ON SOME BIOLOGICAL PARAMETERS OF INSECTS AIMING THEIR UTILIZATION INBIOLOGICAL CONTROL

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ABSTRACT

Due to environmental disturbances and death of natural enemies, the chemical control of pests widely applied in the past time, is being replaced by biological control in large number of agricultural areas. For proper selection of natural enemies of the pests to be controlled, several biological properties of these natural enemies must be evaluated in order to achieve success in the intended control. It is desirable that the natural enemy have short immature phase duration, because the sooner it reaches sexual maturity the sooner it starts reproduction, thus contributing to population increase. It is also desirable that the sex-ratio be female-biased, because this means that there is higher number of egg-laying individuals in the population. In some insect species sex-ratio can be adjusted to availability of food in the environment by special forms of reproduction arrhenotoky and thelytoky. It is desirable that the natural enemy's pre-mating period and pre-oviposition period be short, but without impairing the quality of the eggs. The oviposition period should last for a period of time enough to the female lay all the eggs before dying. It should be selected the females which will lay higher number of eggs, thus contributing to rapid build-up of the natural enemy population. If the females that ended oviposition are useless in the population, the post-oviposition period should be non-existent, as these females compete with egg-laying females for food and shelter. When the natural enemy produces low number of eggs or the eggs and immatures are exposed in the environment, the parental care is very important for the survival of the offspring until it reach sexual maturity.
Key-words: Biological control, oviposition, sex-ratio, parental care.

RESUMO

ALGUNS PARÂMETROS BIOLÓGICOS DE INSETOS OBJETIVANDO SUA UTILIZAÇÃO EM CONTROLE BIOLÓGICO

Devido a distúrbios ambientais e morte dos inimigos naturais, o controle químico de pragas amplamente aplicado no passado, está sendo substituído pelo controle biológico em grande número de áreas agrícolas. Para a seleção adequada de inimigos naturais de pragas a serem controladas, várias propriedades biológicas desses inimigos naturais precisam ser avaliadas para se alcançar sucesso no controle pretendido. É desejável que o inimigo natural apresente curta duração da fase imatura, pois alcançando cedo a maturidade sexual, cedo começará a reprodução, contribuindo para o aumento populacional. É desejável que a razão sexual seja viesado a favor das fêmeas, pois isto significa que há maior proporção de indivíduos que produzem ovos na população. A arrenotoquia e a telitoquia são formas especiais de reprodução que permitem ao inimigo natural ajustar a razão sexual de acordo com a disponibilidade de alimento no meio-ambiente. É desejável ainda que os períodos de pré-acasalamento e pré-oviposição sejam breves, desde que a qualidade dos ovos não seja prejudicada. O período de oviposição deve se estender por um período de tempo suficiente para que a fêmea deposite todos os ovos antes de morrer. Devem ser escolhidas espécies cujas fêmeas coloquem maior número de ovos, contribuindo assim, para o aumento mais rápido da população de inimigos naturais. Se as fêmeas que terminaram a oviposição não tiverem utilidade na população, o período de pós-oviposição deve ser inexistente, pois essas fêmeas competem com aquelas que estão ovipositando pelo alimento e locais de abrigo. Quando o inimigo natural produz reduzido número de ovos, ou os ovos e os imaturos ficam expostos no meio ambiente, o cuidado parental é muito importante para que a descendência sobreviva até alcançar a maturidade sexual.
Palavras-chave: controle biológico, oviposição, razão sexual, cuidado parental

INTRODUCTION

The intensive and abusive sprayings of agricultural crops with chemical pesticides since the 50 decade, have risen many ecological disturbances. These are the development of resistance to pesticides by the pests, death of their natural enemies, resurgence of pests and emergence of new pest species.

Since the last decades of past century, replacement of chemical control by biological methods has been recommended everywhere agricultural activities are being practiced.

When insects are reared under laboratory conditions aiming their utilization in biological control, several biological parameters must be estimated such as immature phase duration, sex-ratio, pre-mating period, pre-oviposition period, oviposition period, post-oviposition period and parental care, in order to evaluate their potential as natural enemies. For the study of population growth, fertility life table must be constructed, with estimation of its parameters. Ideal natural enemies must be predominantly r-strategists to cope with pests which in most of the cases are also r-strategists. Several insect species become serious agricultural pests because they present high values of fertility life table parameters that measure the magnitude of population increase and low values of parameters that measure the speed of population growth. While being reared under laboratory conditions, the natural enemies are protected against adverse conditions of physical and biological environment.Once released into open fields they will be exposed to environmental restrictions which factors must be previously evaluated in order to achieve success in biological control. In this way, the objective of this paper is to give an overview and discuss the importance of these partial concepts.

