

Some aspects of biosystematics of Bruchidae (Coleoptera)

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Abstract. Bruchidae forms a small compact group of phytophagous Coleoptera with well defined ecological limits. Its members are by and large seed eaters, mostly attacking the seeds of Leguminosae including edible legumes. Several genera show definite host plant relationships and many species present strict host specificity. The bruchids of economic importance fall into two categories viz (i) store bruchids and (ii) field bruchids, with separate voltinism and distinct pattern of development. The bruchids of no recognized economic importance also have characteristic host plant relationship, pattern of distribution and avoidance of interspecific competition. Apart from the known taxonomic discrimination on the basis of external morphology, the genera and species can also be characterized from variations in the internal anatomy, the number and structure of chromosomes and the quality and quantity of their macromolecules. Behavioural peculiarities are also useful for the discrimination of species and genera. The time, manner and duration of copulation, site of oviposition and time and methods of emergence provide useful variations. Compatibility and incompatibility of various host seeds dependent on the amount of non protein aminoacids, antiprotease compounds, hemagglutinin fractions and other toxic substances for different bruchid species and the capability of the latter for combating the same also provide valuable demarcative information.

Keywords. Internal anatomy; chromosomes; behaviour.

1. Introduction

It is well known that the conventional taxonomic procedure in different groups of animals is primarily based on morphological characteristics that are stable and discriminatory to facilitate identification and determination of suitable status for different taxa. This procedure has been found by and large quite satisfactory and is rather difficult to replace. Accordingly, the identification of the species and their allocation to higher taxa will continue to be founded on the morphological features for a long time to come. This is so despite the fact that the category of species is now characterized on biological criteria and that the higher taxa like genus and family also show appreciable ecological, biochemical and genetical relationship among different animal groups. However, scattered works on different life processes of many species have provided useful information in the areas other than the external morphology which can be profitably used as supplementary material for the confirmation of taxonomic decisions and for solving complex problems of taxonomy dealing with sibling species and infra specific categories. The true relationship among such taxa is often shrouded by such evolutionary phenomena as convergence, parallel evolution etc. In fact, the need for compilation and evaluation of ecological, biochemical, physiological and behavioural characteristics of the animal species has increased with the increase in the complexity of taxonomic challenges and this area is fast emerging as a distinct field of biosystematics. This communication is an attempt to review and compile the existing knowledge of the biosystematics of the family Bruchidae.

Bruchidae is rather a small family of phytophagous Coleoptera under which about 1300 species referable to about 70 genera have so far been recorded from different parts of the world. It is a compact group with poor genetic differentiation and high degree of interspecific similarity. The eggs are laid on the surface of the seeds, the larvae and pupae live within the seeds and the adults make their exit by pushing against thin caps or windows prepared by the mature larvae just before pupation. Whereas the larvae are voracious eaters, the adults hardly consume any substantial amount of food. The adults, commonly called as seed weevils, are small in size, measuring between 2–5 mm in length and the variation in their size is usually related to the size of the host seeds.

2. Observations

2.1 Ecology

The family Bruchidae is so evolved as to feed on the seeds of different plant families. Excepting some species which are associated with the seeds of families like Malvaceae, Convolvulaceae, Rosaceae, Papaveraceae and Palmae etc, about 90% of the species attack seeds of Leguminosae (Southgate 1979). Out of 5 subfamilies of Bruchidae, the largest Bruchinae is almost completely associated with Leguminosae while other 4 families attack seeds of non-leguminous plants. At the generic level also, there appears a strong pest-host correlation. Several genera such as *Abutiloneus*, *Megacerus* and *Caryotrypes* (Southgate 1979) are restricted to their respective host genera but genera like *Bruchidius*, *Callosobruchus* and *Conicobruchus* have wider ranges of host genera. A limited or varied host specificity is also witnessed at the level of species.

