Variation in Weight, Size, and Sex Ratio of Coccinellid Adults (Coleoptera: Coccinellidae)

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The weight and size of coccinellid adults varied with species, sex, and feeding. Intraspecies variation in weight was generally similar in the eight species studied. Females were more variable than males in body size. Females of some species were heavier and larger than males, and species can be classified on a basis of difference in the weight and size of the sexes.

An increase in the food supply after a period of food scarcity affected the sex ratio, as the minimum food requirement of females was greater than males. Females increased in weight more rapidly than males after feeding. The availability of food in the field affected the weight and size of some species. Adult water content was influenced by feeding but not by sex or the quantity of food given to the larva.

Males were more abundant in species with small sexual differences in weight and size. The degree of difference in weight and size between males and females may be used as a criterion to select species that are best adapted to survive when food is scarce.

Introduction

Insect predators vary in degree of adaptation to changes in quantity of food. Ability to survive when prey are scarce enables a predator to participate in preventing an increase in prey numbers. A method of identifying species that have this ability would be of value in control work. The purpose of this investigation was to define variations in the weight, size, and sex ratio of coccinellid adults and to determine if these can be used to identify species that can tolerate food shortages.

Dixon (1959) reported that adults of *Adalia decimpunctata* (L.) were relatively constant in size. Some large adults were reared from field-collected pupae but no small individuals were obtained. However, he reared adults in the laboratory that varied in size depending on the amount of food that was given to the larvae. Smith (1965c) reared adults of *Anatis mali* Auct. and *Coleomegilla maculata lengi* Timberlake of various sizes and showed that *A. mali* is better able to tolerate a shortage of food than is *C. maculata*. It would be useful to know if coccinellid males and females differ in their minimum food requirements and whether small individuals survive in the field.

Coccinellid species with a greater capacity to vary in size may be better able to adjust their numbers to the available food than those with a lesser capacity. Longevity and fecundity are reduced in small individuals (Smith 1965a). Species in which the females require more food and are much larger than the males may also be better able to adjust their numbers to the available food. When food is scarce, fewer females than males would survive and fewer progeny would result.

This paper describes the effects of varying the quantity of larval food on the weight, size, and water content of males and females of *C. maculata*. It also describes variation in these factors and in the sex ratio of several species of coccinellids collected from different populations in the field.

Effects of Varying Larval Food

Eighty-one first-instar larvae of *C. maculata* were reared individually to the adult stage in the laboratory on different weights of dry aphids, *Acyrthosiphon*

pisum (Harr.) (Smith 1965b). The numbers of adults reared on the various weights of food were: 6 adults on 5.0 mg., 7 on 6.0 mg., 12 on 7.0 mg., 13 on 8.0 mg., 13 on 9.0 mg., 15 on 10.0 mg., and 15 on 13.0 mg. The work was done under constant conditions of about 22° ± 0.7° C. and 65% R.H. The unfed adults were weighed on emergence, killed by exposure to —15° C., dried over calcium sulfate in a desiccator, and weighed again. They were kept in a 10% solution of potassium hydroxide for about 15 days to soften the cuticle. Each adult was then washed in distilled water, sexed by examination of the internal genitalia, and mounted in DeFaure's medium on a microscope slide. Maximum length and width of the body, head width, and length of the right metathoracic femur were measured from the slide mounts. Body size was expressed as the product of length and width and was called the body size index (Dixon 1959). The results of this and subsequent sections were analysed by means of the *F* test and differences significant at the 5% level were considered real.

The live and dry weights of males and females increased as larval food quantity increased up to about 10.0 mg. Females were generally heavier than males. Water content was unaffected by either food quantity or sex and was about 82%. The mean live and dry weights of individuals that were reared on 5.0 mg. of food were 6.2 mg. and 1.0 mg. respectively for males and 5.3 mg. and 1.1 mg. for females. The mean live and dry weights of individuals reared on 13.0 mg. were 10.4 mg. and 2.0 mg. respectively for males and 10.9 mg. and 2.2 mg. for females. Relatively more males than females were produced when small quantities of food were given to larvae. Larvae that were given 5.0 and 6.0 mg. of food produced 10 males and three females whereas larvae given 6.0–13.0 mg. produced 33 males and 35 females.

The body size index, head width, and femur length increased in both sexes with increases in the quantity of food supplied to the larvae and these measurements were significantly greater in females than in males (Fig. 1).

