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Studies on Populations of *Sogatella furcifera* HORVÁTH and *Nilaparvata lugens* STÅL (Hemiptera: Delphacidae) and their Parasites in Sri Lanka

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Populations of *S. furcifera* and *N. lugens* were studied for 3 seasons of rice cultivation at Kalugomuwa, Kandy District, Sri Lanka. In 2 of the 3 seasons, *S. furcifera* was superior in abundance to *N. lugens*. Both species were similar in seasonal trend of adult population to each other, but the proportions of brachypterous forms to the whole adults fluctuated in different ways between the 2 species. *N. lugens* was less aggregative in spatial distribution than *S. furcifera*. Parasitic activities of Elenchidae, Dryinidae, Pipunculidae and Nematoda were sometimes considerably high, but they were neither persistent nor regulative against the host population.

INTRODUCTION

Planthoppers are regarded as most important among rice insect pests in Sri Lanka (Ceylon). From 1973 to 1975, we conducted some research on their population and the influence of parasites upon them, at Kalugomuwa, about 8 km south of Kandy. In the Wet Zone of Sri Lanka, where Kalugomuwa is situated, owing to continuous warmth and availability of plenty of water throughout the year (Fig. 1), 2 seasons' cultivation of rice is practised: Yala, approximately from April to August, and Maha, approximately from September to March succeeding year. Under such circumstances, planthoppers are found in paddy fields nearly all through the year.

METHODS

During the 3 seasons, Maha 1973/1974, Yala 1974 and Maha 1974/1975, an inspection site was established in a stretch of paddy fields along River Mahaweli Ganga, at Kalugomuwa. In that area, insecticides were occasionally sprayed by farmers but they did not seem to be effective. From about 2 weeks after transplanting to just before harvesting, the site was visited once a week, as a rule, to conduct investigations as summarized in Table 1.

In the course of the research work, we caught some planthoppers which were more or less intersexual in appearance (probably due to parasitism). However, they

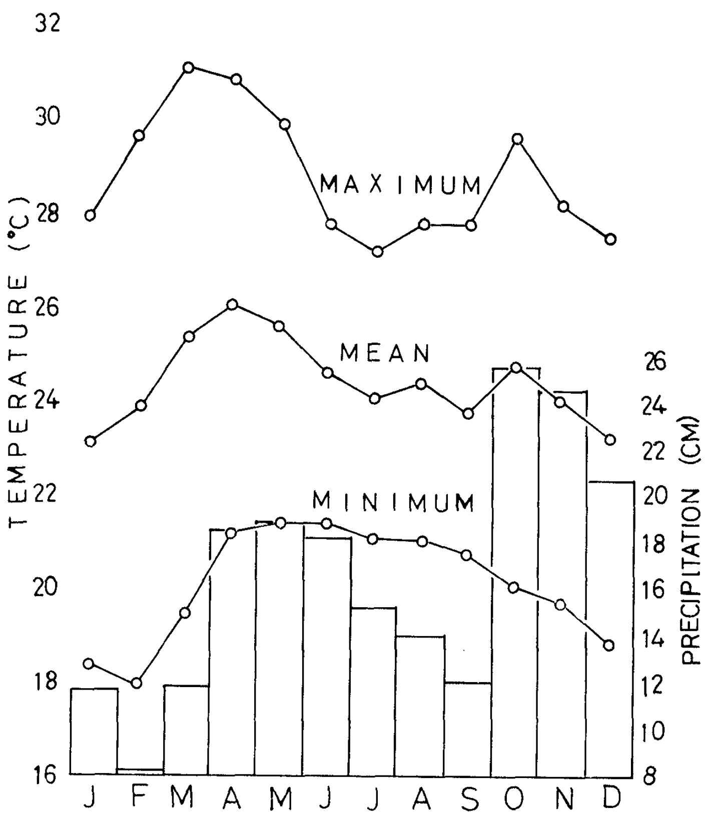

Fig. 1. Average monthly temperatures (solid lines) and precipitation (histogram) in Kandy, Sri Lanka (30 year period, 1931—1960). After Ekanayake (1972).

were classified into males as long as they possessed the chitinized part at the tip of the abdomen, and the others into females.

RESULTS

Population trends

Throughout the investigations, *Sogatella furcifera* Horvâth and *Nilaparvata lugens* Stål were found to be important. Some other minor delphacid species were as scarce as negligible.

