The rearing of beneficial insects

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Abstract

Rearing of beneficial insects encompasses the synchronisation of 3 biological entities—the beneficial species, its host species, and the host plant or food. The purposes of rearing beneficial insects (parasitoids and predators) in the laboratory may be to study the insect itself, to facilitate the establishment of an introduced species, to accomplish a wider distribution of a previously established species, or to supply routinely for release for biological control.

Not all insects can be reared in large numbers in the laboratory. The important qualities required in a laboratory reared insect are short life cycle, high biotic potential, simple food requirement, and alternative hosts. An insect rearing programme may be affected by reproductive, behavioural, environmental, physiological, nutritional and genetic factors.

The goal of a large-scale rearing programme is to produce the maximum number of 'acceptable' insects with minimum labour, space, and cost. This may be achieved through standardisation of procedure, mechanisation of programme, efficient production, maintenance of quality control, effective sanitation, and microbial control contamination in the rearing laboratory.

Keywords: Rearing; mass-rearing; beneficial insects; predators; parasites; review.

INTRODUCTION

Beneficial insects (parasitoids and predators) are reared in the laboratory for several reasons:

1. To study the insect itself, facts pertaining to its life history, habits, habitats, host relationship, and dietary requirement.
2. To facilitate the establishment of an introduced or indigenous species by rearing large numbers for release.
3. To accomplish a wider distribution of a previously established species.
4. To supply routinely or at a specified time large numbers for release for biological control.

In this paper factors affecting rearing and mass production are briefly discussed. This is not a comprehensive review; the concept is rather a summation from the work of several authors—selected references are given.

FACTORS AFFECTING REARING OF BENEFICIAL INSECTS

The laboratory rearing of beneficial insects encompasses 3 biological entities: the beneficial species, the insect host, and the plant host or artificial food. In order to develop a rearing programme it is necessary to study the biology of the beneficial species and its insect host, and to seek information on plant hosts or artificial diets.

Some of the factors involved are common to the beneficial species and the insect host, while others are specific.

1. Reproductive (e.g., mating, fecundity)

Mating habits vary greatly between species and the majority mate most readily at 18-20°C. In unfavourable environments, the female may be encouraged to mate using techniques such as **(i)** changing the ratio of male to female, **(ii)** withholding nourishment from the female for a few hours and then presenting food in the presence of a fully fed male, **(iii)** exposure to air movement in the presence of male(s), **(iv)** keeping at low tempertature and then suddenly increasing to the 'optimum' temperature in the presence of bright light, **(v)** subjecting to chilling or anaesthesia and subsequently confining with the male immediately after recovery but before regaining full activity, **(vi)** shaking the container vigorously to tumble the adults together, and **(vii)** the use of sex pheromones.

The highest fecundity potential should be exploited for a rearing programme. Proper feeding, egg laying surfaces, and timing of egg laying will enhance egg production. The duration of the reproductive life of a species may be a very significant consideration. Some species are still alive and fertile after their progeny have emerged and are also reproducing, while others have a short life span. Sex ratio is influenced by the size of the host (i.e., a small host may produce more males) and within limits, a high female/male ratio of the parasite is more efficient.

2. Behavioural (e.g., superparasitism, cannibalism, diapause, host preference, taxes.)

Superparasitism and cannibalism are detrimental to rearing. Superparasitism may be alleviated by maintaining an optimum host/parasite ratio. Control of cannibalism is one of the chief limiting factors in the rearing of predators. Crowding should be avoided and excess prey should be made available. Factors governing initiation and termination of diapause should be studied since manipulation of diapause increases rearing efficiency. Certain parasite species must feed on the host to acquire protein for egg production. Again, an optimum host-parasite density ratio will increase efficiency.

Taxis (a response of an insect to a stimulus), e.g., orientation to light, should be exploited and utilised to a maximum. A list of natural and alternative hosts should be prepared and the most suitable one selected.

3. Environmental (e.g., temperature, humidity, ventilation, rearing containers, microbial contaminants).

The physical conditions in rearing are as important as biological, behavioural, and nutritional factors.

A. Rearing environment: Special conditions of temperature, light, humidity, air, and dust are required for certain species of insects. These must be adjusted to encompass the tolerance of entomophagous species, host species, and host medium, separately or in combination. Compromises must be made between the optimum environmental conditions and the maximum yield for each species.

A temperature around 26°C and a relative humidity of 55-65% is satisfactory for rearing most species. Too low a relative humidity during emergence can be fatal and too high can result in fungal or other disease problems. Too high a humidity also causes drowning of larvae and asphyxiation of many adults. Rapid larval development of some insects at higher temperatures results in less active adults than those which develop more slowly at a lower temperature. Too low a temperature can destroy the sperm-producing capability of entomophagous males. Quality and quantity of light has tremendous influence on the development of certain species and affects mating ability. Similarly quality of air and circulation affects insect development. Parasitoids are generally sensitive to dust which should be avoided or minimised.