According to another ecological interpretation, the family Bruchidae can be divided into two major categories, viz (i) store bruchids and (ii) field bruchids (Southgate 1979). The store bruchids are obviously pests of edible seeds which are stored after the harvesting of the legume crops. The store bruchids are fast breeders, have short life cycles and life spans and, thus acquire the potentiality of passing a number of generations in the course of the year. With the food supply in plenty, the breeding is continuous without any interruption and the fecundity is high. Such species mainly come from the genus *Callosobruchus* (Arora and Pajni 1957; Arora and Singh 1970; Pajni and Jit 1976) to be shared by a single species each from the genera *Zabrotes*, *Acanthoscelides* and *Bruchidius*. The field bruchids, on the contrary, include representatives of almost all the genera but include only a few species of economic importance. The field bruchids are, as a rule, univoltine and the single generation in the year is marked by long life cycle and long life span, with the intervention of a phase of imaginal diapause. Moreover these bruchids are usually host specific and have an obligatory requirement of feeding on the host flowers for attaining the capability of reproduction. Although this correlation has been verified only in a few species (Pajni 1981, 1984; Pajni and Mittal 1984), but is likely to prove as a general ecological principle for the field species in general. The host plants of the field bruchids however come from a number of genera without obeying any relationship with the bruchid genera. But a rearrangement of genera of both groups on the basis of biochemistry might project their real relationships.

2.2 Behaviour

Several bruchid species are characterized by such behavioural peculiarities as to make them distinctive from other species and are therefore important in their identification. One such character relates to their copulatory behaviour. The males and females copulate in one-above-the-other position and the male holds the female with the help of its fore and middle legs. However, *Callosobruchus theobromae* is exceptional as the male of this species does not hold the female during copulation (Chopra 1986). The time of copulation is also quite variable. Most of the species copulate at all hours of the day but pairing in *Caryedon serratus* takes place only at dusk time (Pajni and Mann 1979) and in *C. theobromae* in the darkness of night or in the early hours of the morning. A similar variation is seen in the duration of copulation, with *Bruchus* and *Callosobruchus* species and, *Zabrotes subfasciatus* having a short duration of less than 8 min (Arora 1977; Pajni and Sood 1984; Pajni and Jabbal 1986) and *Conicobruchus* and *Caryedon* mating for a much longer period of 20-30 min (Pajni and Mann 1979; Chopra 1986). *C. chinensis* is unique in showing the minimum copulation period of about 45 s (Arora and Singh 1970). The males of most species are polygamous but the capacity of male to inseminate the females varies a good deal (Pajni 1987). Similarly, *C. chinensis* and several field species are monoandrous but others show some degree of polyandry.

The identity of *Z. subfasciatus* can be established from the shape of its eggs which are spherical in comparison with the oval eggs of all other species. This species is also distinctive in laying eggs in clumps. The eggs are usually laid on the surface of the seeds or pods where they are cemented with the help of secretion. However *Bruchidius angustifornis* (Singal 1981) and *Conicobruchus indicus* (Chopra 1986) lay their eggs on calyces of the host flowers. Whereas *Neltumius texanus* (Johnson 1978) and *Sennius simulans* (Center and Johnson 1972) have their eggs attached with the help of anchoring strands radiating from the egg chorion, *Acanthoscelides obtectus* simply scatters its eggs among the harvested seeds (Southgate 1979), while other species of this genus insert them in the holes bitten in the outer tissue (Skaife 1926; Zachariae 1958).

The first instar larva in the family Bruchidae is different from the 3 subsequent larval instars in possessing well formed thoracic legs, an H-shaped plate on the prothorax and a hatching spine on each lateral side of 1st abdominal segment, marking some sort of hypermetamorphosis. Genus *Caryedon* is however characteristic in possessing well developed legs even in the mature larvae. In fact, the larvae of this genus and perhaps the entire subfamily Pachymerinae are exceptional in having long salivary glands, two pairs of malpighian tubules, 11 pairs of air sacs and in showing the habit of cocoon formation (Vats 1979). The number of eggs laid on each seed of the host depends largely on the density of the adults and is a poor indicator of the identity of the pest. However the number of adults emerging from a seed has a definite pest-host relationship and is mainly decided by the proportion between the size of the bruchid and the host seed. In this manner, many species like *Callosobruchus maculatus* (Arora and Pajni 1957), *Callosobruchus analis* (Pajni and Jit 1976), *Bruchus pisorum* (Pajni and Sood 1984), *B. lentis* (Pajni and Mittal 1984) and *C. theobromae* show the emergence of one adult from each infested seed. On the other hand, the number of adults that emerge from a single seed has been reported as 21 in the case of *Z. subfasciatus* (Pajni and Jabbal 1986), 8 in *Callosobruchus chinensis*

