Proc. Indian Acad. Sci. (Anim. Sci.), Vol. 96, No. 5, September 1987, pp. 613–618.

Biosystematics in lepidoptera and its importance in forest entomological research*

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Abstract. Lepidoptera constitutes one of the dominant groups of insects in the forest ecosystem, both in terms of species diversity as well as their economic importance. Segregation of taxa in this order is mainly based on the external morphological characters at supraspecific and specific levels, although the morphological details of genitalic armature are also currently being used. More recent trends in the systematics of this group include studies of their ultrastructure, biochemistry, karyology, biometry, cytogenetics etc.

Lepidopterans differ in their habits and habitats, each species having its characteristic habitat requirements, but very sensitive even to slight changes in the environment. As a result, members of different populations which are subject to extrinsic factors affecting the habitats, host-plants or associated organisms exhibit considerable variation. Besides, changes are also brought about by intrinsic factors like parthenogenesis, intraspecific hybridization, changes in the genetic constitution of individuals, etc, which result in a high degree of intraspecific variability within a population.

Keywords. Biosystematics; lepidoptera; Forest entomology.

1. Introduction

Identification of species is basic to any biological research and with this objective, many systems of classification have been proposed from time to time. Of these, the dominant system of classification is the Linnaean system based on the structural details of organisms. According to an estimate by Blackwelder (1964), about 4,000,000 kinds of organisms are classified under this system and it has provisions to include more taxa that are described from time to time. This has been qualified as an 'omnispective' classification. The Linnaean system has undergone considerable modifications in its principles as well as methodology with the advances in the taxonomic research.

2. Development of the biosystematic approach in taxonomy

In the Linnaean system, organisms were classified on the basis of their structural similarity and the structural details of a single specimen representing a population formed the basis for 'species' descriptions. However a species consists of individuals which vary in their morphological details due to individual differences in their genetic make up. In addition to this, there are various extrinsic as well as intrinsic factors that cause variations among the members of a population. The evolutionary concepts of Darwin gave a scientific basis for such variations and 'species' came to be considered as a dynamic assemblage of individuals of varying phenotypes and consequently, species descriptions were formed on the basis of characteristics drawn

*KFRI Scientific paper no. 128

from a group of individuals. Taxonomy thus lost much of its subjectivity and became more objective and theoretical.

It is generally recognized that the more two organisms are similar, the more will they be related in descent. In other words, closely related organisms were expected to possess more characters in common. This led to the proposal of classifications based on a study of a large number of characters which were unselected and unweighted. The results of this purely phenetic approach were not satisfactory, since in such schemes, there were always the danger of the inappropriate characters swamping over the appropriate ones, resulting in unnatural classifications (Blackwelder 1964).

Occurrence of sibling species, seasonal forms, host races as well as allopatric and sympatric variants create confusion in establishing the taxonomic relationships in many 'species groups' using the morphotaxonomic approach. The correct ranking of such variants is often very much needed in applied entomological research since such variants behave entirely different from species to which they are often associated. As a result, a study of living organisms in relation to its environment has become necessary. Taxonomy thus became more biologically oriented and this led to a remarkable interplay of ideas involving biometry, ecology, biochemistry, genetics etc into the taxonomic schemes. The term 'biosystematics' is applied to such classificatory schemes.

3. Classification of Lepidoptera

Lepidoptera which include butterflies and moths, is one of the most advanced groups of insects and are of great economic importance as pests, pollinators and as objects of aesthetic value.

Taxonomy, in most lepidopteran groups is still in a very primitive state. In most cases, segregation of taxa is based on the morphological details of the head appendages, venation of the wings, structure of legs etc, at the higher taxonomic levels, while the general colour and wing pattern are used for species separation. Although considerable progress has been made recently in arriving at a more stable classificatory scheme using newer characters like the morphological details of the genitalia.

3.1 *Role of biosystematic studies in lepidopteran taxonomy*

Any attempt to discuss the role of biosystematics in the classification of Lepidoptera should consider their biological as well as behavioural characteristics, since the manifestation of even slight changes in these characters among the members of a species are often one of the first indications on the occurrence of intraspecific variants.