IMMATURE PHASE DURATION

When an insect is aimed to be used in biological control programs, it is desirable that it presents short immature phase duration, i. e it must be sexually precocious. The sooner it reaches sexual maturity, it means that it begins to produced descendants sooner, and thus sooner contributes for population increase (HUFFAKER e ROSEN, 1990)

As the immatures are more vulnerable to natural enemies attack, the shorter the immature phase, the lower the probability of being predated or parasitized, dying before the mating.

When fertility life tables are constructed, it is considered desirable the mean generation time be short, this is, the immature phase be short, as well as the pre-mating and pre-oviposition periods. The mean generation time is the period of time which lasts from the laying of an egg by a female and the laying of the first egg by the female originated from the first female, i. e, the egg-to-egg period.

SEX-RATIO

Sex-ratio can be defined as the relation of number of females in the population and the total number of individuals (i. e, males and females) of that population.

In monogamic system, where each male mates with only one female and each female with only one male, the desirable sex-ratio is 0.50, because this ratio assures that all the females will be inseminated. The 0.50 sex-ratio is also advantageous where either the males or the females mate with several sex-mates at random. In these systems the genetic variation of the offspring due to recombination (other genetic variation sources being the mutation and genetic flow) tends to be maximized (FUTUYMA, 1992). This genetic variation maximization can be advantageous in heterogeneous or unstable environments, in constantly changing conditions. Having genetically different offsprings, there is higher probability that some of them develop a phenotype that can fit to the environment of the moment. (FUTUYMA, 1992).

If each male is capable to mate with 10 females, it is perfectly possible a population composed by 10% males and 90% females. The higher the proportion of females, it means that there is in the population higher number of egg-producing individuals, with the number of males only being sufficient to inseminate the females (WILSON e PIANKA, 1973; HAMILTON, 1967)

In systems where there is competition between the males for the females, with the emergence of dominant male (intrasexual selection) (WILSON e PIANKA, 1973) it is produced an offspring where each one will carry 50% of of this male. As dominant male is almost always the carrier of superior quality genes, it is expected that this offspring will have the best conditions to adapt to the environment (FUTUYMA, 1992). This happens with some wasp species, in which immature phases are insect parasitoids. The first male that emerges from the egg mass, will take on of all females, chasing away all the males that emerge afterwards, except when the subsequent males are stronger than the first one, which will be overthrown. The endogamy is evident in these systems, as the females of the same egg mass are sisters of all the males of this egg mass (CORREA-FERREIRA, 1993).

Some insect populations as the aphids and some parasitic wasps, are composed exclusively by females, i. e, with 1.0 sex-ratio. During the evolution of such species, the males disappeared from the population or the females began to dispense the males for the reproduction and then the mating need, developing a special asexual reproductive form named thelytokous parthenogenesis. In the thelytoky, the females produce female offsprings without the males participation. Among these species the males are non-existent or very rare. Evidently the thelytoky-produced females are genetically identical to their mother. However, in temperate climate regions, the aphid populations present males and females, with the occurrence of mating, during certain seasons of the year, whereas in others, the populations are composed entirely by females. Then, the sex-ratio in aphids inhabiting temperate climate depends upon the season of the year. In autumn sexual forms production takes place and they migrate to primary host plants, where they overwinter. In spring, thelytokous females are produced and they migrate to secondary host plants, which are generally ephemeral herbs, which existence is restricted to spring and summer. The thelytokous reproduction allows the rapid population build up, to exploit an ephemeral food source.

The species become r-strategist (PIANKA, 1970; 1972; KING e ANDERSON, 1971). During the winter the aphids live on trees, which offer less ephemeral food source. By sexually reproducing in the autumn, genetic recombination and thus production of genetically varied offspring takes place. Among these genetically varied offsprings, there exists probability of suvivorship of some individuals carrying the best phenotypes to endure winter harsh conditions, which represent the bottle neck imposed by the environment (MIYAZAKI, 1987). Under Tropical conditions the aphids reproduce almost exclusively by thelytoky, all year round. Given this reproductive mechanism which allows rapid population build up, and abundance of food proportionated by field crops, it turns easily understandable why the aphids had converted into one of the most serious agricultural pests on Tropics such as in Brazil.

