

BEHAVIORAL POLYMORPHISM IN THE SRI LANKAN STRAIN OF COWPEA WEEVIL (*Callosobruchus maculatus* (F.)) (Coleoptera: Bruchidae))

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ABSTRACT

The cowpea weevil *Callosobruchus maculatus* (F.) exhibits dispersal polymorphism. Certain environmental conditions trigger development of "active adults" capable of flight. Studies on the external morphology reveal that the adults of the two morphs can be distinguished only by the characters of the hind wing. The apical margin of the hind wing of active adults is acutely curved, and the jugum is larger than that of the normal adults. Although both active and normal adults flex their wings, only active adults are capable of flight. The longest distance of the first leg of flight is 3300 cm where as the maximum flying height from the ground level is 900 cm. Mean fecundity of normal adults was significantly higher (81 ± 5) as compared to that of active adults (66 ± 7). Mean fecundity of normal and active adults increased by 27% and 32% respectively when the adult females were allowed to feed on bee-honey. Honey feeding could be advantageous specially for active adults for replenishing the energy sources utilized for flight thereby increasing the fecundity.

KEY WORDS: *Callosobruchus maculatus*. Dispersal polymorphism. Fecundity. Feeding habits. Flight behavior.

INTRODUCTION

In order to ensure survival in the face of deteriorating local environments, many species of insects are equipped with effective mechanisms of long-range dispersal which allow them to exploit the widest possible feeding situations. Increased population density, declining food resources and adverse changes in the environment are known to trigger off the production of specialized dispersing morphs or flying adults (Caswell, 1960; Sano-Fujii, 1986). Increased population density or crowding has a particularly powerful effect on insects that use it as a cue to produce flying adults. At low densities populations of these species typically consist of highly fecund sedentary adults. As

crowding increases some juveniles follow a separate development path and become morphologically distinct adults capable of flight (Messina, 1987). Crowding-induced dispersal polymorphism has been widely observed in several insect species (Harrison, 1980).

Cowpea weevil, *Callosobruchus maculatus* (F.), is a major pest of stored legumes in most parts of the tropical and subtropical world (Gia and Smith, 1981). Females glue their eggs to the seed surface and hatching larvae chew their way into the seed directly beneath the oviposition site. Larval development takes place entirely within the seed causing quantitative and qualitative losses to stored legumes (Mitchell, 1975;

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Wijeratne, 1998). Dispersal polymorphism in cowpea weevil arouses a great deal of interest in applied entomology because of its practical implications.

Utida (1954) was the first to note the presence of flying and sedentary adults in a crowded colony of cowpea weevil and designated the two morphs "active" and "normal" respectively. Subsequently several attempts have been made to distinguish the two morphs by their external characters (Southgate *et al.*, 1957; Caswell, 1960) and also to identify the factors responsible for the production of active adults, and some aspects of their behavior (Sano-Fujii, 1967; Ouedrago and Huignard, 1981). However no definite character has yet been identified that could be used in separating the two forms. Studies on biology reveal that the active adults exhibit delayed reproduction with low fecundity (Nwanse *et al.*, 1976; Messina and Renwick, 1985). Although the adults of the two morphs require neither food nor drink, there is evidence of increased fecundity when the adults are allowed to feed on bee-honey or nectar.

Apparently, the active adults of cowpea weevil are capable of flying a great distance and initiating infestation in distant fields. The pods or seeds infested with active adults, when harvested and brought to stores, will provide the impetus for infestation. Without pre-harvest infestation initiated by the active adults in the field, endemic populations within the stores cannot be expected. Thus information on the various aspects of biology and behavior of active adults is extremely important in developing control strategies to arrest the initiation of field infestation leading to more successful management of this pest under storage conditions.

Experiments were conducted to identify the external characters that could be

useful in separating the two forms, and to make a comparative study of the flight activities, and oviposition behavior of the active and normal adults in response to feeding.

