in the literature is the variability of the active transmitters among different insect collections. Genetic variability among individual insects and among insect colonies is not uncommon (Black 1953). Shinkai (1962) reported that the percentage of *N. cincticeps* (Uhler) transmitting the rice dwarf virus varied from 0 to 69% according to the locality in Japan. In other words, if the insect collection used for the transmission study has a very low percentage of active transmitters it would be difficult to obtain positive transmission unless many insects are involved in the experiment. Another possible reason is insufficient acquisition feeding. Since the transmissive efficiency of *N. apicalis* is low, the insects have to be provided with a maximum charge of the virus by prolonging the acquisition feeding period. Extending such period to 4 to 5 days would increase the possibility of positive tungro disease transmission by *N. apicalis,* especially when the insects are tested daily and are allowed supplementary daily reacquisition feedings.

The number of disease-transmitting days as defined above is proposed for comparing the transmissive ability of 2 or more groups or species of insects. The number of disease-transmitting days of a nonpersistent virus group is equal to the length of the retention period following an acquisition feeding if the daily transmission pattern of the insect is consecutive (for a clarification of the term consecutive, refer to Ling 1969). In the case of the tungro virus in *N. impicticeps* and in *N. apicalis,* the number of disease-transmitting days for 1 acquisition feeding should theoretically be greater than 1.0 but smaller than 2.0 because more than 50% of the infective insects lose their infectivity the following day (Ling 1966). If the insects are exposed to more than 1 acquisition feeding, their transmissive ability can be compared by their number of disease-transmitting days but not by the length of the virus retention period, the latter no longer being applicable due to repeated feeding of the insects on diseased plants. Furthermore, the disease-transmitting days can also be used for comparing the transmissive ability of different groups or species of insects of the persistent virus group if the daily transmission pattern of the insects is intermittent.

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The Survival Value of Its Jumping Cocoons to *Bathyplectes anurus*,[1] a Parasite of the Alfalfa Weevil[2,3]

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ABSTRACT

The jumping activity of cocoons of *Bathyplectes anurus* (Thomson) increased about 3-fold when they were exposed to light and/or heat (43°C). When equal numbers of cocoons of *B. anurus* and *B. curculionis* (Thomson) (the latter species cannot jump) were exposed to the hyperparasite *Dibrachys cavus* (Walker) in the laboratory, 5 times more *B. curculionis* were attacked. These results suggest that this unusual behavioral characteristic increases the survival of diapausing *B. anurus* larvae in cocoons by enabling many to escape hyperparasites and unfavorable microclimates in alfalfa fields.

For more than 10 years, the USDA has been introducing parasites of the alfalfa weevil, *Hypera postica* (Gyllenhal), into the eastern United States. Two of the species that have subsequently become established (Brunson and Coles 1968) are the ichneumonids *Bathyplectes curculionis* (Thomson) and *B. anurus* (Thomson). L. M. Walkley (retired), Systematic Entomology Laboratory, Agr. Res. Serv., USDA, stated in a personal communication (1968) that *B. anurus* is the species previously referred to as *B. corvina* (Thomson) by Chamberlin (1924) and as *B. anura* (Walkley 1967).

In most respects, the 2 species of parasites are much alike; the eggs, larvae, cocoons (Fig. 1), pupae, and adults are similar in appearance, both oviposit in alfalfa weevil larvae and later construct their cocoons inside the weevil cocoon, and both spend the greater part of the year in alfalfa fields, where they diapause in their cocoons. The chief differences are in the life cycle (*B. curculionis* is bivoltine, and *B. anurus* is univoltine) and in the behavior of the diapausing larva in its cocoon (only the larva of *B. anurus* is capable of the sudden movement that causes its cocoon to "jump"). This movement may be as much as 5 cm vertically, more than 15 times the cocoon's

[1] Hymenoptera: Ichneumonidae.
[2] Coleoptera: Curculionidae.
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[4] The author gratefully acknowledges the assistance of R. W. Fuester, who furnished most of the cocoons used.