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Short Communication

Mathematical Model of the Relationship between the Parasitoids (Hymenoptera, Ichneumonidae) and their Host Pupae (Lepidoptera)

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Abstract

The experiments show that the ichneumonid parasitoids (Phaeogenes sp., Phaeogenes plutellae, Xanthopimpla flavolineata) only attack the host pupae (Cnaphalocrocis medinalis, Lepidoptera) with the young developed stages (DS) (as prepupa, 1st-,2nd-,3rd-,4th- day) the highest parasitism is in the host pupa with the 2nd-day (31%) then in the decrease order is the 1st -, 3rd -, 4th- day, prepupa with 25%, 22%, 19%, 2.7% respectively. However, they completely no attack the pupa with the 5th- day or the older. So it elicits to build the model of relationship between the attack on the pupae of Lepidopteran pests by the Hymenoptera parasitoids, which was indicated and discussed.

INTRODUCTION

The ichneumonid wasps (Ichneumonidae Hymenoptera) insert an egg into pupae of Lepidopteran pest where it hatches, grows and often remaining within the skin of its host throughout its immature development. Adult parasitoids are free-living and feed on nectar or body fluids of their host-pupae.

Several studies have already showed that many hymenopterous insects, which are generally considered the most important parasitic group which reduce the other insect populations [1,2].

Several model [3-7] have described the relationships between parasites and their host, one of them is Thompson's predator-prey model [8] such as: $X_{ha} = X \{ 1 - \exp(^{-ky}/x) \}$, where X_{ha} is a host number were attacked, X is a host female number, y is a parasite female number, k is a mean number of egg of the parasite female. This model is seem to be show that all the host stages were suitable for the attack of parasites, so it mean that all the individuals of the host population will be possible attacked by parasites, or all of the host individuals were joined in the encounter with parasites. That model shows when at the end of the process, both of the population of the host and the parasites are reduced to zero. That is disagreement in nature, because both of the remain of the parasites and their hosts were still livable together. All model of host-parasitoid system mentioned above are unstable: they generate oscillations with increasing amplitude. However, in nature host-parasitoid population never show oscillations with infinitely increasing amplitude. This is not because the models do not capture the mechanisms of host- parasitoid interactions, but because additional ecological processes. So it suggests us to make the other model, which may be more agreement to meet the situation are happened in nature

MATERIALS AND METHODS

In the experiments, the parasitic species (Phaeogenes sp., Xanthopimpla flavolineata, Goryphus basilaris) were reared for many generations on the their host pupae (Cnaphalocrocis medinalis, Plutella xylostella).The host pupae (Cnaphalocrocis medinalis, Brachmia sp., Naranga aenescens) were reared individual by the rice fresh leaves into each a tube and the host pupae are changed by every day to provide they are fresh for their parasites

To research on the selecting host pupa by parasitoids: to release 10 of parasitoid couples (male and female) into 10 of glass- bells with 10 litre in volume, in each one, there were host-pupae with all of developed stages (DS) such as: prepupa, 1st-, 2nd-, 3rd-,4th-, 5th- day. In which the number of each developed stage (DS) is 6 individuals. So that the total of 36 pupae/ glass-bell/ couple. The experiments were last until 10 of couples were dead.

We Apply the Newton binomial formula (I) for assessment whether the selections of host pupa with different developed stages (DS) was facultative or not:

$$A = N.C_m^k.p^K.q^{m-k} \quad (1)$$

- Where A is theoretical number of pupal hosts were attacked by parasitoids;

- N is a number of host pupae were joined into the experiments;

- k is a really number of each DS of host pupae that were attacked by parasitoid;

- m is a number of each DS of host pupae in experiments

- p is a probability of host pupa will be attacked by parasitoids (in this experiment p equal 1/6, because there are 6 DS of host pupa), q is a probability of host pupa will not be attacked by parasitoid (in this experiment q equal 5/6, because reason mentioned above); DS is a developed stage of host pupa;

And where $C_m^k = \frac{m!}{k!(m-k)}$

And then to estimate whether the difference between the 2 sets of theoretical

and experimental data with $\chi^{2.}$

RESULTS AND DISCUSSION

Table (1) shows the experimental data from our laboratory and the theoretical data were calculated by the Newton binomial. The experimental data indicate that the highest parasitism is in the host pupa with 2nd DS (31%) then in the decrease order is 1st -, 3rd -, 4th-Day, prepupa with 25%, 22%, 19%, 2.7% respectively. Especially the parasitoids always avoi to lay eggs in the host pupa with 5th Day or older.