In Maha 1973/1974, 2 kinds of methods, sucking and sweeping, were used for investigating the trend in planthopper population. The results obtained from these 2 investigations were different from each other in some aspects as seen in case of *S. furcifera* in Fig. 2. In Inv. I (sucking), 4th- and 5th- instar nymphs (called 'aged nymphs' hereafter) and brachypterous females which tend to be located at the base of plant must have been comparatively easy to collect. On the contrary, males (nearly all macropterous) and macropterous females tend to move up to the crown, particularly so in the former, so that they must have been collected in greater numbers in Inv. Ia (sweeping). Thus, both methods do not seem to be satisfactory enough to assess the real constitution of population. Of these, however, the sucking method seemed to bring about comparatively stable and reliable results in indicating the general trend in population. It

Table 1. METHODS EMPLOYED IN THE KALUGOMUWA INVESTIGATIONS FOR RICE PLANTHOPPERS

Inv.	I	Ia	Ib	II
Purpose	Population fluctuation, the proportion of brachypterous forms, and parasitism	Population fluctuation and the proportion of brachypterous forms	Parasitism	"True" extent of brachypterousness and parasitism[a]
Sampling				
No. of paddy fields[b]	5	15	Not fixed	Not fixed
No. of samples in each field	6 rice hills	10 strokes with a butterfly net[c]		
Sample size	30 rice hills	150 strokes		
Collecting				
Method	Sucking[d]	Sweeping	Sweeping	Sweeping and sucking
Material	4th- and 5th-instar nymphs and adults	4th- and 5th-instar nymphs and adults	Adults	5th-instar nymphs
Treatment	Preservation in alcohol, and then external observation and dissection[e]	Preservation in alcohol	Rearing[f]	Rearing
Season				
Maha 1973/1974	○	○	○	—
Yala 1974	○	—	—	○
Maha 1974/1975	○	—	—	○

[a] The meaning of "true" is given in text.
[b] As a rule, fields with rice variety Bg 11-11 were chosen.
[c] The diameter of the net was 36 cm.
[d] A glass aspirator was used.
[e] Work was done under a binocular microscope.
[f] The insects were individually kept in test tubes with rice seedlings.

was therefore decided to adopt this method in the following 2 seasons.

As seen in Table 2, *S. furcifera* was overwhelmingly superior in abundance to *N. lugens* in Maha 1973/1974, but in the next season, the situation was completely reversed. In Maha 1974/1975, *S. furcifera* regained dominance, although its density remained low as compared to Maha in the previous year.

In Maha 1973/1974, the density of female *S. furcifera* attained its highest level about 40 days after the commencement of investigation. It lasted about half a month, and then steadily decreased. The peak of nymphal density came later; at that time, however, the paddy being at the heading stage was getting unsuitable for planthoppers as guessed from the change in the proportion of brachypterous females. At the final phase of that season, *i. e.*, the latter half of February 1974, a large number of *S. furcifera*, mainly macropterous adults, were found on weeds surrounding the paddy fields. They must have been on the way of dispersal.

In case of *N. lugens* of Yala 1974, there were 2 peaks in the female density. When sampling error is considered, however, it is doubtful whether they were true peaks. It may therefore be reasonable to consider that a comparatively high density level in females lasted from mid-July to mid-August that year. Unlike *S. furcifera* in Maha 1973/1974,

