The Prevalence of Infections of *Nosema meslini* (Microsporida: Nosematidae) in Field Populations of *Artogeia rapae* (Lepidoptera: Pieridae) Adults in Hawaii

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ABSTRACT

Infections by *Nosema meslini* (Paillot) in adults of the imported cabbageworm, *Artogeia rapae* (L.) were at epizootic levels at Kahuku, Pearl City and Wahiawa and at enzootic levels at Kahaluu, Waianae, and Waipahu in March 1983. Monthly samples of adults made at Pearl City and Wahiawa showed that the disease was present in these populations at an enzootic or epizootic state throughout the year. The annual cycle of disease in the two areas was almost identical although the physical parameters, temperature, rainfall and elevation in the two areas were quite different. It was apparent that the physical parameters measured did not significantly effect the annual cycle of the disease. The prevalence of the disease indicated that it may be a significant factor in regulation of populations of the imported cabbageworm in Hawaii.

Artogeia rapae (L.), the imported cabbageworm, which was introduced into Hawaii from California in 1897 (Zimmerman, 1958) is a major pest of crucifers in Hawaii (Tanada, 1956). Crucifers are grown throughout the year in Hawaii and adults of this pest are almost always seen in and around fields at any time of the year.

In 1951 Tanada discovered a microsporidium infecting larvae of *A. rapae* collected in Waimanalo, Hawaii. He identified the pathogen as *Perezia meslini* = *Nosema meslini* (Paillot, 1985) Weiser, 1961 and described its life cycle and pathology in *A. rapae* (Tanada, 1953). In the field, he found that 45.3 and 73.8% of the 4th and 5th instar larvae and 49.3 and 27.0% of the adults collected in January 1953 from Manoa and Waimanalo respectively, were infected (Tanada, 1955). This was a high prevalence of the disease in the field.

Although microsporidia generally cause debilitating rather than rapid fulminating diseases, there are studies that indicate that they may be significant factors in the regulation of insect populations (Brooks, 1973; Frye and Olson, 1974; Henry, 1981; Andreadis, 1984; Maddox, 1987). Microsporidia not only can cause larval and pupal mortality, but can also infect adults to cause infertility, reduced fertility, reduced fecundity, reduced longevity, or effect the viability of eggs (Zimmack and Brindley, 1957; Thompson, 1958; Verber and Jasic, 1961; Tanabe and Tamashiro, 1967; Gaugler and Brooks, 1975; Windels et.al., 1976). Infected adults

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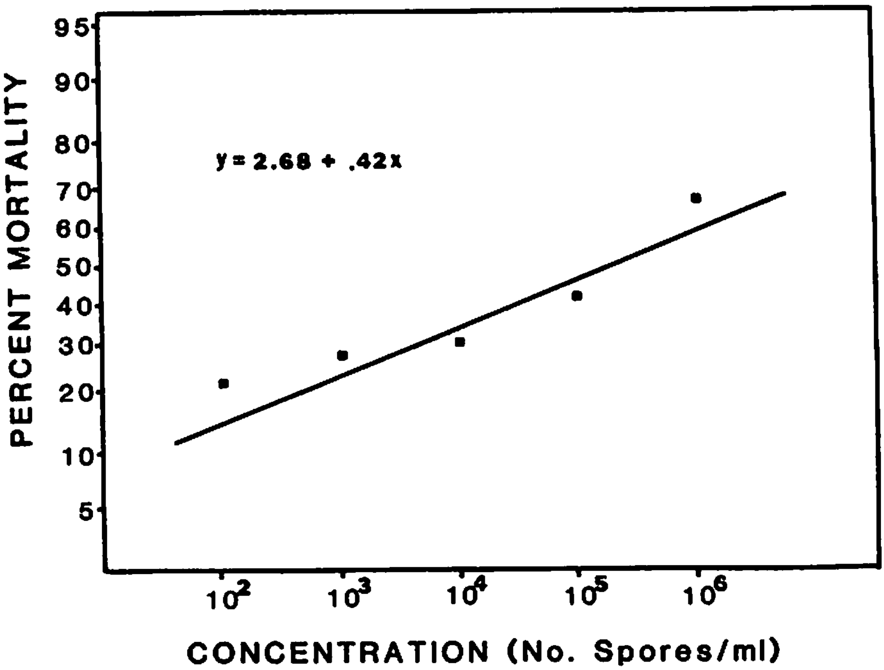

FIGURE 1. Concentration mortality curve for 3rd instar larvae of *Artogeia rapae* (L.) fed spores of *Nosema meslini* (Paillot)

are produced when infected larvae are able to survive and complete development.

