

ECOLOGICAL STATUS OF HOST RANGE AND POLYMORPHISM IN BRUCHIDAE

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Abstract

Observations made on the bionomics of 6 species of storage and field bruchids during the last 25 years have revealed that different species show wide variations in their host-seed range. The storage bruchids are usually polyphagous and multivoltine, undergoing uninterrupted development on the stored seeds. The host range of the individual species is rather variable and each species fails to breed on one or more common pulses. The incompatibility of such pulses is determined by the presence in their seeds of certain non protein amino acids, lectins or other secondary substances which afford protection against the bruchid attack. The field species, on the contrary, are generally monophagous, univoltine and attack green pods of their hosts. Host specificity is decided by the indispensable feeding of the adults on the pollen and nectar of the host. The storage bruchids show considerable variation in the colour pattern of their bodies which characterise different morphs, resulting in distinct dimorphism/polymorphism in different species. These morphs appear in the laboratory cultures during different seasons of the year in varying percentages and show differences in their fecundity. The polymorphism in these bruchids denotes a self-regulating system for keeping the population under control. Cosmopolitan Callosobruchus maculatus (F.) is well known for its pronounced dimorphism but the different behaviour of its abnormal female in different regions of the world, makes the phenomenon more complex. The polymorphism in Callosobruchus chinensis (L.), Callosobruchus analis (F.) and Zabrotes subfasciatus (Boh.), though less pronounced, is closely related to that of C. maculatus in as far as its periodicity and reduction in the fecundity of the abnormal form is concerned. The capability of Acanthoscelides obtectus (Say) of breeding both in the field and the store is a case of behavioural polymorphism which is not externally manifested but can be resolved through electrophoresis and might be discernible in the fine structure of the chemoreceptors.

Introduction

Members of the family Bruchidae are mostly associated with seeds of leguminosae. Many of the species infest the seeds of edible legumes and are responsible for colossal losses. The field bruchids are largely host specific, but the storage bruchids generally have a wide range of host seeds, showing selective preference for a few of them. The degree of host specificity is dependent on several factors. Some of these, based on studies on several bruchid species in this

laboratory during the last quarter of a century, are detailed in this communication.

The storage bruchids are generally fast breeders and are subjected to a high degree of inbreeding, resulting in the appearance of several morphs in each species. Such morphs differ not only in their morphology but also exhibit physiological and behavioural differences. Moreover, the appearance of these morphs also appears to have a deeper ecological significance. The information collected from observations on four common species of storage bruchids namely: Callosobruchus maculatus (F.), C. analis (F.) C. chinensis (L.) and Zabrotes subfasciatus (Boh.) is also presented in this report.

Observations and discussion

Host range

Studies on C. maculatus, C. analis, C. chinensis, and Z. subfasciatus reveal that the first mentioned three species attack a number of host pulses, while the last mentioned infests only two major pulses (Table 1). However, the host range for the three congeneric species of Callosobruchus is also quite variable. C. chinensis does not attack Phaseolus vulgaris (L.) Glycine max Merr. and Vigna mungo Hepper while C. maculatus in addition spares Lens esculenta Moench and Eriesema chinense Vog. but does attack V. mungo. On the other hand, C. analis also excludes Cicer gigas, Pisum sativum L. and Vigna umbellata Ohwi from its attack, although it can sometimes attack G. max. Likewise, Z. subfasciatus only rarely attacks V. unguiculata Verdc. in addition to its primary hosts, P. vulgaris and G. max. It is also noticed that the results of laboratory rearing are somewhat different from the attack in nature. The host specificity of the bruchids and the incompatibility of different host seeds to individual species of bruchids, according to Applebaum (1964), is due to nutritive as well as digestive factors responsible for inhibition of development. Studies on the incompatibility of P. vulgaris to several species of bruchids show that this is due to many growth hindering substances such as pentose sugars (Ishii and Urushibara, 1951), phytohemagglutinin fractions (Honavar et. al., 1962; Gokhale and Srivastava, 1969; Janzen et. al., 1976), and HCN-rich glucoside Linamarin (Janzen, 1977). Similarly, the incompatibility of soy bean seeds is due to the presence of soybean saponins (Applebaum, et. al., 1965; Applebaum, 1969) or low carbohydrate/protein ratio (Applebaum et. al., 1968b). Bell and Janzen (1971), hold L-dopa (L-3,4-dehydroxyphenylalanine) responsible for the protection of many seeds. Roy and Bhat (1975) discovered a significant correlation between levels of trypsin inhibitors in Lathyrus sativus and susceptibility to attack by C. chinensis. Janzen et. al., (1977) reported that some of the non-protein amino acids like L-dopa, when added to the diet of C. maculatus at 0.1% concentration prove highly toxic. According to Podoler and Applebaum (1971) a high amount of amylose in certain varieties of pea provides poor nutrition for C. chinensis feeding on them. Thus the incompatibility of different