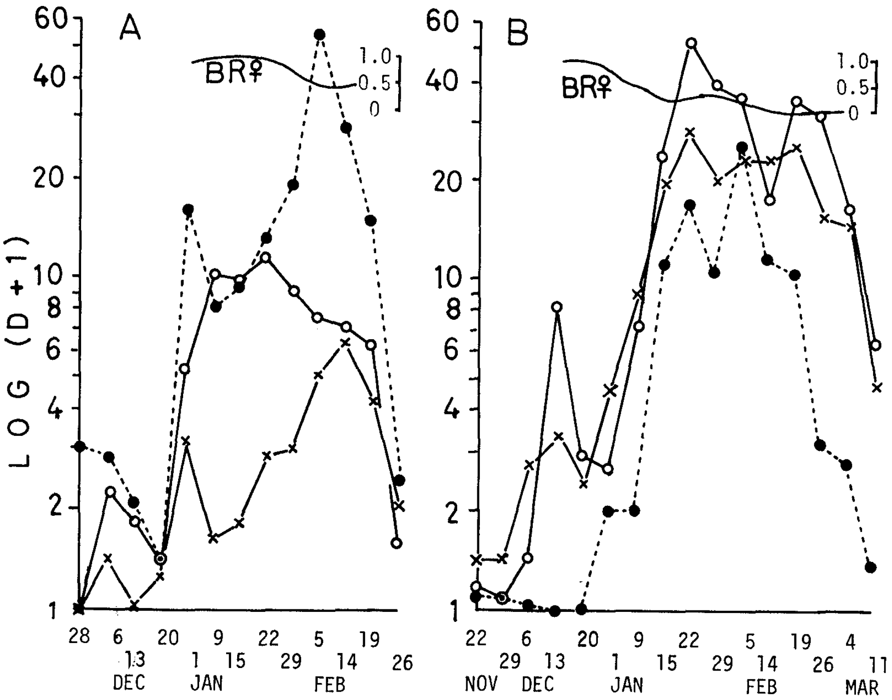

Fig. 2. Comparison in population trend of *S. furcifera* between Investigations I (A) and Ia (B), in Maha 1973/1974. D: no. of insects per paddy field; --●--, —×— and —○—: aged nymphs, adult males and females, respectively; BR ♀: proportion of brachypterous forms to the whole adult females.

N. lugens' aged nymphs attained the highest density almost at the same time as the adults, in Yala 1974.

In both *S. furcifera* of Maha 1973/1974 and *N. lugens* of Yala 1974, the largest number of females collected from 30 rice hills on a day of investigation was about 50, *i.e.*, about 1.7 per hill.

Proportions of brachypterous forms to the whole adults in each sex

As already mentioned, the brachypterous form was to have greater chance of being caught by the method in Inv. I than the macropterous one had. Moreover, the latter form was to be much more active in dispersal behaviour than the former one. So, it is certain that the proportion of brachypterous forms obtained in Inv. I tended to be higher than the so-called "true" one. Kisimoto (1965) recommends to rear 5th-instar nymphs collected from the field up to the adult stage in order to obtain the true proportion of brachypterous forms. Our investigation II was designed to match with his recommendation. However, on most of the investigation days, we could not collect sufficient numbers of 5th-instar nymphs, and so in Table 3, several days' data were gathered together before calculating the proportions.

Examining the results given in Tables 2 and 3 together, the following can be pointed out: (1) in *S. furcifera* males, the proportion was generally very low, while in *N. lugens* males, it attained the level as high as females of the same species did; (2) in *S. furcifera* females, the pattern of change in the proportion differed between the 2 different methods of investigation: in Inv. I, the decrease took place after the time of high population, while in Inv. II, fairly high values of the proportion were maintained only during the

Table 2. Results of Investigaton I

<table>
<tr><th>Date</th><th></th><th>Nov. 28</th><th>Dec. 6</th><th>13</th><th>20</th><th>Jan. 1</th><th>9</th><th>15</th><th>22</th><th>29</th><th>Feb. 5</th><th>14</th><th>19</th><th>26</th><th>Total</th></tr>
<tr><td colspan="16">Maha 1973/1974</td></tr>
<tr><td colspan="16">S. furcifera</td></tr>
<tr><td>Ny[a]</td><td>n[b]</td><td>10</td><td>9</td><td>5</td><td>2</td><td>74</td><td>34</td><td>40</td><td>59</td><td>87</td><td>265</td><td>137</td><td>68</td><td>7</td><td>797</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>2</td><td>0</td><td>1</td><td>11</td><td>3</td><td>4</td><td>9</td><td>10</td><td>20</td><td>26</td><td>16</td><td>5</td><td>107</td></tr>
<tr><td></td><td>BR[c]</td><td colspan="5">0.07</td><td colspan="3">0.50</td><td>0.20</td><td>0.00</td><td>0.08</td><td colspan="2">0.33</td><td>0.19</td></tr>
<tr><td>♀</td><td>n</td><td>0</td><td>6</td><td>4</td><td>2</td><td>21</td><td>45</td><td>43</td><td>51</td><td>39</td><td>33</td><td>30</td><td>26</td><td>3</td><td>303</td></tr>
<tr><td></td><td>BR</td><td colspan="4">0.83</td><td>0.86</td><td>0.89</td><td>0.98</td><td>0.92</td><td>0.72</td><td>0.42</td><td>0.40</td><td colspan="2">0.52</td><td>0.75</td></tr>
<tr><td colspan="16">N. lugens</td></tr>
<tr><td>Ny</td><td>n</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3</td><td>2</td><td>8</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td>1</td><td>6</td><td>3</td><td>14</td></tr>
<tr><td></td><td>BR</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>0.93</td></tr>
<tr><td>♀</td><td>n</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td><td>4</td><td>2</td><td>0</td><td>2</td><td>2</td><td>2</td><td>6</td><td>2</td><td>22</td></tr>
<tr><td></td><td>BR</td><td colspan="7">0.88</td><td colspan="6">0.64</td><td>0.73</td></tr>
</table>

