

Studies on the biology and taxonomy of some *Chilocorus* spp. (Coleoptera : Coccinellidae) preying on *Aulacaspis* spp. (Hemiptera : Diaspididae) in East Africa, with the description of a new species

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Abstract

Field studies of predators on *Aulacaspis tegalensis* (Zhnt.) and laboratory breeding experiments, supplemented by taxonomic studies, showed that *Chilocorus discoideus* Crotch and *C. bilineata* Korsch. are junior synonyms of *C. schioedtei* Muls. and that two other forms, originally described as 'aberrations', may also belong to this species. Similarly, *C. erythrocephalus* Muls. and *C. solitus* Weise are junior synonyms of *C. distigma* (Klug). *C. rufoplagiatus* sp. n., allied to *C. distigma*, is described from the shores of Lake Victoria, and the Oriental species *C. nigrinus* (F.) is recorded from the African mainland for the first time. *C. distigma* is found in the savanna and steppe areas of Africa and *C. schioedtei* in the forest and adjoining zones. Comparative studies suggest that, although *C. schioedtei* has a higher fecundity, it is not displaced by *C. distigma* as, unlike the latter, it is unable to breed under hot dry conditions. Comparison of host records for these two species show that *C. distigma* is not restricted to feeding on Diaspididae, as is *C. schioedtei*, but that otherwise the range of hosts and associated plants is similar for both species. The potential of these species and *C. nigrinus* for use in biological control is discussed and it is suggested that *C. schioedtei* is only suitable for trial in tropical areas without a dry season, but that *C. distigma* and *C. nigrinus* may be useful under a wider range of conditions.

Introduction

Although *Chilocorus* spp. are well known as predators of hard scales (Diaspididae) in Africa, no studies on their biology have been published and such information as exists consists of little more than host records, reports of their usefulness as natural enemies, and records of their use in biological control (summarised by Greathead, 1971).

As a result of a survey of the sugar-cane scales (*Aulacaspis* spp.) in East Africa undertaken (by DJG) in order to find species suitable for introduction into Mauritius (Greathead, 1970; Williams & Greathead, 1973), field observations on *Chilocorus* spp. associated with *Aulacaspis* spp. were made and the more abundant species were bred

in the laboratory. During this work it was noticed that two species, *C. schioedtei* Mulsant and *C. distigma* (Klug), had mutually exclusive distributions, that several putative species were merely colour pattern variants of *C. schioedtei*, that there was a new species allied to *C. distigma* present in the Lake Victoria area and that *C. nigrinus* (F.), an Oriental species, is established in East Africa. These discoveries are reported in this paper.

Taxonomy

The only recent comprehensive treatment of the African species of *Chilocorus* is the annotated key of Mader (1954). This key separates species largely on the grounds of colour pattern and puncturation, which the present work shows are unreliable specific characters when used without supporting biological data.