MATERIALS AND METHODS

Maintenance of insect stocks

A sample of *C. maculatus* Sri Lankan strain was collected from a sample of infested beans (*Phaseolus vulgaris* L.) obtained from a farmer at Rikillagaskada. The insect cultures were maintained at room temperature ($30\pm3^{\circ}\text{C}$) and humidity (70 ± 6 RH) in the laboratory of the Plant Genetic Resources Centre, Gannoruwa, Peradeniya. For routine cultures about twenty five adults were placed in 225 ml glass jars containing about 1000 seeds of an unidentified Sri Lankan variety of cowpea (*Vigna unguiculata* (L.) Walp.). The jars were closed with a piece of cloth and a rubber band. Under these conditions new adults started to emerge in 3-4 weeks.

Newly emerged (0-24 h old) adults were used in all the experiments. In order to obtain virgin adults the seeds showing "windows" were removed from the culture jars and isolated in small glass vials, one seed per vial, and kept under constant observation for collection of adults as they emerged. The beetles were sexed immediately using the male and female characteristics described by Southgate *et al.* (1957).

External characters of the normal and active form adults of *C. maculatus*

The experiment for the collection of normal and active adults was conducted in a small room with a floor space of 8100 cm^2 . An aluminium tray (30 x 40 x 6 cm) with water up to 3 cm high was placed in the centre of the floor and an empty dish was placed in the middle of the tray. About one thousand

newly emerged adults of cowpea weevil collected from routine cultures were placed in the dish. The insects placed in the dish were unable to walk out because of the water barrier but could fly away. After 2 h, ten adults that flew away and landed on the walls and ten adults incapable of flight were collected with an aspirator. The external characters of these adults were carefully examined under the dissecting microscope. In this study particular attention was focused on the wing dimensions, width of the abdominal segments, and characters such as body colour, black spots on the elytra and the density of pubescence described by Southgate *et al.* (1957).

Flight behavior of the active adults

This experiment was carried out in an open environment in the absence of wind. Ten culture jars containing newly emerged adults were kept open in the sun so as to facilitate their escape and flight. The active adults gradually started flying. Many of the active adults landed on the white walls of the buildings in the surrounding area. The flying paths of these adults were followed and the distance (distance of the first leg of their flight) and the flying height were recorded. Flying height was the height from the ground up to the point of the wall where the insects landed.

Effect of honey feeding on the fecundity of active and normal adults of *C. maculatus*

This experiment was conducted in a randomized complete block design replicated 10 times. The experiment consisted of four treatments. A pair of virgin male and female was introduced to each of Belfast-disposable petridishes containing 50 seeds of cowpea (M1 35). The lid of each petridish was perforated to enable air circulation. Bee honey was

provided for a set of active and normal adults. The other set was not provided with any food. All the petridishes, placed on a water bath to protect them from invasion by ants, were kept in the laboratory under normal room temperature for oviposition. Daily counts of eggs laid by each female was recorded.

RESULTS AND DISCUSSION

External characters of the normal and active form adults of *C. maculatus*

The sample of insects examined contained ten active and ten normal adults. In this sample we found seven active and one normal adults with broad abdominal segments; three active adults and nine normal adults were with narrow abdominal segments. In the insects with narrow abdominal segments, the sternite apparently consisted of three portions. The anterior portion of the sternite is light brown whereas the posterior portion is dark brown. The posterior margin of the sternite is lined with a band of gray pubescence so that the entire abdominal segment appears to consist of 3 portions as illustrated in Fig. 1. Sternites of the narrow abdominal segments are devoid of the band of gray pubescence and therefore, appear to be narrow. We examined the other morphological characters such as body colour, black spots on the elytra and the density of pubescence on active and normal adults. Grouping and sub grouping of insects based on the above characters is depicted in Fig. 2. Although Southgate *et al.* (1957) described the body colour, pubescence density, and the presence of black spots on the elytra as significant characters in separating active and normal adults, it is quite apparent from our study that none of these characters is satisfactory as we were unable to use these characters in discriminating between active and normal adults. For example there were nine active adults with