<table>
<tr><th>Date</th><th></th><th>June 7</th><th>17</th><th>24</th><th>July 2</th><th>10</th><th>16</th><th>31</th><th>Aug. 7</th><th>15</th><th>22</th><th>27</th><th>Sept. 4</th><th>12</th><th>20</th><th>24</th><th>Oct. 2</th><th>Total</th></tr>
<tr><td colspan="19">Yala 1974</td></tr>
<tr><td colspan="19">S. furcifera</td></tr>
<tr><td>Ny</td><td>n</td><td>0</td><td>2</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>0</td><td>1</td><td>1</td><td>1</td><td>0</td><td>2</td><td>3</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>9</td></tr>
<tr><td></td><td>BR</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>0.11</td></tr>
<tr><td>♀</td><td>n</td><td>0</td><td>0</td><td>0</td><td>1</td><td>2</td><td>6</td><td>5</td><td>3</td><td>2</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>20</td></tr>
<tr><td></td><td>BR</td><td colspan="6">0.22</td><td colspan="4">0.27</td><td colspan="6"></td><td>0.25</td></tr>
<tr><td colspan="19">N. lugens</td></tr>
<tr><td>Ny</td><td>n</td><td>2</td><td>3</td><td>4</td><td>7</td><td>48</td><td>36</td><td>107</td><td>171</td><td>103</td><td>19</td><td>2</td><td>3</td><td>14</td><td>20</td><td>0</td><td>0</td><td>539</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>0</td><td>0</td><td>1</td><td>12</td><td>12</td><td>8</td><td>19</td><td>19</td><td>19</td><td>4</td><td>1</td><td>0</td><td>8</td><td>0</td><td>0</td><td>103</td></tr>
<tr><td></td><td>BR</td><td colspan="5">0.23</td><td colspan="2">0.55</td><td>0.68</td><td>0.58</td><td>0.68</td><td colspan="6">0.85</td><td>0.60</td></tr>
<tr><td>♀</td><td>n</td><td>1</td><td>3</td><td>4</td><td>12</td><td>32</td><td>43</td><td>25</td><td>21</td><td>48</td><td>19</td><td>17</td><td>3</td><td>3</td><td>16</td><td>4</td><td>0</td><td>251</td></tr>
<tr><td></td><td>BR</td><td colspan="4">0.80</td><td>0.66</td><td>0.49</td><td>0.68</td><td>0.67</td><td>0.71</td><td>0.79</td><td colspan="3">0.96</td><td colspan="3">0.95</td><td>0.71</td></tr>
</table>