Variation in Field Collections

Coleomegilla maculata

Measurements were made on male and female *C. maculata* that were collected in the field from different plants and at different times. The collections were: from corn, *Zea mays* L., in August — 49 pupae and 41 adults; in September — 25 pupae, 27 adults in the first week and 24 adults in the third week; from flowering marsh marigold, *Caltha palustris* L., in May — 34 adults.

The adults on marigold had overwintered and fed on the pollen of marigold. Those on corn were young adults that had probably fed on the pollen of corn and on the corn leaf aphid, *Rhopalosiphon maidis* (Fitch). Adults from the pupae emerged in the laboratory and were not fed.

The sex ratio of each collection was calculated and the live and dry weights, water content, body size index, head width, and femur length were determined for individual males and females. In this and subsequent sections means of weight are given with the coefficients of variation and means of body size index, head width, and femur length are given with the ranges.

Fewer males than females emerged from pupae that were collected in September (32.0% males). Adults from pupae that were collected in August were significantly heavier than those of September. Water content differed little

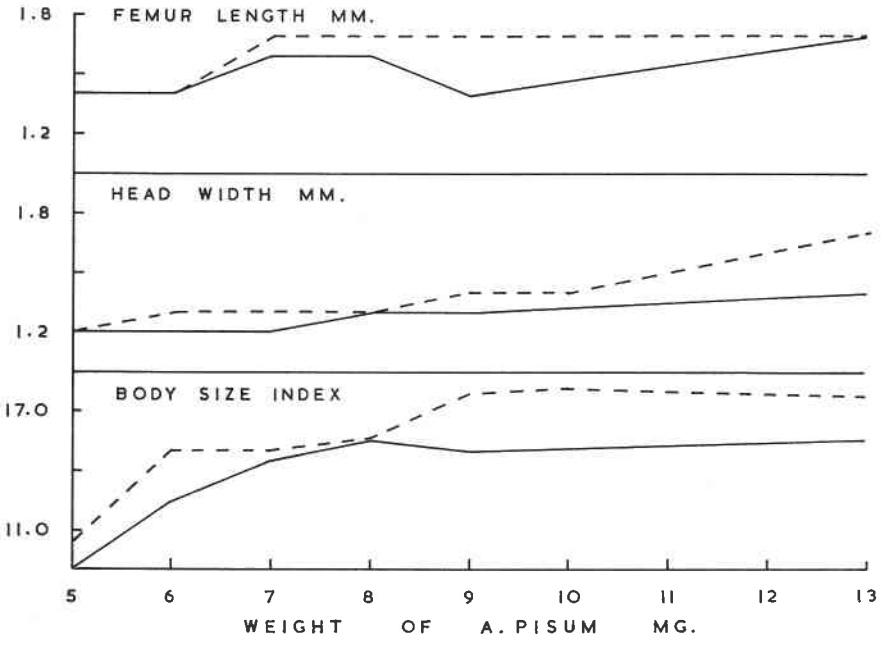

Fig. 1. Variation in femur length, head width, and body size index in male (—) and female (---) adults of *C. maculata* with increases in the quantity of food given to the larvae.

in the sexes and was about 80%. The live weight of females was significantly greater than that of males but the dry weights of the sexes differed little.

The mean live and dry weights of the August collection were 10.8 mg. (11%) and 2.2 mg. (10%) respectively for males and 12.3 mg. (11%) and 2.3 mg. (10%) for females. The mean live and dry weights of the September collection were 8.5 mg. (23%) and 1.8 mg. (28%) respectively for males and 10.6 mg. (24%) and 1.9 mg. (23%) for females. No significant differences in the body size index, head width, or femur length were attributable to sex or time of collection and their respective values were: 13.6 (10.3–21.6); 1.4 (1.0–1.5) mm.; and 1.6 (1.3–1.8) mm.

Adults from flowering marigold were 50% males. Females were significantly heavier than males, i.e. 11.9 mg. (17%) and 3.9 mg. (12%) respectively for the live and dry weights of males and 13.3 mg. (19%) and 4.5 mg. (26%) for females. Water content was about 67% in both sexes. The body size index of females was 18.6 (14.0–22.3) and was significantly greater than that of males at 15.5 (13.2–17.1). However, head width and femur length did not differ significantly in the sexes and were 1.3 (1.2–1.5) mm. and 1.6 (1.2–1.8) mm. respectively.