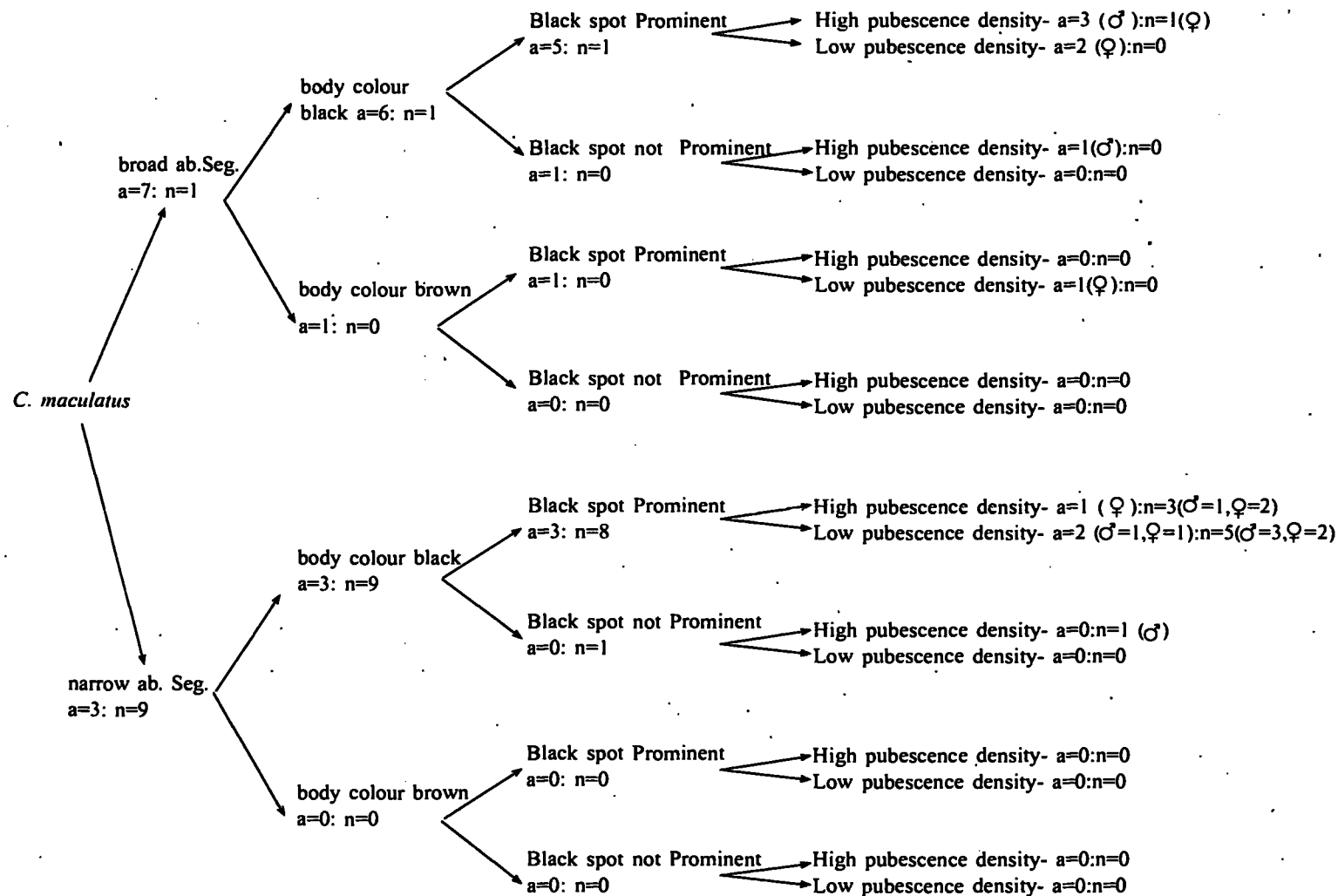


Fig. 2. Variation in morphological characters of active (a) and normal (n) adults of *C. maculatus*.