<table>
<tr><th>Date</th><th></th><th>Dec. 31</th><th>Jan. 7</th><th>17</th><th>21</th><th>29</th><th>Feb. 6</th><th>11</th><th>19</th><th>26</th><th>Mar. 3</th><th>12</th><th>Total</th></tr>
<tr><td colspan="14">Maha 1974/1975</td></tr>
<tr><td colspan="14">S. furcifera</td></tr>
<tr><td>Ny</td><td>n</td><td>10</td><td>6</td><td>2</td><td>2</td><td>15</td><td>10</td><td>28</td><td>2</td><td>2</td><td>48</td><td>16</td><td>141</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>0</td><td>2</td><td>0</td><td>0</td><td>2</td><td>1</td><td>2</td><td>0</td><td>0</td><td>0</td><td>7</td></tr>
<tr><td></td><td>BR</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>0.14</td></tr>
<tr><td>♀</td><td>n</td><td>0</td><td>8</td><td>7</td><td>4</td><td>1</td><td>13</td><td>14</td><td>10</td><td>1</td><td>6</td><td>3</td><td>67</td></tr>
<tr><td></td><td>BR</td><td colspan="4">0.63</td><td colspan="2">0.79</td><td>0.71</td><td colspan="4">0.25</td><td>0.57</td></tr>
<tr><td colspan="14">N. lugens</td></tr>
<tr><td>Ny</td><td>n</td><td>1</td><td>0</td><td>0</td><td>2</td><td>0</td><td>1</td><td>3</td><td>4</td><td>0</td><td>0</td><td>2</td><td>13</td></tr>
<tr><td>♂</td><td>n</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>4</td><td>1</td><td>0</td><td>0</td><td>6</td></tr>
<tr><td></td><td>BR</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>—</td><td>0.17</td></tr>
<tr><td>♀</td><td>n</td><td>0</td><td>0</td><td>6</td><td>2</td><td>0</td><td>5</td><td>1</td><td>15</td><td>5</td><td>1</td><td>0</td><td>35</td></tr>
<tr><td></td><td>BR</td><td colspan="6">0.54</td><td colspan="5">0.32</td><td>0.40</td></tr>
</table>

[a] Aged nymphs.
[b] Total no. of insects collected on 30 rice hills at each date.
[c] Proportion of brachypterous forms (=brachypterous males or females/the whole males or females).

Table 3. Proportions of Brachypterous Males and Females in Investigation II

Date		June 7	17	24	July 2	16	31	Aug. 7	15	22	Sept. 4	12	20	24	Oct. 2
								Yala 1974							
S. furcifera															
♂	nr[a]	3	0	3	14	18	8	9	2	2	1	0	1	0	0
	BR[b]		0.15					0.08							
♀	nr	1	1	30	73	50	19	37	12	1	0	0	0	0	0
	BR		0.51					0.12							
N. lugens															
♂	nr	0	0	1	1	1	0	3	15	0	1	5	1	1	0
	BR							0.32					0.75		
♀	nr	0	0	0	2	2	0	8	29	2	2	9	6	1	0
	BR							0.37					0.72		

Date		Jan. 17	21	29	Feb. 6	11	19	27	Mar. 5	12	20	25	Apr. 3
							Maha 1974/1975[c]						
S. furcifera													
♂	nr	2	2	2	13	13	4	1	22	8	11	2	0
	BR		0.00				0.00				0.00		
♀	nr	0	9	1	48	27	5	4	41	7	17	1	0
	BR		0.60				0.26				0.20		

[a] No. of insects reared from the 5th-instar to the adult stage.
[b] Proportion of brachypterous forms as given in Table 2.
[c] *N. lugens* in this season was omitted because nr was very small in either of both sexes.

first stage of population growth; and (3) in *N. lugens* females, high proportions were realized at the final stage of population.

The intensity of aggregation

The following index of aggregation, $\hat{C}_A$, given by Kuno (1968) was calculated on the basis of the numbers of planthoppers on the respective rice hills sampled in Inv. II (all of the 5 fields were pooled on each day of investigation).

$$\hat{C}_A = \frac{\hat{\sigma}^2 - \hat{m}}{\hat{m}^2 - \hat{\sigma}^2/n},$$

where n means sample size (=30 hills), and $\hat{m}$ and $\hat{\sigma}^2$, sample mean (=the number of insects per hill) and variance, respectively. Of the $\hat{C}_A$ values thus calculated, ones corresponding to $\hat{m}$ values as low as 0.5 or less were very variable. So, they were omitted on calculating the averages of $\hat{C}_A$, $\sum(\hat{\sigma}^2 - \hat{m})/\sum(\hat{m}^2 - \hat{\sigma}^2/n)$, in Table 4. It is noteworthy that the values in the table indicate a tendency of less intensive aggregation in *N. lugens* than in *S. furcifera*.

Parasitism

Parasites obtained in the investigation were an elenchid, *Elenchus* sp. (Strepsiptera), the dryinid, *Haplogonatopus orientalis* Rohwer (Hymenoptera), a pipunculid (Diptera)[1],

[1] We failed to obtain adult flies.