Haji-Mamat and Tamashiro (1987) found that spores of *N. meslini* fed to lst, 3rd, or 5th instar larvae of *A. rapae* at concentrations of 10^2, 10^4, and 10^6 spores/ml respectively, was sufficient to infect all of the adults developing from these larvae. Figure 1 presents the concentration mortality curve for 3rd instar larvae of *Artogeia rapae* fed spores of *Nosema meslini*. These adults laid fewer eggs of which only 34 percent hatched. Moreover, 83% of the larvae hatching from these eggs were infected with *N. meslini*. Microsporidian infections in adults, therefore, can significantly effect the size of larval populations. In addition, these infected adults can also serve to sustain and spread the pathogen in the population. This study was undertaken to determine the field prevalence of the *N. meslini* in adults of *A. rapae* on Oahu and to observe the fluctuations of disease in the adult populations during the year.

MATERIAL AND METHODS

The initial collections of adults were made in March 1983 in Kahuku, Pearl City, Waiahole, Waianae, Wahiawa, and Waipahu. Subsequently, collections were made at monthly intervals for one year at Pearl City and

Wahiawa. These areas had crucifers continuously grown throughout the year. Approximately 2 hours were spent at each location to collect the sample. The adults were netted and placed individually in plastic bags and brought back to the laboratory and sexed.

The adults were then homogenized individually in sterile tubes with a small amount of sterile distilled water. A drop of this suspension was examined under a phase contrast microscope to ascertain whether the insect was infected. The infection was confirmed by the presence of sporonts or spores. The adults usually were examined on the day they were caught. In those few instances where this was not possible, the adults were kept in the refrigerator until they could be examined.

RESULTS AND DISCUSSION

Table 1 presents the elevations, rainfall and average temperatures and the prevalence of infections in the areas initially sampled. The samples revealed that the *N. meslini* was present at all six locations (Table 2) indicating that the pathogen was well distributed on Oahu. Moreover, the disease at Pearl City (78.9%), Kahuku (77.7%) and Wahiawa (50.0%) was at epizootic levels. The lowest prevalence was at Waipahu where 12.5% of the adults were infected. Epizootics, therefore, were occurring in 3 of the 6 local populations sampled.

The monthly samples of adults subsequently made at Pearl City and Wahiawa indicated that the disease was continuously present in the two populations in an epizootic or enzootic state throughout the year. The prevalence varied from a high of 78.9% in March to a low of 9.8% in November at Pearl City (Table 3) and a high of 50% in March and a low of 4.5% in December at Wahiawa (Table 2). The prevalence of the disease in the two populations followed the same general pattern for the entire year gradually dropping from the epizootic levels in March to very low levels in the fall and winter. There were no statistically significant differences in the prevalence of the disease between the two areas.

TABLE 1. Annual temperature and rainfall, and elevation of the sites on Oahu sampled in March 1983, the number of adults of *Artogeia rapae* (L.) caught and the percent infected by *Nosema meslini* (Paillot).

Location	Ave. Temp. C	Rain (cm)	Elev. (m)	No. Caught	Percent Infected
Kahuku	22.4	105	8	16	77.7
Pearl City	23.9	61	12	34	76.4
Wahiawa	19.2	140	279	16	50.0
Waiahole	21.5	190	36	18	27.8
Waianae	24.8	10	8	4	25.0
Waipahu	23.7	62	26	9	12.5

TABLE 2. Sex ratio and percentage of adults of *Artogeia rapae* (L.) infected by *Nosema meslini* (Paillot) in monthly samples from Wahiawa, Hawaii, 1983-84.