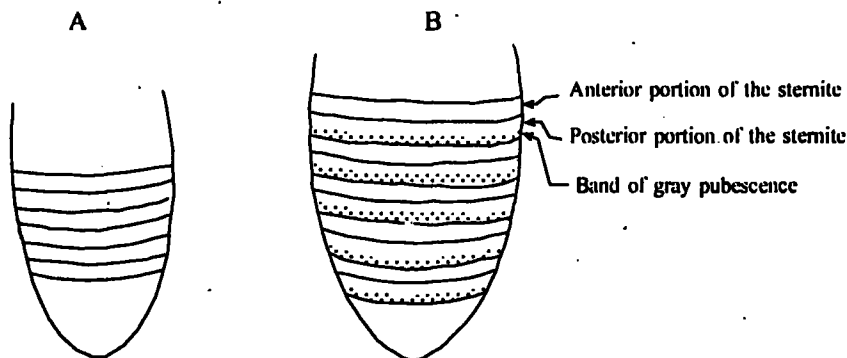


Fig.1. *C. maculatus* with (A) Narrow abdominal segments (B) Broad abdominal segments.

black body colour and one active adult with brown body colour. However, the body colour of all normal adults was black. There were nine active adults and nine normal adults with prominent black spots on the elytra. Similarly there were five active adults and five normal adults with high pubescence density (Fig. 2).

Southgate *et. al.* (1957) pointed out that the active adults are black while the normal

adults are brown. They also noted the presence of black spots on the elytra of both active and normal adults, but these spots in the case of active adults stand out sharply as the rest of the elytra is covered with golden pubescence. The ground colour of the pygidium in both forms is dark brown to black with a narrow white stripe of pubescence along the central line. In the normal form the rest of the pygidium is bare, but in the active form the

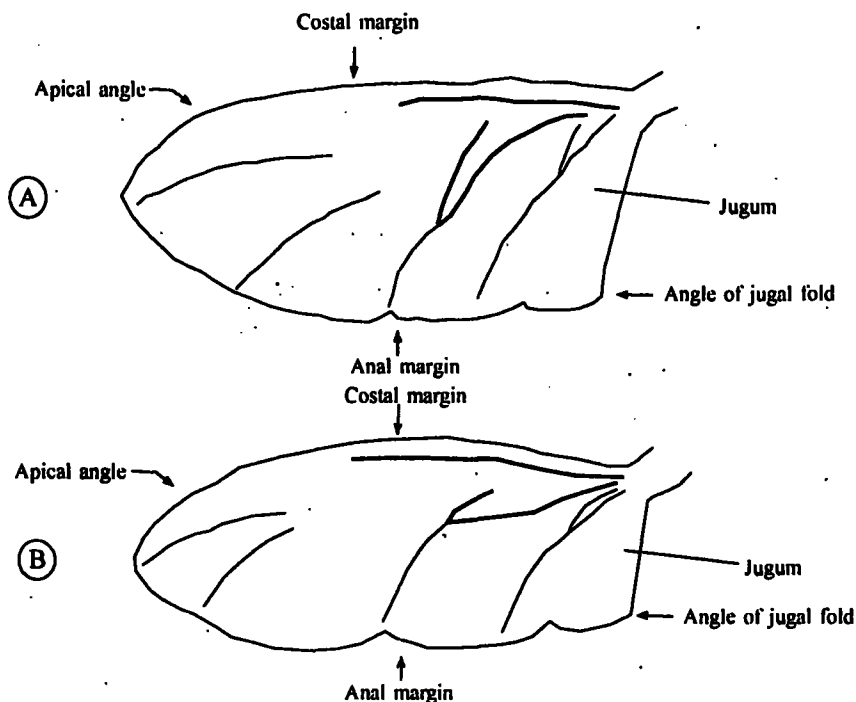


Fig. 3. Hind wings of (A) active adult (B) normal adult of *C. maculatus*.