Table 4. AVERAGED VALUES OF THE INDEX OF AGGREGATION, $\hat{C}_A$[a]

Species	*S. furcifera*	*N. lugens*
Adults only	0.915	0.560
Aged nymphs and adults	0.729	0.635

[a] In each category, data for the 3 seasons were pooled.

and a nematode. Hymenoptera, including at least 2 species, were occasionally found to be parasitic on dryinid larvae.

In *Elenchus* sp., the extrusion of a puparium containing a male pupa or the opening of an adult female on the abdomen of the host is conspicuous as an external symptom of its parasitism. In *H. orientalis*, the age-advanced larva forms an outstanding sac on the dorsal part of the abdomen of the host. These external symptoms of parasitism both in the elenchid and in the dyinid often appeared some days after the commencement of rearing of the hosts.

The lack of the ovipositor in female host was another symptom of parasitism. Through Inv. Ib and II, it was shown that the majority of the female planthoppers with the external symptoms of the parasitism by the elenchid possessed no ovipositor. A part of the female hosts with dryinids' sacs were also without ovipositors, but there was no case in which a pipunculid larva or a nematode emerged from a female host which possessed no ovipositor. In these 2 kinds of investigations, a fairly large numbe of ovipositor-lacking female planthoppers showed no other external symptom of parasitism before they died in the rearing tubes. However, judging from the results of observation mentioned above, they were regarded as parasitized by the elenchid or dryinid species.

There was no conspicuous external symptom in parsitism by the pipunculid or nematode. These parasites at times emerged from hosts that were reared in Inv. Ib and II, and they were easily found inside hosts which were dissected in Inv. I. Elenchids and dryininds inside hosts were difficult to detect by dissection.

Actually, there was no difference in the intensity of parasitism by the parasites mentioned above between *S. furcifera* and *N. lugens*. So, these 2 host species were pooled and Table 5 was made. When the table is examined, it would be noticed that the results of calculation originated from the dissection method (Inv. I) and the rearing method (Inv. Ib and II) largely differ from each other. This difference would be explicable as follows: —In the course of rearing, it was often observed that elenchids and dryinids emerged from planthoppers which had appeared normal at the time of collection. In Inv. I, the specimens were killed just after collection in order to preserve in alcohol, and also it was not always possible to detect any of the above-mentioned parasites from an apparently normal planthopper through dissection. This would be the main reason why in Inv. I, elenchids and dryinids were comparatively scarcely detected as compared to Inv. Ib and II. On the other hand, as already mentioned, pipunculid larvae and nematodes were easy to detect through dissection of host, but they did not frequently emerge before their hosts died, thus resulting in underestimation of parasitism by them in the rearing investigation.

In Inv. I, the parasitism by nematodes often exceeded 10%, sometimes attaining 20% or more, and that by pipunculids tended to increase at the end of season (Table 5). However, it is somewhat doubtful whether the late-season increase in parasitism by pipunculids truly represented the heightened activity of the parasites at that time; if

Table 5. Seasonal Changes in Parasitism of Pooled *S. furcifera* and *N. lugens*

Date	—	Nov. 28	Dec. 6	13	20	Jan. 1	9	15	22	29	Feb. 5	14	19	26	Total
Maha 1973/1974															
Inv. I															
A[a]	—	0	8	5	3	34	52	50	61	51	56	59	54	13	446
B[b]	—		0.13			0.03	0.06	0.04	0.02	0.02	0.02	0.03	0.06	0.15	0.04
C[c]	—		0.06			0.00	0.04	0.00	0.02	0.02	0.04	0.08	0.33	0.31	0.08
D[d]	—		0.00			0.03	0.06	0.06	0.20	0.24	0.05	0.12	0.19	0.15	0.12

Date	Nov. 20	27	Dec. 4	11	18	Jan. 2	10	17	24	31	Feb. 7	—	22	28	Total
Inv. Ib															
A	18	21	27	52	36	204	215	365	239	535	505	—	551	316	3084
B	0.11	0.10	0.07	0.00	0.03	0.05	0.11	0.13	0.13	0.13	0.12	—	0.12	0.28	0.13
C	0.00	0.00	0.04	0.00	0.08	0.00	0.00	0.00	0.01	0.01	0.01	—	0.00	0.01	0.01
D	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	—	0.00	0.00	0.00