Majority of Lepidoptera being phytophagous, depend on plants for sustenance. Some of them can feed on a variety of host plants while some show considerable specificity in host selection. For instance, the toon shoot borer, *Hypsipyla robusta* (Phycitidae), the teak defoliator, *Hyblaea puera* (Hyblaeidae), the teak carpenter worm, *Cossus cadambae* (Cossidae), the paddy caseworm, *Nymphula depunctalis* (Pyraustidae) etc show specificity to certain plants, while the bagworm *Eumeta crameri* (Psychidae), the teak sapling borer, *Sahyadrassus malabaricus* (Hepialidae), the castor fruit borer, *Dichocrocis punctiferalis* (Pyraustidae), the flour moth, *Cadra* *cautella* (Phycitidae) and the grain moth, *Crocera cephalonica* (Galleriidae) are polyphagous and can develop on a variety of hosts.

Lepidopterans show considerable diversity in its habits. Even the same family may contain species having diverse habits. There could be leaf feeders, stem borers, fruit borers and so on. Even among those with a more or less similar habit, there could occur many variations in their relative behaviour. For example the foliage feeders may include species that feed exposed or concealed. Similarly the stem borers may include species that prefer to bore into the top shoot portion, or the basal portion of the stem, or in the roots.

The adults normally feed on the nectar of phanerogamic plants. However some species prefer to feed on the juice of over-ripe fruits (*Euthalia garuda*, *Othereis* spp.); on the liquid portion of animal excreta (some butterflies); on the lachrymal secretion of vertebrates (*Lobocraspis griseifusa*); or even on blood (*Calyptra eustrigata*). Such diversification in the habits of Lepidoptera is in response to the nutritional requirements of the particular species and to ensure better survival chances for it.

Being highly mobile organisms, the chances of Lepidoptera in getting distributed over a wide geographical region are relatively high. Large scale migration of many butterflies and moths have been reported from many parts of the world (Ford 1972). In addition to this, there are also chances of their accidently getting distributed through commerce, especially with the recent advancements in the transport system.

Changes in the climatic or edaphic conditions are known to affect the biological processes of living organisms. For example, the duration of life cycle in the carpenterworm, *Zeuzera coffeae* is reported to vary in different climatic zones (Beeson 1941). Similarly, many lepidopterans (Psychidae) can remain dormant as larvae or pupae over long periods especially during adverse weather conditions. Instances of reproductive diapause have been reported in the nymphalid butterflies, *Speyeria coronis* and *S. zerene* in California. In the females of these butterflies, a delay in the ovarian development occurs during the warm summer season, which delays the onset of oviposition until late summer or early fall thus decreasing the exposure time of the overwintering first instar larvae to dessicating conditions (Sims 1984). Studies on the cabbage butterfly, *Pieris rapae* have shown that the food plant on which this insect was previously feeding influenced its further selection of the same host plant (Hovanitz and Chang 1962). Brakefield and Larsen (1984) have reported the occurrence of seasonal forms, in butterflies that occur in habitats characterised by changing environmental conditions. Similarly, in a study of the bagworm, *Pteroma plagiophleps* (Psychidae), Mathew (1986) reported the occurrence of 6 types of variants. Difference in the general colouration coupled with a certain extent of host preference has been noticed in populations of *Atteva fabriciella* (Yponomeutidae), collected on *Quassia indica* and *Ailanthes triphysa* respectively (Mohana Das K, unpublished results). Since living organisms are the physical manifestation of a series of continuing changes in the environment, such changed conditions are likely to affect the biological characteristics of organisms, which may be reflected in their phenotype.

Besides changes in the phenotype, and the relative host preference, Lepidoptera may also show variations in its behaviour on different host plants. For example, the cotton (*Gossypium* spp.) leaf webber, *Sylepta derogata* (Pyraustidae) usually feed singly within folded leaves. It makes only a single fold per leaf on the latter host. However, on balsa (*Ochroma pyramidale*), which has broader leaves, several folds may be seen on the same leaf, each harbouring a larva (Mathew 1980). The reasons for such host associated behavioural responses remain to be worked out but probably be dependent on the texture of the foliage, its chemical nature, structure of the ingestive organs of the insect as well as its digestive physiology.