rest of the pygidium is covered with dark pale golden pubescence. However, we found that only the characters of the hind wing are useful to distinguish the active and normal adults. We observed that the apical margin of the hind wings of the active adults is more acutely curved compared to that of the normal adults. The jugum of the active adults was much larger than that of the normal adult (Fig.3). The other important character is the width from the costal margin to the anal margin of the hind wing which is much greater in the case of active adults. We observed these differences to be consistent with the sexes of both forms. Yasui (unpublished) pointed out that of the morphological characters he examined the wing dimension was the only character that was useful in separating active and normal adults. However, Yasui failed to provide a detailed account of the wing characters that may be useful in separating the two morphs. Based on the wing characters that we have described the normal and active adults can easily be separated.

Flying behavior of active adults

Although both active and normal adults flex their wings, only active adults were capable of being airborne. Due to practical difficulties it was not possible to estimate the full range of flight, and our measurements were thus restricted only to the first leg of flight. The first leg of flight of 42 insects ranged from 240 cm to 3300 cm (Table 1a). Flying height of these insects ranged from 10

cm up to 900 cm above ground level (Table 1b). We observed that these adults show a tendency to land for resting on the objects that stand on the course of flight.

Utida (1954) reported a series of dropping tests and confirmed that the population of *C. maculatus* contains adults capable of flight. Similarly Taylor and Agbuje (1974) conducted some experiments with suction traps in a cowpea store and confirmed the presence of adults with flight abilities. All these studies on the flight activity of *C. maculatus* has been confined to the closed environments of store rooms where observations on the full range of flight behaviour have not been possible. The results of our experiments provide quantitative data that demonstrate clearly that the active adults of *C. maculatus* are strong fliers and they could fly a long distance and infest new stores or crops in the fields. Dispersal polymorphism has been observed in other bruchid pest species *Acanthoscelides obtectus* (Huignard and Biemont, 1978), *C. chinensis* and *C. subinnotatus* (Sano-Fujii, 1984). According to Utida (1972) dispersal polymorphism in many species of beetles that attack seeds under storage conditions may represent a transition between life in the field and in stored beans and so be a key to the evolution of some stored product pests. In this scenario it can be argued that the normal form adults of these beetles including *C. maculatus* may have evolved as a direct consequence of the prolonged storage of legumes where the flight

Table 1a. Flying distance of the active adults of *C. maculatus*.

Flying distance (cm)	Number of adults
240-1000	16
1001-2000	23
2001-3300	03

Table 1b. Flying height of the active adults of *C. maculatus*.

Flying height (cm)	Number of adults
10-100	04
101-500	24
501-900	09

ability does not reflect consequences for individual fitness unless their survival is challenged by the depletion of resource supplies or the negative effects of the environment within stores.

Effect of honey on the fecundity of the two morphs of *C. maculatus*

Analysis of variance revealed that the mean fecundity of normal females and active females differed significantly ($p < 0.001$). Normal females and active females that were not provided with any food source laid a mean of 81 and 66 eggs respectively (Table 2). Honey feeding increased the fecundity of the normal females by 27% and that of active females by 32%. Thus the mean fecundity of active adults fed on honey increased up to 87 whereas that of normal adults increased up to 103.

The females of the two morphs showed a similar temporal pattern of oviposition (Fig. 4). The highest egg production of the two morphs was observed on the first day of emergence which gradually decreased through time. The egg laying period of the two morphs was limited to seven days.

Caswell (1960) and Utida (1972) demonstrated that the fecundity of active adults was significantly lower as compared with the fecundity of normal adults. According to Caswell (1960) the reproductive system of the active adults does not mature until a week or more after emergence due to which they showed delayed oviposition and low fecundity. However, in our experiments the active adults did not show delayed oviposition although their fecundity was significantly low as compared to that of the normal adults. The amount of energy source carried by normal and active adults on emergence is the same (Caswell, 1960). Thus the lower fecundity of the active females can be explained on the premise that the active females partition a major portion of this energy for flight activities resulting in decreased fecundity. In our experiments fecundity of the adults were observed in petridishes which did not provide adequate space for free movement and flight activities. It is presumed that in the normal environment the fecundity of active adults could be further reduced as they utilize more energy for long distance flight. If the active adults could replenish the utilized energy sources by feeding on honey it could increase the fecundity thereby maximizing the fitness and the contribution to the next generation.