Date	June 7	17	24	July 2	10	16	31	Aug. 7	15	22	27	Sept. 4	12	20	24	Oct. 2	Total
Yala 1974																	
Inv. I																	
A	1	3	5	15	47	61	40	46	70	39	21	4	3	24	4	0	383
B			0.00		0.04	0.03	0.03	0.09	0.09	0.08		0.14			0.29		0.07
C			0.00		0.00	0.00	0.00	0.02	0.03	0.26		0.29			0.19		0.06
D			0.08		0.04	0.13	0.18	0.15	0.10	0.08		0.04			0.04		0.10
Inv. II																	
A	4	1	34	90	—	71	27	57	58	5	—	4	13	8	2	0	375
B		0.03		0.06	—	0.06	0.48	0.12	0.21		—			0.14			0.13
C		0.00		0.00	—	0.00	0.00	0.00	0.00		—			0.00			0.00
D		0.00		0.00	—	0.01	0.00	0.00	0.00		—			0.00			0.00

Date	Dec. 31	Jan. 7	17	21	29	Feb. 6	11	19	27	Mar. 5	12	20	25	Apr. 3	10	Total
Maha 1974/1975																
Inv. I																
A	0	8	15	6	2	20	16	31	7	7	3	—	—	—	—	115
B		0.04			0.18		0.19	0.16		0.06		—	—	—	—	0.13
C		0.00			0.00		0.00	0.00		0.00		—	—	—	—	0.00
D		0.04			0.07		0.13	0.10		0.18		—	—	—	—	0.10
Inv. II																
A	—	0	3	11	3	62	40	9	5	63	15	28	3	0	0	242
B	—		0.18			0.18	0.22		0.37		0.40		0.26			0.26
C	—		0.00			0.00	0.00		0.00		0.00		0.00			0.00
D	—		0.00			0.00	0.00		0.00		0.00		0.00			0.00

[a] Total no. of planthoppers at each date.

[b] [No. of hosts parasitized by elenchids and dryinids]/A. (In the numerator, hosts which had no symptom of parasitism other than the lack of ovipositor are included.)

[c] [No. of hosts parasitized by pipunculids]/A.

[d] [No. of hosts parasitized by nematodes]/A.

parasitism brought about more or less serious decline of dispersal activity on the part of adult planthoppers, the proportion of parasitized ones would necessarily increase at the end of the season independent of the activity on the part of parasites. The same situation may have arisen even in elenchids and dryinids (cf. WALOFF, 1973). Thus, Inv. II is said to have been meaninfgul, because in it, the planthoppers were collected at the final nymphal stage, which is not yet very positive in dispersal behaviour, and continued to be observed up to the adult stage.

At the end of Inv. Ib, the parasitism by combined elenchids and dryinids reached the maximum (Table 5). The same tendency was observed in Inv. I of Maha 1973/1974 and Yala 1974. In Inv. II, however, no such trend was detectable, and therefore, at least as to the elenchid and dryinid species, we assume with considerable plausibility the effect of accumulation of parasitized hosts in the field at the end of season.

DISCUSSION

Recently, infestation by *N. lugens* has become serious in the rice-growing tracts along the eastern coast of Sri Lanka. However, in and around Kandy, there is no record of such severe infestation of *N. lugens* so far. In this region, *S. furcifera* is regarded as superior in abundance in paddy fields. From this point of view, Yala 1974 may have been a rather exceptional case of *Nilaparvata* superiority (Table 2). In that season, *Sogatella* population was remarkably suppressed. Therefore, one assume the existence of competition between the 2 species of planthoppers. However, according to KUNO's theoretical study (KUNO, 1968), interspecies competition between them is nearly impossible to take place under the condition of such moderate population density as in the present case.

In Japan, *S. furcifera* and *N. lugens* pass 3 or 4 generations during the rice cultivating season, June to October. Based on his 6-year observation in Kyusyu, Japan, KUNO (1968) schematically gave standard patterns of seasonal population trends in both species, and in case of adults, each of the species had 2 distinct peaks, of which the latter one was superior. In our study, however, such bimodal pattern in adult population did not take place (Table 2). Probably, this was due to much shorter period of rice cultivation in each season, which would not permit the planthoppers to build up the second rise of population, and also to more frequent immigration of fresh individuals from the surroundings.