Among wasps and honey bees there is another parthenogesis form, which is the arrhenotoky. In these systems, fertilized eggs develop into females and unfertilized eggs develop into males. The sex-ratio of the offspring is determinated by the females, which are capable to control the release of the sperm stored in their spermathecae (ROSEN e DeBACH, 1990). In this case, the sex-ratio is variable, according to environmental conditions. If food is abundant, the female fertilizes most of the eggs, producing offspring with high female proportion. If the environmental conditions are not favorable, the female does not fertilize the eggs, producing higher proportion of males. The strategy in arrhenotoky is the production of higher proportion of egg-laying individuals (females) when there is food abundance, i. e., the female "expends" the sperm only when the environment is worthwhile (ROSEN e DeBACH, 1990; WAJNBERG, 1994)

PRE-MATING PERIOD

Some insect species are capable to mate soon after emergence as adults, the pre-mating period being non-existent. In other species there is a period during which the just-emerged female is not sexually receptive, becoming so only when she begins to produce sexual pheromone to attract males. An example of females with pre-mating period occurs with the predatory bug *Podisus nigrispinus* Dallas 1851(ZANUNCIO, unpublished data). Examples of non-existent pre-mating period occur in some flies and some wasps.

PRE-OVIPOSITION PERIOD

The pre-oviposition period lasts from the mating to the laying of the first egg. During this period egg maturation takes place, and for good fulfillment of this maturation, it is important for the female to find carbohydrate and protein-rich foods. In fruit flies, the mated females require the consumption of sugars and proteins for production of high quality eggs. In mosquitoes the mated females need vertebrate blood such as avian or mammal blood, i. e, high protein content meals, in order to achieve egg maturation (GALLO et al, 1988).

A mated female can be considered a guardian of both sexes sexual investment, and thus is a valuable property to be defended in the population against natural enemies until the onset of the oviposition period (ALEXANDER e SHERMAN, 1977). Among most of the insect species, the females are bigger and stronger than the males. This trait could evolved because it awards higher defensive capacity to the egg-laying sex then with high fitness value.

OVIPOSITION PERIOD

This period among the insects presents variable duration according to environmental conditions such as temperature, relative humidity and photoperiod. A long oviposition period would be advantageous when the oviposition substracts are found scattered over a large environmental area (HUFFAKER, 1958). Nevertheless, the duration of oviposition period would be indifferent for good flying insects. When the adult longevity is short, the oviposition period is obviously short too, or at least with duration extending to the whole duration of adulthood. In this case, the efficiency in finding oviposition substract must be high, allowing the female time enough to lay all the eggs she carries before dying.

NUMBER OF EGGS PER FEMALE PER UNIT OF TIME

This parameter depends upon the total number of eggs produced by the female during her whole reproductive life, and the duration of oviposition period.

When fertility life table is constructed, parameters like rm (intrinsic rate of increase) and λ (finite rate of increase) are estimated. Both parameters indicate the number of eggs produced by the female per unity of time. But they are estimated by different mathematical formulae, conducting then to different values.

When an experiment is conducted for the estimation of fertility life table parameters, the females batch which will enter the experiment need to be standardized in order the reduce the sources of fertility variability. Thus, high weighted females will produce higher number of eggs, i. e, they are more fertile than low weighted females (EVANS, 1982). It is recommended to discard from the experimental batch, the females with high weight, as well as the females with low weight. The confident limit is 20% for both tails. Thus only females which weights are situated between these extremes will enter the experiment.

The higher the number of eggs per unity of time, more rapidly will increase the number of individuals of the population. Mean generation time and doubling time are fertility life table parameters that measure the velocity of the population growth. The doubling time will be as smaller as smaller is the mean generation time and the higher the number of eggs produced by a female per unity of time (SOUTHWOOD, 1980).

POST-OVIPOSITION PERIOD

From a female that ended laying eggs, nothing more can be expected, i. e, she is an useless individual for the population. These females compete with ovipositing females for food and shelter (BIRCH, 1957). It is desirable that the post-oviposition period be short or even non-existent, i. e, the female should die soon after laying the last egg. An exception is the case of some butterflies species, where the females in post-oviposition period stay more exposed in the environment than the ovipositing females. Then, these exposed females are preferentially predated by birds and other natural enemies, preserving the ovipositing females which are found in more protected places of the environment.