(Arora and Singh 1970) and 28 in the case of *Bruchus rufimanus* (Riley and Washington 1892) in their respective hosts of *Phaseolus vulgaris*, *Cicer arietinum* and *Vicia faba*. On the other extreme, there are several instances where the maturation of the larva to the adult stage requires the consumption of up to 4 seeds as reported in the case of *Conicobruchus* spp. attacking *Crotolaria* spp. (Skaife 1926; Prevett 1967; Chopra 1986) and *Sennius* spp. attacking *Cassia baubinioides* (Center and Johnson 1972).

Pupation generally occurs within the seed cavity, one edge of which has only the thin seed coat intact and is demarcated on the out side as a circular window or cap. The cap is subsequently incised along the margin and pushed out by the emerging adult. However, species consuming the entire or the major part of the seed prepare the cap on the surface of the pod as for example in *C. indicus* (Chopra 1986) and *Bruchidius saundersi* (Arora 1977). The larva of *C. serratus* prepares a papery cocoon for its pupa which emerges partially out of the host seed (Pajni and Mann 1979) or remains within the pod (Southgate 1979). In *C. theobromae*, the mature larva has to cut a hole in the seed as well as the adherent part of the pod (Chopra 1986) for the exit of the adult from unripe seed. Other species consume the seeds and the adults wait for the subsequent splitting of the pod for dispersal as in *Bruchidius ater* (Frankenhuyzen and Perquin 1972).

2.3 Internal structures

Apart from the special anatomical features in the subfamily *Pachymerinae* stated above, the subfamilies *Bruchinae* and *Amblycerinae* can also be characterized from the number of air sacs in their mature larvae which are 4 pairs in the former and 5 pairs in the latter (Vats 1972). In the adults also, a good amount of anatomical variation, particularly in the reproductive organs is witnessed. The testes in this family always comprise of two pairs of follicular structures and the number of follicles in each testis is highly variable, being 14–28 in *Caryedon* (Singh 1981), 1–18 in *Bruchidius* (Singh 1978a) and 8 in *C. maculatus* (Pajni 1968). Similarly, the number of male accessory glands also varies at the level of genera. There are 5 pairs of these glands in *Specularius*, 4–5 pairs in *Callosobruchus* and 4 pairs in *Conicobruchus*, *Bruchidius*, *Sulcobruchus* and *Zabrotes*, 3 pairs in *Bruchus* and *Caryedon* and the minimum of 2 pairs in *Spermophagus*. The histology, shape and position of the glands show differences at the species level (Singh 1978b). In the females, the number of ovarioles per ovary varies in different species. A low number of 3–5 ovarioles per ovary is present in *Amblycerinae* followed by 6 ovarioles per ovary in a majority of *Pachymerinae* and *Bruchinae* and ranging between 7–18 ovarioles per ovary in genera *Bruchidius*, *Conicobruchus* and *Bruchus* (Singh 1973). Studies on the karyology of bruchids show that in the subfamily *Pachymerinae*, the diploid number of chromosomes varies from 18–20 and is supposed to be primitive, followed by *Bruchinae* with diploid number of 20–22 chromosomes which rises to 26–32 chromosomes in *Amblycerinae* which is therefore the most specialized subfamily (Yadav 1973). Different species cannot be characterized by the number of chromosomes or sex mechanism but a few polytypic species like *Callosobruchus chinensis* have been reported to show different number of chromosomes in component sub species or strains (Takenouchi 1955, 1971; Sharma *et al* 1967; Yadav 1969, 1971). A similar type

of intraspecific chromosomal variation has been recorded in *C. maculatus* (Yadav 1971). The noted variation in the chromosome number of certain populations within a species is related to the appearance of morphologically expressed polymorphism in *Callosobruchus* species (Arora and Pajni 1957; Pajni 1986a, b, 1987). Different morphs have also been found to differ in their fecundity and month of appearance in the laboratory cultures.