B. Rearing containers: The selection of rearing containers depends on species, stage, size, behaviour, and insect numbers. They should have the following characteristics: **(i)** be secure against escape; **(ii)** construction material should be non-toxic to insects; **(iii)** be adequately ventilated to prevent the accumulation of excessive heat, moisture, and odour; **(iv)** be easily cleaned, disinfected, or disposable; **(v)** be of adequate size for mating and host search; **(vi)** be adaptable for use in the several phases of rearing operation; **(vii)** be of standard size and easily procurable; **(viii)** be designed to take advantage of the insects behavioural taxis; and **(ix)** be adaptable to automated handling. **C. Microbial contamination:** Microbial contamination can be caused from the field, laboratory, and artificial food.

(i) **Field:** The hazard of incipient contaminations of pest insects and pathogens is coincident with the bringing in of field material to the laboratory. Every effort should be made immediately to eliminate these undesirable organisms while the insect colonies are small. The best approach is to set up several small units and discard those which are undesirable. To accomplish this will require at least 1 or 2 generations of rearing in the laboratory. The large-scale rearing programme should not be launched until a clean initial stock of host insect is established. The safest stage to start a culture in the laboratory from the field is either to collect eggs or fertile adults. The eggs should be surface sterilised.

(ii) **Laboratory:** The rearing laboratory should be managed like an operating theatre in the hospital. 'Prevention is better than cure' applies most appropriately to the situation. Strict hygiene and sanitary practices should be observed. All equipment should be sterilised. The problems of microbial contamination and their solution are discussed by Singh (1980).

(iii) **Dietary:** Inclusion of antimicrobial agents in the food and use of aseptic techniques will suppress the presence of microorganisms which cause spoilage. Antimicrobial agents can be detrimental. It is recommended that they should be carefully selected with due regard to the species of microorganisms causing contamination, and to the tolerance of the insect species concerned.

4. Physiological (e.g., host searching ability, enzyme, pheromone and sound production).

Laboratory rearing could induce changes and affect the physiological state of insects which in turn will affect their performance. For example, host searching ability of the parasite may be reduced or ability to produce pheromone, enzymes, sound, etc., is impaired. In some cases visual perception is affected. Singh (1981) has given examples of how these factors can affect insects in culture. These and other physiological factors should be throughly studied especially if the rearing has to be maintained over several generations.

5. Nutritional (e.g., alternative host, nutritional requirements, factors relating to artificial diets).

The food available to insects has a profound influence on growth, development, metamorphosis, reproduction, physiology, and behaviour. Consideration of the depletion of nutritional reserve requires special attention. The best food should be selected. How the performance of laboratory reared insects could be affected by the use of artificial diet is reviewed by Singh (1981).

6. Genetic (e.g., inbreeding, sex ratio, genetic drift, size of founder colony).

MacKauer (1976) reviewed genetic problems associated with rearing of beneficial insects. Reports on the genetic decline of insect cultures due to prolonged inbreeding can usually be traced to improper maintenance although in entomophages, male dominant production can debilitate the culture. Selective breeding programmes and development of special strains is recommended. The addition of wild stock every so often may help to alleviate inbreeding problems, but there is a risk of introducing disease. If it is intended to maintain the colony for a long time, then the founder colony should be increased.

REARING OF HOST INSECTS

The object of rearing an insect host is to provide a pure population of optimum density on, or in, an easily manipulated and acceptable medium. The host could be natural, unnatural, or artificial. Convenience, ease of handling, and economics are some important criteria in selecting a host.

The qualifications of the ideal laboratory insect host for the rearing of beneficial insects are **(i)** ready acceptance by beneficial insect, **(ii)** ease of rearing, **(iii)** ease of mating, **(iv)** ease of separation from its enviroment, **(v)** general feeding habits, **(vi)** immunity to diseases, **(vii)** having a high fecundity, **(viii)** showing little or no internecine activity, **(ix)** producing no by-products such as honey dew or wax, and **(x)** lacking diapause and cannibalistic traits.

PRODUCTION OF HOST PLANTS OR ARTIFICIAL DIETS

There are 3 types of hosts used in rearing of entomophagous insects: **Natural:** A natural host is one that an entomophagous insect usually attacks in nature. **Unnatural:** An unnatural host is used in the insectary in place of the natural host mainly for the sake of convenience and economics. It is seldom if ever attacked by the entomophagous insect in nature. **Artificial:** An artificial substrate is one that is prepared or formulated by man, such as artificial diets. Several species of insects now can be conveniently reared on such diets and some progress has been made whereby entomophagous insects can now be directly reared on such artificial diets. Though large-scale rearing is yet not practical technology is advancing fast in this direction. Two predatory groups (*Chrysopa* spp. and coccinellids) have been reared in great numbers on synthetic diets and some success has been achieved with dipterous parasitoids.