PARENTAL CARE

Parental care is widely observed among vertebrates, being relatively rare among the insects. Defense, care and offspring feeding are mainly supplied by k-strategist insects, in which the number of eggs produced is relatively low (PIANKA, 1970; 1972; 1974; KING e ANDERSON, 1971; FORCE, 1972).

Parental care evolved among the animals because it increases the probability of offspring survivorship, and the offspring is the carrier of parental genes, that should be perpetuated to next generations. The adults have higher ability to get foods than the youngs, localizing food sources more rapidly and have higher capacity to process the food, and lower vulnerability to natural enemies (TRUMBO, 1996).

Offspring protection is one of the most important pillars of the evolution of parental care, mainly in species which does not construct nests, staying the eggs and immatures exposed to natural enemies. In species in which parental care is not observed, the eggs are laid isolatedly and distributed in vast area of the environment, or laid in protected place or the egg shell is hard, or still the egg masses are hidden by scales or wax-covered (GALLO et al, 1988; TRUMBO, 1996).

In most of the species the parental care is proportionated by the females, having yet species in which the parental care is supplied by females as well as by males. In rare species the parental care is provided exclusively by males (TRUMBO, 1996). It is recognized about 1,000 species of insects belonging to Dermaptera order. In all these species, the parental care is proportionated by the females. They protect the egg masses after laying them. If the egg masses are stirred, the females predate or abandon the egg masses. After hatching, the initial stage nymphs stay together and receive digested food from their mothers. As the nymphs acquire the capacity to digest the foods, they apart from the female, or she abandons them. (TRUMBO,1996).Under Tropical conditions, dermapteran insects show rapid build up of their populations thanks to maternal care of eggs and youngs. Among the spiders, the females protect the egg sacs, but they cannibalize part of the hatched immatures. This apparent paradox can be explained by natural selection action, as will survive only the immatures that succeed in climbing on the mother’s back or flee away escaping from predation. Certainly these youngs are carriers of genes that proportionate best capacities to get food which exists in limited quantity in the environment, and to defend or escape from natural enemies and thus surviving until the adult stage. Reaching adulthood, these individuals are certainly the best ones to succeed in conquering sexual partners and produce more vigorous and fertile offspring (FUTUYMA, 1992). If in nature the cannibalism practiced by the females helps to reduce competition for food and shelter places among the immatures, in laboratory mass rearing, which has as objective the production of large number of spiders for utilization in biological control, it is an undesirable behavior. To bypass this problem, the egg sacs must be separated from the females. The withdrawal of egg sacs probably will not cause nutritional troublers for the females, as under laboratory conditions the food is plentifully supplied (GALLO et al., 1988).

Parental care proportionated by both sexes is observed for example, in carrion feeding beetles *Nicrophorus* spp. The adults (parents) bury the cadaver and defend it against the approximation of intra and inter-specific competitors. The adults control the carrion decomposition by removing feathers and hairs and injecting antimicrobial secretions. Few days before the egg hatching, the female opens a hole in the soil giving easy access to the cadaver for the immatures. Besides that, the parents supplement the nourishment of the youngs by regurgitating liquefied cadaver which is offered to the youngs. Both parents defend the immatures against attacks from predators of the same or other species. Among biparental care insects the withdrawal of the male results in lower number of surviving immatures. The presence of the male in the proximity of the nest while the female goes out to seek food, reduces the probabilities for the immatures being attacked by natural enemies (TRUMBO, 1996).

Species in which the male does not participate in parental care, the biological role of this sex ends with the fertilization of the eggs.

Males from rare insect species supply parental care by carrying eggs, Protecting environmentally exposed immatures or building nests to Shelter the offsprings. Egg carrying males are more easily accepted by the females (intersexual selection) (WILSON e PIANKA, 1973).

Than non-egg carrying males or with built nest, as happens in *Zygopachilus albomarginus* insect. Egg-carrying males or nest owners are indicative of their indicative of their ability to provide egg and young protection (TRUMBO, 1996). Apparently the egg transportation by the males leads to polyginy, but subsequent females have as habit to destruct the previous females eggs, before confiding their eggs to the males. Then the new females warrant the perpetuation of their own genes in the offspring left in care of the males (DAWKINS, 1989). Besides that, with this procedure, the females reduce competition that the immatures would face if the previous females eggs were allowed to survive (BIRCH, 1957).

CONCLUSION

By estimating or having data on the previous knowledge of these parameters the researcher will be capable to make best decisions on the species of natural enemies to be introduced for biological control of the pests in the crop.

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