The same experiments were conducted with parasitoid yellow wasp, Xanthopimpla flavolineata and Phaeogenes plutellae (its host pupa is Plutella xylostella) are the same data with brown wasp (Phaeogenes sp.).

There were a great difference between the experimental and theoretical data with $\chi_{= 35.3}$ ($p_{< 0.001}$), which indicates that the oviposition of the parasitoids on the developed stages (DS) of host pupa is not facultative, but it is belonging for the preference of the host pupa'DS.

Discussion

Since the host pupa's generations have developed overlap each other in nature, the host pupa's populations often having more or less the number of individuals in every DS at any time. Table (1) shows that the parasitoids always avoi to attack on host pupa with 5th DS or older, so that there often have a number of host pupa-DSs, which have been attacked by parasitoids. If in the case that all of host pupa, except the 5th- DS or older, which will be attacked by the parasitoids, then we have:

$$N_a = nA$$

- where N_a is a number of host pupa killed by parasitioids; n is a number of parasitoid female; A is an effect of parasitism or a number host pupa was killed by one parasitoid.

As a parasitoid goes to find only the host pupa with the DSs suitable for lay their eggs and the seeking process have conducted stochastically, so the probability of parasitism only occur in the host pupae which are suitable to laying their eggs, then we have:

$$p = \frac{N_a}{N-Q} \quad (2)$$

Then $$q = 1 - \frac{N_a}{N-Q} \quad (3)$$

Where P is a probability of the parasitism, N is a total host pupae in the fiels, Q is a number of host pupae which is not suitable to be attacked by parasitioids (for example: 5th –DS or older) then (N – Q) is a number of host pupa which can be attacked by parasitoids, N_a is from (1), q is a probability of case without parasitism. From (3) we obtain the equation for the survival host pupa's population:

$$N_n = (N - Q)(1 - \frac{N_a}{N-Q}) + Q \quad (4)$$

Where N_n is a number of the survival host pupae

Equation (4) indicate that a number of the survival host pupae depends on the

Parasitism, N_a, which including a quantity and an effect of parasitoids If N_a is

Increased then N_n is decreased and on the contrary when N_a is decreased then N_n is

Increased If in the especial case that all of the host number (Na= N - Q) were killed by the parasitoids , but the parameter Q is always still existed so the parameter N_n will not becom zero. Therefore the relationship between the host pupae and parasitoids were described by the model (4), seem to be similar to the process are happened in nature. Or another to say if all

Table 1: Parasitism of Phaeogenes sp. on the developed stages (DSs) of host pupae (Cnaphalocrocis medinalis).

Total of host pupae in the experiment	Total of host pupae were not attacked	Number of host pupae were attacted on the DSs by parasitoids													
		Total		Prepupa		1st -day		2nd- day		3rd -day		4th -day		5th- day	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
216	180	36	100	1	2.7	9	25	11	31	8	22.2	7	19.1	0	0
Theo	164	52	100	2	3.8	10	19.2	3	5.7	15	28.8	22	42.3	0	0

$\chi_{= 35.5; P < 0.001}$
Note: N is number of host pupa; Theo is theoretical data; DS is Developed Stage.

the suitable host will be attacked, the parameter Q will be a base to develop the new population. So that model (4), different from Thompson`s model [9], which assumption implies unlimited search abilities of parasitoids. In nature, parasites often do not realize their potential fecundity or parasitic effect, because they can not find enough hosts. Thus, the model of Thompson may overestimate parasitism rates especially if host density is low. In addition to explanation of development of new population of host and parasitoids in all the case, which happen in nature, the parameter Q in model (4), including assumes that parasitoid female is able to examine area a ("area of discovery") and the during its life time and parasites can distinguish between the DS of host as show in our experiments. Q also depends on the population density of host and parasitoids.

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