Lepidoptera also exhibit changes in response to different geographical regions. Occurrence of distinct geographical races have been recorded in many butterflies and moths. Such geographical races differ only slightly and their segregation is often difficult using the conventional taxonomic methods. Coexistance of closely similar species or intergradation of species in the areas of contact has also been reported. Hudson (1973) stated that there are about 200 species of moths belonging to the genus *Euxoa*, many of which bear close similarity rendering recognition difficult. In a study on the paddy leaf roller, *Chaphalocrocis medinalis*, Mathew and Menon (unpublished results) came across a new species which could be identified only by a detailed study of the genitalic morphology.

Besides the host associated and geographical variations mentioned above, Lepidoptera may also offer variations due to gene mutation. Since in the classical taxonomy, identification is based on the characters of the preserved specimens, such variants might get misidentified as distinct species. Only by studies with the living organism, it is possible to ascertain their taxonomic relationships and the role of biosystematic studies in Lepidoptera is mainly to distinguish such intraspecific and interspecific variants.

3.2 *Progress so far made on biosystematics in Lepidoptera*

As stated previously, recognition of intraspecific categories become important while comparing different populations of a species that show clear-cut host specificity or for distinguishing variants that occur in a geographical region or within the population of a species. To facilitate this, a number of studies have been made in several areas, such as micromorphology, cytology, genetics, biometry and biochemistry. A short summary of the progress in some of the above fields is given below.

3.2a *Micromorphology*: Application of scanning electron micrography has made it possible to locate and evaluate a wide variety of micromorphological characters previously unstudied, with a view to generate as many characters as possible for computer analysis. These characters were selected from the different life history stages and mainly include studies on the chorionic sculpture, structure and position of aeropyles, primary cells etc of the eggs (Byers *et al* 1975; Salkeld 1973, 1976); the structure of sclerotized and pigmented areas especially of the prothoracic shield, anal plate as well as the pinacula (Mutuura 1980) and the morphology of the pyloric portion of the hindgut in the larvae; the microstructure of head and genitalic appendages (Davis 1986), the structure of spermathecal cells, as well as the number and structure of chromosomes in the adult. Munroe (1972) reported the occurrence of a tuft of specialised scales on the head 'chaetosema' in pyralids and used this character for segregation of suprageneric categories. Computer analysis of large sets of characters in the hope of arriving at useful combinations have also been attempted by some workers.

3.2b *Biochemistry*: Most studies in this line involved the electrophoretic patterns of the egg proteins, serological relationships between egg antigens as well as hemocytological studies. Of these, electrophoretic studies on enzymatic similarity are being increasingly used to trace genetic relationships among taxa showing close phenotypic resemblance. At the lower taxonomic levels, the more labile group II enzymes have been successfully employed to distinguish between species having identical anatomical phenotypes. However, the biochemical compounds fail to simplify taxonomic interpretation of disjunct groups of contemporary populations (Stephen 1973). The importance of comparative biochemistry in systematics lies principally in characterising homologues at the supraspecific levels.

4. Relevance of biosystematics in forest entomological research

Two aspects, viz the management of forestry important insect pests as well as conservation of ecologically important species are currently the main themes in forest entomological research (Collins and Morris 1985). With increasing demand for timber, forest plantations of a variety of indigenous as well as exotic tree species are being raised in extensive plantations. In addition to this, hybrids of several plant species are also being developed for possible resistance against insect or disease problems as well as for boosting productivity. Such large scale afforestation programmes involving the introduction of new germplasm may affect the biological attributes of organisms. Since the characteristics of an organism are to a great extent governed by climatic, edaphic or biotic factors, drastic changes in the ecosystem may also affect the biotic balance between various organisms. The recent epidemic of the bagworm, *Pteroma plagiophleps* on the introduced trees, *Albizia falcataria* as well as *Delonix regia* in Kerala is a striking example to this. This insect when first reported from southern India was only a pest of minor importance on *Tamarindus indica* and epidemics due to this insect have never been reported either on *T. indica* or any other native tree species. Biosystematic studies can play a major role in elucidating the factors leading to such pest outbreaks on forest plantations.

Other than the appearance of new pests, the development of new host races has been a phenomenon observed in many Lepidoptera. The host races behave differently from the natural populations of the species and establishment of the exact identity is very often required since modern pest management strategies are highly species specific.