Adults from corn were 46.5% males in August, 29.6% in early September, and 29.2% in mid-September. The water content of both sexes was about 64%. No differences in weight were attributable to the time of collection but females were significantly heavier than males. The mean live and dry weights were 12.5 mg. (14%) and 4.5 mg. (37%) respectively for males and 15.9 mg. (15%) and 5.9 mg. (30%) for females. The body size index of females was 18.6 (13.8–27.8) and was significantly greater than that of males at 16.0 (12.9–19.3). Head width and femur length did not differ significantly in the sexes and were the same as for the collection from marigold.

TABLE I
Sex ratio and mean and coefficient of variation (percentage in parenthesis) of live weight and dry weight for males and females of various species of coccinellid adults

Species	% Males	Live weight, mg.		Dry weight, mg.	
		Male	Female	Male	Female
Adalia bipunctata	33.3	11.5 (16)	16.1 (21)	4.3 (21)	5.9 (24)
Coccinella trifasciata	27.7	15.8 (36)	27.6 (24)	5.4 (49)	7.6 (23)
Coccinella novemnotata	44.0	25.6 (17)	30.3 (19)	9.3 (17)	10.6 (20)
Hippodamia convergens	62.5	15.2 (14)	19.6 (21)	5.8 (24)	7.3 (32)
Hippodamia parenthesis	41.6	9.7 (12)	11.7 (23)	3.3 (13)	3.9 (23)
Hippodamia tredecimpunctata	47.6	11.3 (15)	11.5 (29)	4.1 (16)	4.2 (27)

Anatis mali

This species was collected from pine, fir, and spruce in June. The collections were: 44 pupae from *Pinus resinosa* Ait. and *P. sylvestris* L.; 42 pupae from *Abies balsamea* Mill. and *Picea glauca* Voss.; and 40 adults from *P. resinosa*. The larvae of the individuals from pine had fed on aphids whereas those from fir and spruce had fed on larvae of the spruce budworm, *Choristoneura fumiferana* (Clem.). The sex ratio of each collection was calculated and the live and dry weights, water content, etc. measured as for *C. maculata*.

A. mali adults that emerged from pupae collected on pine were 36.1% males and those from fir and spruce were 11.9% males. Adults collected from pine were 15.0% males. The water content of both sexes was about 66% for adults that had fed and about 75% for unfed individuals. Adults that emerged from pupae on fir and spruce were significantly heavier than those from pine, and adults that had fed were much heavier than unfed individuals. Females were significantly heavier than males.

The mean live and dry weights respectively of males from the different sources were: pupae on fir and spruce, 36.0 mg. (16%) and 9.7 mg. (26%); pupae on pine, 33.0 mg. (18%) and 7.6 mg. (25%); and adults on pine, 45.6 mg. (22%) and 15.6 (23%). The corresponding data for females were: 46.1 mg. (15%) and 12.3 mg. (23%); 40.7 mg. (14%) and 9.6 mg. (21%); and 66.1 mg. (24%) and 22.6 mg. (22%).

A. mali adults varied considerably in body size index, head width, and femur length. Females were significantly larger than males. The means of body size index, head width, and femur length respectively of males were: 32.9 (26.2–43.0), 4.3 (4.1–4.8) mm., and 4.6 (4.2–5.4) mm. The corresponding data for females were: 43.4 (36.1–50.0), 4.9 (4.5–5.4) mm., and 5.0 (4.5–5.4) mm.

Other Species

Determination of the sex ratio and measurements of weight and size were made for various other species of coccinellid adults. The collections consisted of 30 *Adalia bipunctata* (L.) from an unidentified shrub in May, 32 *Hippodamia convergens* (Guérin-Menville) from the beach of Lake Ontario in September, and the following from alfalfa, *Medicago sativa* L., in May: 29 *Coccinella trifasciata perplexa* Muls., 25 *Coccinella novemnotata* Hbst., 24 *Hippodamia parenthesis* (Say), and 31 *Hippodamia tredecimpunctata tibialis* (Say). The adults of all species except *H. convergens* had overwintered and had fed on aphids.