legumes is largely dependant on the quality and quantity of non-protein amino acids, lectins, alkaloids and certain toxic substances present in them and its intensity is also modified by the relative concentration of other components like protein, lipids and carbohydrates. The incompatibility of P. vulgaris and G. max may be due to high concentration of phytohemagglutinin, high concentration of aspartic acid or the lack of vicilin and legumin-like proteins (Harborne et. al., 1971). The higher susceptibility of Vigna as compared with Phaseolus species may be traced back to the complete absence of pipercolic acid in the former. Likewise, Vigna and Glycine also differ from Phaseolus in the relative ratio of two polyamines, spermine/spermidine, in their seeds.

Table 1: Infestation of common legumes by four common bruchid species under natural and laboratory conditions.

Pulse	Bruchid species							
	<u>C. chinensis</u>		<u>C. maculatus</u>		<u>C. analis</u>		<u>Z. subfasciatus</u>	
	N	L	N	L	N	L	N	L
<u>Phaseolus vulgaris</u>	-	-	-	-	-	-	+	+
<u>Glycine max</u>	-	-	-	-	+	-	+	+
<u>Vigna unguiculata</u>	+	+	+	+	+	+	+	+
<u>Vigna radiata</u>	+	+	+	+	+	+	-	+
<u>Vigna mungo</u>	-	-	+	+	+	+	-	+
<u>Vigna aconitifolia</u>	+	+	+	+	+	+	-	+
<u>Cicer arietinum</u>	+	+	+	+	+	+	-	-
<u>Cicer gigas</u>	+	+	+	+	-	+	-	+
<u>Pisum sativum</u>	+	+	+	+	-	+	-	+
<u>Lens esculenta</u>	+	+	+	+	-	+	-	-
<u>Cajanus cajan</u>	+	+	+	-	+	+	-	+
<u>Eriesema chinense</u>	+	+	-	-	-	+	-	-
<u>Vigna umbellata</u>	+	+	+	+	-	+	-	-

N = Attack in nature

- Negative

L = Attack in laboratory

+ Positive

In spite of the presence of defensive chemicals, certain species of bruchids have devised means of dealing with potentially toxic substances as shown by the attack of Z. subfasciatus and Acanthoscelides argillaceus on HCN-rich wild P. lunatus (L.), (Janzen, 1977) and the association of Caryedes brasiliensis with the L-canavanine rich (8% dry weight) seeds of Dioctria megecarpa (Rosenthal et. al., 1976; Rosenthal, 1981). This has led to a high degree of adaptability in the bruchid species, initiating behavioural differences in their trophic relationships and resulting in some cases in morphological polymorphism. The flexible adaptability on the part

of bruchid species is also directly related to the reported intra-specific variations in the protein contents (Mosse and Pernollet, 1982) and alkaloids (Jolivet and Mosse, 1982) in the individual fields, plants and pods of the same species.

In contrast to the trophic relationships of the storage bruchids, the host range of the field bruchids is extremely limited. Bruchus pisorum L., Bruchus lentis Froel. and Callosobruchus theobromae L. which are the respective pests of P. sativum, Lens esculenta and Cajanus cajan (L.) Millsp. are monophagous and attack the green pods of their hosts (Pajni and Sood, 1976; Pajni, 1981; Pajni and Mittal, 1984). The host specificity in all these three species is determined by the obligatory feeding of the adults on the pollen and nectar of their hosts for the maturation of the gonads and subsequent initiation of copulation and oviposition. The host specificity is thus the result of a process of co-evolution between the pest and host that ensures the matching of the reproductive process of the pest with the availability of host food and the dormancy of the adults during the period of non-availability of the food. The same ecological phenomenon appears to be operative in other field bruchids and is perhaps applicable to many other field species for bringing complementary co-adaptation.