2.4 Biochemistry

The suitability of a particular host for the attack of a bruchid species is determined by the biochemical composition of the seeds and the adaptive characteristics developed by the bruchids for tackling the toxic contents of such seeds. Accordingly, some legumes are incompatible or less compatible for the development of some bruchid species. This correlation decides the host range of various species of store bruchids leading to different degree of host specificity. The 3 common *Callosobruchus* species each can attack a wide range of edible legumes although the number and type of host seeds is different in each case. *Zabrotes subfasciatus*, on the other hand, has *P. vulgaris* as its major host but can also thrive on *Glycine max.* *P. vulgaris* is not attacked by any of the other store bruchids, showing their inability to neutralize the incompatible contents of these seeds. In spite of these limitations on their host range, the bruchids express a high degree of adaptive capacity to attack a variety of legumes in different parts of the globe. This is also supported by their successful breeding in the laboratory on such host seeds which other wise escape their attack in nature (Pajni 1986b).

Various species of store bruchids studied for the variations in their metabolic reserves also provide useful information for their characterization. According to Sharma and Sharma (1979a, b), the fresh females of *Z. subfasciatus* have 45.7% total lipids (TL) as compared to 36.9% of TL in *C. maculatus*. The corresponding figures for the males of these species are 38.2% and 32.3% respectively. These two species also differ in their body weight and water content, with the female of *C. maculatus* weighing two times more than that of the female *Z. subfasciatus* and the male of the former weighing 3 times more than that of the male of the latter (Sharma and Sharma 1984). There is however only a slight difference in the glycogen contents (Sharma and Sharma 1980) and tissue proteins (Sharma and Sharma 1980) in the two sexes of both the species.

It follows from the foregoing account that different species of bruchids can be easily distinguished on the basis of non-morphological characters pertaining to their ecology, behaviour, physiology and biochemistry. The morphs of the dimorphic/polymorphic species can also be similarly characterized. Such information is accordingly of great utility in strengthening the morphological basis of taxonomy and in solving its intricate problems.

3. Discussion

The foregoing review on the biosystematics of Bruchidae reveals that the members of this family form a well knit compact group and show striking similarity in their outer appearance. A correct identification of the species can be only confirmed from the

study of their male genitalia. Accordingly, the use of morphological criteria for specific determination is rather a difficult and laborious process. The bruchid species, however, can also be characterised on the basis of biological characteristics. Several species have a strict host plant relationship and can be easily made out from their respective host plants. The reproductive behaviour of bruchids is also highly variable and several species can be separated on the basis of time, manner and duration of copulation as well as from the condition of polygamy. Likewise, the time and pattern of oviposition is also characteristic in many species. The shape of the egg and the structure of the larvae present very useful discriminatory features as also the pattern of egg laying in these forms. The feeding behaviour of the larvae, the emergence of the imago and the number of adults emerging from a host seed are some other features in which different species show specific behaviour. The univoltine and multivoltine types of development vertically divide the family Bruchidae into two categories of field-bruchids and store-bruchids. A number of structural features of the internal anatomy show differences not only at the level of species and genera but also at the level of sub-families. These include number of air sacs and malpighian tubules in the larvae and the number of accessory glands, ovarioles and testicular follicles in the adults. The number of chromosomes show a definite correlation at the level of subfamilies and has been found to differ even in various morphs of the polymorphic species. The quality and quantity of macromolecules, which is dependent on the larval food, also shows significant variations in closely allied species. A study of all these aspects is of utmost importance for a complete understanding of the bruchid species and for their characterization in biological terms.

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