Females exceeded males in number in all species except *H. convergens* (Table I). The live and dry weights of *A. bipunctata* and *C. trifasciata* and the live

TABLE II
Mean and range of body size index for males and females and of head width and femur length for the sexes combined of various species of coccinellid adults

Species	Body size index		Head width, mm.	Femur length, mm.
	Male	Female		
Adalia bipunctata	14.9 (11.7–18.8)	17.4 (14.8–22.7)	1.2 (1.1–1.4)	1.2 (1.1–1.4)
Coccinella trifasciata	17.5 (15.1–21.4)	19.6 (14.4–23.0)	1.4 (1.0–1.5)	1.4 (1.2–1.6)
Coccinella novemnotata	24.5 (24.1–28.1)	24.7 (19.1–30.4)	1.6 (1.4–1.7)	1.6 (1.4–1.7)
Hippodamia convergens	20.7 (19.5–21.6)	25.5 (19.3–30.2)	1.4 (1.1–1.5)	1.6 (1.5–1.9)
Hippodamia parenthesis	13.4 (11.9–14.4)	13.4 (8.6–16.5)	1.2 (1.0–1.4)	1.3 (1.2–1.4)
Hippodamia tredecimpunctata	16.3 (16.2–18.1)	16.8 (11.0–20.3)	1.3 (1.0–1.4)	1.5 (1.2–1.7)

weights of C. *novemnotata* and *H. convergens* were significantly greater in females than in males. No significant differences in water content attributable to sex or species were observed; water content was generally about 64%.

The body size index of females was significantly greater than that of males in *A. bipunctata*, *C. trifasciata* and *H. convergens* (Table II). Head widths and femur lengths did not significantly differ in the sexes of any species.

Discussion and Conclusions

The weight and size of coccinellid adults varied with species, sex, and feeding. The means of weight and body size index ranged from 5.3 mg. and 9.0 respectively in *C. maculata* adults reared in the laboratory to 66.1 mg. and 49.0 in *A. mali* adults from the field. Corresponding changes occurred in the dry weights, head widths, and femur lengths. The dry weights were generally more variable than the live weights. Intraspecies variation in weight was similar in all species except *C. trifasciata* where it was higher in males. Intraspecies variation in size of females was about double that of males.

The females of some species were heavier and larger than males and the magnitude of the difference depended on the species. Female *A. mali* were about 34% heavier and 32% larger than males and female *C. maculata* were about 20% heavier and 15% larger than males. The arrangement of species in descending order of the magnitude of differences in weight and body size of males and females was: *A. mali*, *C. trifasciata*, *A. bipunctata*, *H. convergens*, *C. maculata*, *H. parenthesis*, *C. novemnotata* and *H. tredecimpunctata*. Sexual differences in weight and size may be a primitive characteristic of coccinellids as three of the first four species listed belong to taxonomically primitive groups and three of the last four listed belong to more advanced groups (Watson 1956).

An increase in food after a food scarcity increases the proportion of females of species with sexual differences in the weight and size of adults. The proportion of female *C. maculata* increased when larval food was increased beyond the minimum requirement for the production of an adult. This indicated that the minimum food requirement of the female is greater than that of the male.

Newly emerged adults increased in weight after feeding and the increase was greater in females than in males. Adults of *A. mali* and *C. maculata* increased in live weight by about 36% and in dry weight by 97% after feeding. The increases in females was about 36% greater than in males.

The weight and size of adults were influenced by the availability of food. Differences in the mean weights and sizes of *A. mali* collected from fir, spruce, and pine and in *C. maculata* collected in August and September probably reflect

differences in the amounts of available food. The very lightest and smallest adults do not survive long in the field, as no field-collected adults of *C. maculata* were as small as some adults that were reared in the laboratory.

The water content of adults is affected by feeding but not by sex. After feeding, the water content was generally about 64%. In unfed adults it was about 75% in *A. mali* and 80% in *C. maculata*. The water content of *C. maculata* was unaffected by the quantity of food supplied to the larvae and the water content of all species was unaffected by sex.

Males were relatively more abundant in species with small sexual differences in weight and size. About 36% of the field-collected adults were males and the proportion of males ranged from about 21% in *A. mali* to 62% in *H. convergens*. The arrangement of species in ascending order of the percentage of males is the same, except for the position of *H. convergens*, as the arrangement of species in descending order of sexual differences in weight and size. Differences in the longevities of males and females are probably less pronounced in species with the sexes of similar weight and size.

Degree of difference in the weight and size of males and females may be used as a criterion to select species that can survive when food is scarce. In these, the minimum food requirement of the female will be greater than that of the male. A relatively smaller number of females than males will reach the adult stage when food is scarce. Thus some species can adjust their numbers to a limited food supply by reducing the number of females that are produced. These species can also respond to an increase in the food supply as more females than males are always present owing to the greater longevity of the former.

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