When nymphs and adults are considered together in KUNO's schematical drawing, increase in density of *N. lugens* is remarkable at the latter half of the season, while the maximum population in *S. furcifera* comes a little before the middle of the season (KUNO, 1968). Through his elaborate study in Sikoku, Japan, KISIMOTO (1965) clarified the population process of *Nilaparvata* up to their attaining very high density in late season. In Fiji, HINCKLEY (1963) showed that dense populations of *S. furcifera* on young rice and *N. lugens* on older rice were most apt to occur in fields of transplanted rice. However, in our study, as seen in Table 2, such difference in population trend was not detectable between the 2 species; for instance, in Maha 1973/1974, the maximum in the totalled density of aged nymphs and adults of *S. furcifera* took place in the latter half of the season, and in Yala 1974, that in *N. lugens* was located at the middle of the season.

In Japan, *N. lugens* usually multiply at a higher rate than *S. furcifera* on paddy. According to KUNO's schematical drawing, the number of adult *Nilaparvata* per rice hill is about 3 times as large in maximum as that of adult *Sogatella* (Kuno, 1968). However, in Inv. I of our study the adult density in *Nilaparvata* in Yala 1974 did not exceed that of *Sogatella* in Maha 1973/1974.

In *N. lugens*, a tendency of high aggregation on rice hills is said to be a characteristic as well as the tendency of rapid multiplication. Kuno (1968) calculated distinctly high values of $\hat{C}_A$ in *Nilaparvata* as compared with those in *Sogatella*. However, in our populations, the former species was inferior in averaged $\hat{C}_A$ to the latter one (Table 4). Even from this evidence, it could be said that *Nilaparvata* population at Kalugomuwa did not reveal its real vigour during the period of our study.

The tendency of very low proportion of brachypterous males in *S. furcifera* (Tables 2 and 3) coincides with Kuno's observation (1968). He claims that male *S. furcifera* hardly grow up to brachypterous adults except when they have been parasitized early. In *N. lugens*, the proportion of brachypterous males was not very low as in the findings of Kisimoto (1965) and Kuno (1968). According to Kuno (1968), the pattern of generation-to-generation change in the proportion of brachypterous females was fundamentally common between *Sogatella* and *Nilaparvata*. They had the highest proportion at the early season generation. In the case of *N. lugens* at Kalugomuwa, however, remarkable increases in both apparent and true proportions of brachypterous forms were recorded at the final stage of the 1974 Yala season (Tables 2 and 3). It is not known why this occurred after the host plant had become less suitable for the insect.

Considering the results of Inv. I, Ib and II together in Table 5, we may say that the parasitic activity of elenchids and dryinids (Inv. Ib and II) and that of nematodes (Inv. I) were rather steady season to season as compared to pipunculids (Inv. I). Percentage parasitism of adult planthoppers by the first group of parasites attained the 40% level and that by nematodes came close to 20%. In none of these parasites, however, high level of parasitization was persistent. Pipunculids were fairly active in the first 2 seasons of our investigation but did not appear so in the third one.

The combined effect of the above-mentioned parasites on the planthopper population is said to have sometimes been considerably high. However, it was not always raised as the density of the host population rose. We can thus conclude that the parasites were more or less effective in checking the planthopper population but their function was neither persistent nor regulative against the host population. Kuno (1968) demonstrated that parasites including an egg parasite, *Anagrus* sp., played a fairly important role, as a rule, in controlling *Sogatella* and *Nilaparvata* populations in Kyusyu, Japan.

Both sucking and sweeping methods adopted in the present study were found not to be very suitable to estimate planthopper populations with high accuracy. In order to prevent the escape of insects, it would be recommendable to cover the sampled rice hills with something like a nylon-gauze bag before sucking as done by Kisimoto (1965) and Kuno (1968).

Rearing of 5th-instar nymphs is advisable to clarify the so-called "true" proportion of brachypterous forms and the "true" extent of parasitism. We should notice, however, that these two "true" values thus obtained are not always very meaningful when the immigration of macropterous forms is intensive, because in that case, the immigrants often significantly modify the proportion of brachypterous forms and the extent of parasitism in the indigenous population, which are obtainable by the rearing of 5th-instar nymphs. It is another problem to improve the method for collecting a large number of nymphs than we did.

As for the technical aspect in the study on parasitism, dissection of planthoppers dead in the course of rearing would be necessary in order to detect internal parasites, particularly pipunculids and nematodes.

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