Polymorphism

The occurrence of C. maculatus in two different forms is well known (Utida, 1954; Arora and Pajni, 1959; Caswell, 1960). The more active form has been designated as 'flight' form which is reported to leave the store and fly to the field for reproduction. However, the flight form is less fecund than the normal form. Factors found responsible for the flight form include change in temperature, humidity, population density (Utida, 1956; Sano, 1967), photoperiod, low temperature, and total water contents of the seeds (Utida 1965, 1968, 1969, 1970; Utida and Takahashi, 1958). Utida (1974) also suggested the role of a hereditary factor in the appearance of this form, while Utida (1972) and Nwanze *et. al.*, (1976) held the reduced level of juvenile hormone to be responsible for the same. The same two forms of C. maculatus have also been recorded from African countries (Caswell, 1956, 1960), and their biological characteristics have been studied by Taylor (1974), Taylor and Agbaje (1974), Taylor and Aludo (1974), Ouedraogo and Huignard (1981) and Alzouma (1981). The abnormal form in the Indian strain of C. maculatus was first recorded by Arora and Pajni (1959) who also recorded the differences in colour pattern of elytra and pygidia of the two forms. The abnormal form of the Indian strain, however, is completely sterile and therefore there is no question of its going to the field for reproduction. Moreover, the sterile form appears in the laboratory culture during April, gradually reaches its peak population in June-July whereafter it slowly disappears by the end of October. In addition to the hot and dry months which favour development of the sterile form, the latter also makes its appearance in heavily infested and metabolically heated

culture jars. Arora *et. al.*, (1967) reported significant differences in the genitalia of the normal and sterile males whereas Bawa *et. al.*, (1971, 1972, 1974a, 1974b), and Sidhu *et. al.*, (1984) recorded biochemical and physiological differences in the two types of males. Spirina (1974) has also reported variations in the bursa-copulatrix of normal and abnormal females which are also present in the Indian strain. It is thus evident that even the so-called abnormal form of *C. maculatus* shows different behaviour in different regions and the species is in a way polymorphic. The abnormal female is recognizable by its white pygidium in all the regions.

Two distinct forms in the Japanese strain of *C. chinensis* were recorded by Nakamura (1966, 1969) one of which was reported to be active and less fecund than the other but the two forms do not show any morphological differences. Applebaum *et. al.*, (1968a) found an Israeli strain of this species different in its antennae and the arrangement of setae on prothorax and pygidium from another strain from Japan, but they did not comment on their relative fecundity. Fujii (1968), collected four strains of *C. chinensis* from different localities of Iran and Japan and did not find much differences in fecundity, fertility and longevity of the adults. Three types of females differing in the pattern of setae on their pygidia have been noticed in the laboratory culture of the Indian strain of *C. chinensis*. These three morphs appear during different months of the year and show variable fecundity (Table 2). The polymorphism of the females characterized by morphological and physiological differences and conditioned by different seasons of the year, more or less matches the better known phenomenon in *C. maculatus*.

Table 2: Incidence and fecundity of three types of *C. chinensis* females throughout the year.

Month (1984- 1985)	Brown pygidium		White pygidium		Black pygidium	
	% Incidence	Fecundity (\pm S.E.)	% Incidence	Fecundity (\pm S.E.)	% Incidence	Fecundity (\pm S.E.)
March	81.4	60.7 \pm 5.3	18.6	48.3 \pm 4.8	-	-
April	80.9	61.7 \pm 6.1	19.1	47.7 \pm 6.7	-	-
May	79.6	37.6 \pm 5.4	20.4	30.8 \pm 4.4	-	-
June	61.7	50.3 \pm 5.6	38.3	41.6 \pm 3.9	-	-
July	56.0	69.4 \pm 6.6	44.0	58.7 \pm 4.7	-	-
August	30.2	78.6 \pm 7.1	69.8	61.8 \pm 4.9	-	-
Sept.	32.7	69.1 \pm 3.5	67.3	51.0 \pm 4.8	-	-
Oct.	41.7	63.6 \pm 6.5	20.8	46.0 \pm 6.0	37.5	74.1 \pm 8.3
Nov.	47.9	53.3 \pm 7.2	-	-	52.1	60.3 \pm 6.7
Dec.	53.0	54.0 \pm 4.8	-	-	47.0	65.5 \pm 10.4
Jan.	60.9	52.1 \pm 6.4	-	-	39.1	58.1 \pm 5.8
Feb.	57.5	53.7 \pm 5.9	-	-	42.5	55.9 \pm 6.7