With the increasing interest on conservation of nature, studies on the forest ecosystem are becoming very important. Correct identification of species is fundamental to any ecological study. Lepidopterans being mostly phytophagous affect the distribution and abundance of vegetation in any habitat. Shapiro (1985) reports that feeding by an inflorescence feeding pierid (*Anthocharis sara stella*) destroyed between 41 and 49% of potential seed output of a crucifer in California. Information on the extent of variation in the wild condition will also be of indicative value in monitoring the effect of environmental changes on organisms, since the phenomenon like industrial melanism is known to produce strikingly different colour patterns in many lepidopterans.

Since the objective of a classification is to allow easy identification of the included taxa, the classificatory schemes need to be simple to operate. In the morphotaxonomy, direct matching of species is still considered to be an accepted method of identification, and this limits its application in dealing with intraspecific categories with comparatively less morphological distinction. Taxonomic ranking of such categories though not much needed for the conventional taxonomist, is needed for the applied researcher who is working with living organisms. Since biosystematics involve studies with the living organism, it can not form part of the conventional taxonomy and probably further refinement is necessary to make it more practicable for routine identification of Lepidoptera.

Acknowledgements

I am grateful to Dr M G Ramdas Menon, formerly of the Division of Entomology, Indian Agricultural Research Institute, New Delhi, for suggestions and useful discussions.

References

Beeson C F C 1941 *The Ecology and Control of the Forest Insects of India and the Neighbouring Countries* (Government of India)

Blackwelder R E 1964 Phyletic and phenetic versus omnispective classification; in *Phenetic and Phylogenetic classification*. (eds) V H Heywood and J McNeill (London: The Systematics Association) No. 6, pp 17-28

Brakefield Paul M and Larsen Torben B 1984 The evolutionary significance of dry and wet season forms in tropical butterflies; *Biol. J. Linn. Soc.* **22** 1-12

Byers J R, Hinks C F and Lafontaine J D 1975 Biosystematics of the genus *Euxoa* (Lepidoptera, Noctuidae) II. A description of the immature stages of *Euxoa* basalis and a redescription of the adult; *Can. Entomol.* **107** 1083-1094

Collins N M and Morris M G 1985 *The threatened swallowtail butterflies of the world* (The IUCN Red data book, UK)

Davis Donald R 1986 A new family of monotrysian moths from Austral South America (Lepidoptera: Palaephatidae), with a phylogenetic review of the monotrysia; *Smithson. Contrib. Zool.* No. 434, p 202

Ford E B 1972 *Moths* (London: Collins)

Hovanitz William and Chang Vincent C S 1962 *J. Res. Lepid.* **1** 51-61

Hudson Anne 1973 Biosystematics in the genus *Euxoa* (Lepidoptera: Noctuidae); *Can. Entomol.* **105** 1199-1209

Mathew George 1980 Occurrence of *Sylepta derogata* Fb. (Lepidoptera Pyraustidae) as a pest of balsa (*Ochroma pyramidale*) in Kerala; *Entomon* **5** 71-72

Mathew George 1986 Variations in the wing venation of *Pteroma plagiophleps* (Lepidoptera Psychidae); *J. Res. Lepid.* **24** 359-363

Munroe Eugene 1972 *The Moths of North America*; Fasc. **13** 1A pp 12-14

Mutuura Akira 1980 Morphological relations of sclerotized and pigmented area of lepidopteran larvae to muscle attachments with application to larval taxonomy; *Can. Entomol.* **112** 697-724

Salkeld E H 1973 The Chorionic architecture and shell structure of *Amathes c-nigrum* (Lepidoptera-Noctuidae); *Can. Entomol.* **105** 1-10

Salkeld E H 1976 Biosystematics of the genus *Euxoa* (Lepidoptera: Noctuidae) VII Eggs of subgenera *Chorizagrotis, Crassivesica, Longivesica, Crosagrotis* and *Pleonectopoda*; *Can. Entomol.* **108** 1371-1385

Shapiro Arthur M 1985 The impact of pierid feeding on seed production by a native California crucifer; *J. Res. Lepid.* **24** 191-194

Sims R S 1984 Reproductive diapause in *Speyeria* (Lepidoptera: Nymphalidae); *J. Res. Lepid.* **23** 211-216

Stephen W P 1973 Biochemical systematics and the higher categories; *Can. Entomol.* **105** 1223-1233