Table 2. Effect of honey feeding on the fecundity of normal and active females of *C. maculatus*.

Treatment	Mean fecundity $\pm$ SE
Active (Honey)	87 $\pm$ 9b
Normal (Honey)	103 $\pm$ 8a
Active (Without Honey)	66 $\pm$ 7c
Normal (Without Honey)	81 $\pm$ 5b

CV = 11.02

Values followed by the same letter are not significantly different at 5% level of DMRT.

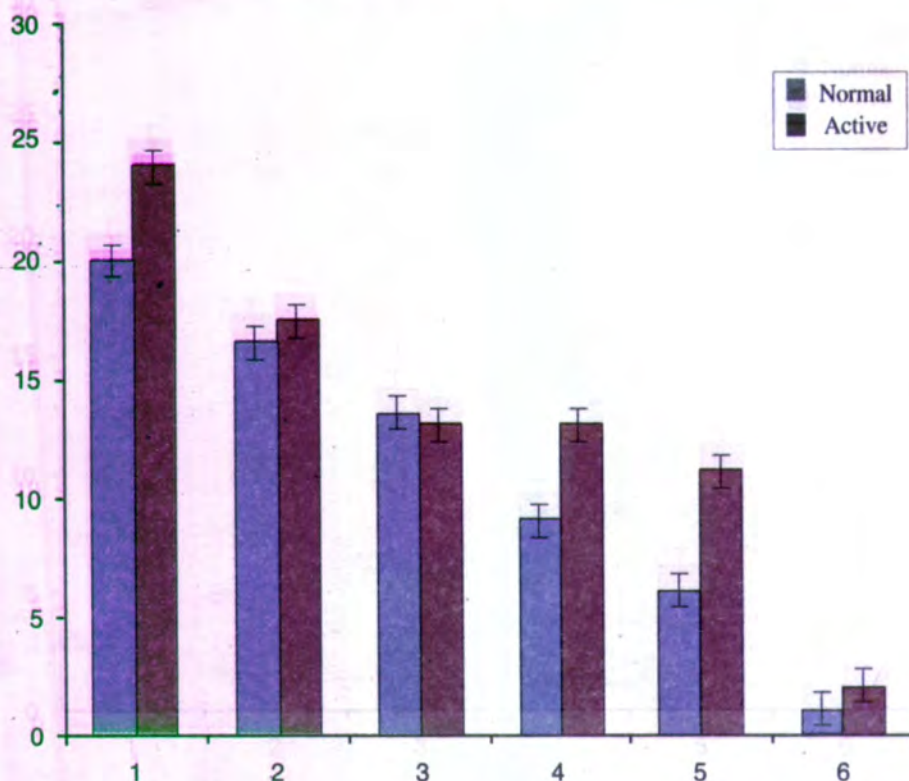


Fig. 4. Daily egg production of active (first column from left) and normal females (second column) of *C. maculatus* that did not feed on any food source. Vertical bars indicate SE.

CONCLUSIONS

Stored legumes are attacked by the larvae of cowpea weevil, *Callosobruchus maculatus*. Available evidence indicates that the preharvest infestation initiated by the active adults leads to population expansion within stores. It is evident that without field infestation initiated by the active adults, endemic populations within stores cannot be expected. Therefore, control strategies should be geared to arrest the production and spread of active adults. Development of such strategies would undoubtedly require information on the life history traits and behavioral aspects of the active adults. In this study we demonstrated the flight behavior of active adults and identified

important external characters for separation of the active and normal adults. It was found that the fecundity of the active adults was significantly lower as compared to that of normal adults. However, honey feeding increased the fecundity of the two morphs. Honey feeding could be particularly advantageous for the active adults to replenish their energy utilized for flight behavior which in return increases fecundity.

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