The function of the host plant or artificial diet is to support optimum populations of the insect host. An ideal host-supporting substrate should be **(i)** easily available, **(ii)** amenable to laboratory techniques, **(iii)** able to provide nutritional requirements, **(iv)** convenient to handle, **(v)** slow to deteriorate, and **(vi)** economical.

FEEDING OF ADULT ENTOMOPHAGES

A crucial factor in efficient production of entomophagous insects is the provision of adequate supplies of the appropriate food for the adult stages. In nature they may prey on their hosts or feed on nectars and honey dews. In the laboratory a source of carbohydrate and/or protein usually suffices and is critical for egg maturation, oviposition, and longevity. The quality of adult food can influence fecundity and apparently can induce diapause in their progeny.

Feeding habits and nutritional requirements of individual species must be understood to achieve maximum vigour and reproduction.

Dried or soaked raisins are a good source of natural food in the laboratory. Sugar cubes or weak sugar solution (5-10%) is satisfactory. Straight honey, equal parts of honey and water, or 1 part of honey and 2 parts of water (streaked on glass in tubes, or cages, or on wax paper, cotton-soaked wicks) are commonly used. Stiffer honey compound can be prepared by mixing agar with different proportions of sugar and honey which can be varied depending on rearing relative humidity. Candied diets compounded from honey, sugar, and enzymatic yeast hydrolysate have been used for coccinellids and chrysopids.

CONCEPT, GOAL, AND APPROACHES TO MASS PRODUCTION

The concept of mass production may be defined as the skilful and highly refined processing of an entomophagous species and its host and substrate through insectary procedures which result in the economic production of large numbers of beneficial insects.

The goal of a mass production programme is to produce the maximum number of quality 'acceptable' entomophagous insects with minimum labour, space, and cost. Criteria of acceptability vary and are dependent on the use made of the laboratory reared insects. These may be different for insects required for release for biological control as compared with insects required for pathogen production or for sterile insect release. The term 'acceptable insect' should not be confused with 'normal insect'. Normal insects may be regarded as healthy insects bred in favourable conditions with a gene complex typical of a field population. A special strain can be developed to achieve a programme goal which may not be 'normal' but 'acceptable'.

In approaching a mass production programme the work is usually developed in the laboratory in the following sequence. Firstly, an adequate reservoir of the host support medium and, then, sufficient numbers and sustained volumes of the host species are produced. The entomophagous species is reared and maintained at a sufficiently high level, to give the maximum number of insects for field colonisation. Once the research and development is completed in the laboratory, attention is paid to **(i)** standardisation of procedure, **(ii)** mechanisation of the programme, **(iii)** production efficiency, **(iv)** maintenance of quality control, and **(v)** maintenance of a trouble-free insectary operation. The latter may include the control of contaminants, sanitation, sterilisation, and movement of personnel.

About 50 species of beneficial insects have been successfully mass produced and utilised in the field for biological control by augmentation. A great many advances have been made in rearing these insects economically in China, Holland, the United Kingdom, the U.S.A., and the U.S.S.R.

PERFORMANCE AND QUALITY OF ENTOMOPHAGOUS INSECTS

Quality can be defined as the relative degree of excellence in some trait of skill that a thing possesses. Entomologists responsible for control of quality in insect rearing are faced with 2 basic decisions: **(i)** what is the standard of reference for measuring quality, and **(ii)** what are the behavioural traits that must be evaluated, and how can they be measured?

Several traits related to quality of laboratory reared insects are listed by Chambers (1977), particularly vigour, activity, sound production, response threshold, reproductive potential and drive, and biotic potential. Some of the changes that may affect quality are alterations in metabolic functions, or nutritional reserve content, tolerance to temperature, and toxins. Other factors are fertility, fecundity, longevity, or population stress, and changes in biological conformity such as rhythm, mating behaviour, and host specificity. Chemical and physical responses, pheromone production, or mate recognition are also important.

The total performance of a particular entomophagous species depends on the searching ability of the female, effective reproductive capacity, sex ratio, synchrony with the host species, and availability of nutrients in the environment. Any one or combination of these factors will affect the perfomance and even the survival of a species in a given environment.

CONCLUSION

Rearing of beneficial insects in the laboratory is a specific operation in which optimum conditions of environment, cage size and shape, illumination, feeding, and host preferences, have to be worked out afresh for each species. There are virtually no 'rules' to indicate how best to tackle any idividual species. Any practical rearing scheme must be based on technique develped in the laboratory and then modified for cheap large-scale production.

There is a special kind of person who can successfully rear insects. Quoting from Fisher (1963):

> "The good insectary worker is a dedicated artisan with a sense of right or wrong procedure regarding the handling of his charges—which, because they are living things, do not always behave in a perfectly predictable manner".

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