The laboratory cultures of Z. subfasciatus, a strictly storage bruchid in India, have also revealed the presence of two different females, one with the pygidium coated with black setae crossed in the middle with a streak of whitish setae, and the other with the pygidium almost uniformly covered with whitish setae. The former is present throughout the year, constitutes larger percentages of the population, is more fecund and may therefore be considered as the 'normal' form. The other morph appears during the hot months in much smaller numbers, is relatively less fecund and may be designated as 'abnormal' form (Table 3). The total lipids, proteins and DNA contents also show differences in the two types of females. Accordingly, the condition of dimorphism in this species also falls in the general pattern shown by the Callosobruchus species.

Table 3: Monthly records of abnormal and normal forms of Zabrotes subfasciatus, oviposition, and climatic data.

Month (1984- 1985)	% abnormal form	Average number of eggs/female	Temp. range (daytime) °C	% R.H. range (daytime)
		abnormal form	normal form	
Feb.	8	7	27	11.5-21.5 45-50
March	22	12	28	17.5-26.5 60-63
April	38	15	31	28.5-33.5 29-61
May	15	17	33	32.0-41.8 34-72
June	15	18	33	32.5-39.5 34-68
July	18	21	42	30.0-33.5 28-79
August	20	23	45	28.0-31.5 67-86
Sept.	16	24	51	28.5-31.5 65-89
Oct.	NIL	-	-	25.5-30.5 70-92
Nov.	NIL	-	-	13.8-26.1 21-92
Dec.	NIL	-	-	8.7-24.2 21-52
Jan.	NIL	-	-	8.0-24.5 27-62

The on-going studies on C. analis also indicate the presence of two types of females in the laboratory culture of this species. One type has the posterior halves of the elytra and pygidium coloured dark black and the other has a brownish tinge in the same areas. Preliminary observations also show that the proportions of the two types of females vary during the course of the year and they exhibit differences in fecundity. The exact periodicity of appearance of the two forms and their month-wise fecundity is being studied.

Apart from the noted polymorphism in the above mentioned four species, distinct behavioural diversity has also been recorded in Acanthoscelides obtectus in different regions such as Mexico (Biemont and Bonet, 1981; Hodek et. al., 1981); France (Jarry, 1981); and Colombia (Huignard and Biemont, 1981).

It follows from the foregoing that the seasonal appearance of different morphs showing differences in the morphology and behaviour is a prevalent phenomenon among the storage bruchids. It is also noticed that the less fecund morphs generally appear during the adverse hot and dry months. The phenomenon shows the existence of a deep rooted self-regulating system for controlling the rate of reproduction in accordance with the prevailing environmental conditions, supply of food and the population density of a particular species, rather than a mere change in colour pattern of the body. The noted externally manifested dimorphism/polymorphism in bruchid species may be traced back to their genomes. Takenouchii (1971a, 1971b) has recorded different numbers of chromosomes in the males from different populations of C. chinensis and C. maculatus. According to Kasiwagi and Utida (1972), the black coloured adult mutant of C. chinensis behaves as a single recessive autosomal trait in the crossing experiments. Likewise, the red, black and white-coloured mutants of C. maculatus constitute a multiple alleleomorph system (Breitenbecher, 1921). The decrease in the flight form of C. maculatus after a large number of generations (Caswell, 1960; Utida, 1974), according to Utida (1981) is caused by the genetical background in the expression of the two forms in the adult. The case of behavioural polymorphism reported in A. obtectus (Pouzat, 1981) can be better characterized through electrophoresis techniques and might be discernible in the fine structure of the chemoreceptors and tactile receptors of this species. The behavioural polymorphism in bruchids and other stored grain pests causes a great challenge to the applied entomologists. A proper characterization of the known strains of the pests and parasites is warranted as the only alternative, howsoever tedious the exercise might be. Recognition of 'Biotypes' denoting the slightest deviation and the initiation of polymorphism in any population is the first step. Subsequent physiological changes without or with minor phenotypical variation in some cases and distinctive morphological differentiation resulting in markedly different morphs in other cases can be followed easily. An increased role of electrophoresis and the rapidly developing field of chemical ecology (Bell and Carde, 1984) is thus called for. A similar exercise is needed for the standardization of cultivars of the common edible legumes in the interest of uniformity and reliability of results from the pest-host experimentation.

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