Month	No. of adults caught	Sex ratio m/f	Percent infected total	Percent infected males	Percent infected females
1983					
Mar.	16	2.2:1	50.0	54.5	40.0
Apr.	26	1.9:1	34.6	23.5	55.6
May	58	6.2:1	22.4	20.0	37.5
June	72	2.8:1	36.1	35.8	36.8
July	54	2.2:1	38.8	32.4	52.9
Aug.	42	1.3:1	26.2	29.2	22.2
Sept.	16	3.0:1	31.2	33.3	25.0
Oct.	26	2.7:1	11.5	15.8	0.0
Nov.	39	2.5:1	7.6	7.1	9.0
Dec.	39	2.5:1	4.5	7.1	0.0
1984					
Jan	20	9.0:1	10.0	11.1	0.0
Feb.	22	7.3:1	18.1	5.3	66.7

TABLE 3. Sex ratio and percentage of adults of *Artogeia rapae* (L.) infected by *Nosema meslini* (Paillot) in monthly samples from Pearl City. Hawaii, 1983-84.

Month	No. of adults caught	Sex ratio m/f	Percent infected total	Percent infected males	Percent infected females
1983					
Mar.	34	3.2:1	78.9	73.1	87.5
Apr.	30	3.0:1	40.0	40.9	37.5
May	79	3.2:1	34.2	36.7	26.3
June	46	3.6:1	30.4	30.5	30.0
July	37	2.7:1	29.7	29.6	30.0
Aug.	44	2.4:1	38.6	35.5	46.2
Sept.	16	3.0:1	12.5	8.3	25.0
Oct.	60	2.5:1	11.6	14.0	5.9
Nov.	61	3.4:1	9.8	8.5	14.3
Dec.	34	1.8:1	14.7	18.2	8.3
1984					
Jan	31	4.1:1	12.9	16.0	0.0
Feb.	32	7.3:1	27.9	25.0	50.0

The similarity in the disease prevalence was surprising since the two areas were quite different in the physical attributes. There was a 267 m difference in elevation between the two areas which translated into significant differences in temperature and rainfall. Wahiawa is at 279 m elevation averages 19.2° C in temperature and 140 cm in rainfall per year while Pearl City is at 12 m elevation, averages 25.2° C in temperature and 48.2 cm in rainfall per year.

The fact that the annual disease cycles were almost identical, indicated that physical factors, at least rainfall and temperature, did not greatly influence the disease cycle. This thesis is also supported by the fact that there was no epizootic at Waipahu, a site which is only about two km from Pearl City and is physically almost identical to Pearl City while there was an epizootic at Kahuku which climatically falls in between Pearl City and Wahiawa. The trigger(s) for the epizootic therefore, was probably in some biological or physical parameter(s) which was not measured.

There were also no correlations between disease prevalence and population size. This again was unusual since epizootics are usually though not necessarily associated with high host populations (Steinhaus, 1954, Tanada, 1963; Tanada, 1976). Moreover, the consistency of the data indicated that larger and more frequent samples would not have changed the results. In any case, more samples could not be taken in this study because the fields of crucifers were relatively small and the sampling technique necessarily reduced the population of adults in the field for a short period.

There also were no significant differences in the prevalence of the disease between the sexes. However, the sex ratio of the adults in the samples was highly skewed in favor of the males (Tables 2 and 3). This was unusual since the normal sex ratio for this species is approximately 1:1 (Richards, 1940; Muggeridge, 1942; Haji-Mamat and Tamashiro, 1987). Moreover, laboratory experiments indicated that the sex ratio in adults developing from infected larvae significantly favored the females (Haji-Mamat and Tamashiro, 1987). This should have skewed the population more heavily in favor of the females.

The abnormal sex ratio in the field samples apparently was due to the fact that the males tended to stay in the fields, while the females moved out of the fields when they were not ovipositing (Scott, 1973; Ohsaki, 1980; Tabashnik, 1980). *A. rapae* apparently exhibited this behavior since females were often seen outside the fields. In addition, even when the females were in the fields, they were more difficult to net than the males because they flew in an unpredictable zig-zag pattern.

The observations made in this study indicate that *N. meslini* plays an important role in the regulation of populations of *A. rapae*. It was present in the population throughout the year at epizootic or enzootic levels. Since the effect of the *N. meslini* is known to be very detrimental to the reproductive capacity of *A. rapae*, the disease must have had a depressive effect on the population.

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