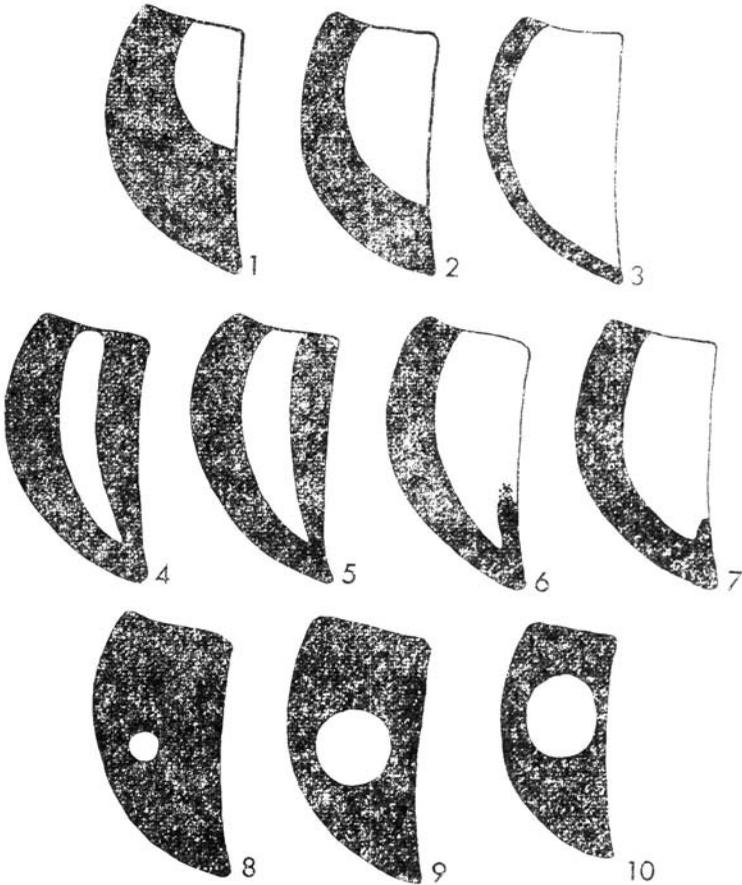


Fig. 1-10.—Diagrammatic representation of colour patterns of left elytron of *Chilocorus* species and colour forms. 1, *schioedtei*; 2, *schioedtei* × *discoideus*; 3, *discoideus*; 4, *bilineata* extreme from Kyembogo, Uganda; 5, *bilineata* from Lugazi, Uganda; 6-7, *bilineata* × *discoideus*; 8, *distigma*; 9, *erythrocephalus*; 10, *rufoplagiatus*.

Chilocorus schioedtei* MulsantChilocorus schioedtei* Mulsant 1850: 456. [Type not examined].*Chilocorus discoideus* Crotch 1874: 184. **Syn. n.** [Type examined].*Chilocorus bilineata* Korschefsky 1940: 1. **Syn. n.** [Types examined].

A number of large species of *Chilocorus* with yellow head, underside and legs black, prothorax and elytra with black lateral margins and red at least over a large part of the middle have been described. At Lugazi, Uganda, three of these nominal species, together with intermediates, were found feeding and breeding in numbers on *Aulacaspis tegalensis* (Zehntner). The dominant form was *C. discoideus* (Fig. 3), but individuals showing all gradations between this form and *C. schioedtei* (e.g., Fig. 2) were present, as well as a few exhibiting a typical *schioedtei* pattern (Fig. 1). As there was no discontinuity of variation, accurate counts of the proportion of the different 'species' was not possible but pure '*schioedtei*' comprised less than 1%. In the laboratory, selection of the most extensively black individuals and breeding from these produced progeny with a '*schioedtei*' pattern and a back-cross using these and '*discoideus*' produced the complete spectrum of variation. It is therefore concluded that these two nominal species are extreme forms controlled by polygenic inheritance. The distribution (Fig. 15) indicates that in West Africa '*schioedtei*' is the only known form; in Zaire both forms occur, while in East Africa this form has been collected only rarely.

Individuals of *C. bilineata* (Fig. 4 & 5) could also be recognised in the Lugazi (Uganda) population and also individuals with a rudimentary median stripe running forwards from the posterior end (Table I and Fig. 6 & 7). Crosses (Table II) showed

TABLE I. Incidence of '*bilineata*' pattern in the population of *C. schioedtei* at Lugazi, Uganda, in samples collected during 1969

	"discoideus" + "schioedtei"	Intermediate	"bilineata"
5.v.	251	50	1
15.v.	26	5	0
3.vi.	225	106	4
26.vi.	599	161	2
5.viii.	86	46	1
Total:	1187	368	8
Ratio:	148.4	46.0	1

TABLE II. Result of crossing different colour pattern forms of *C. schioedtei*. (There was no correlation between sex and colour pattern.)

	Progeny		
	"discoideus"	intermediate	"bilineata"
"discoideus" × "bilineata"	"intermediate only"		
"intermediate" × "bilineata"	—	67	63
"intermediate" × "discoideus"	58	56	—
"intermediate" × "intermediate"	89	186	101

that a single allele is involved. However, as the extent of the rudimentary stripe is variable, there are probably also modifying genes present. The distribution of '*bilineata*' is more restricted (Fig. 15), as it is known only from the area between central Zaire and central Uganda.

Individuals exhibiting both *bilineata* and *schioedtei* characters were also found in the field and bred in the laboratory. No indication of loss of fertility was found in any of the experiments. It is therefore concluded that these three colour pattern forms

belong to a single species for which the name *schioedtei* has priority, and that *bilineata* and *discoideus* are synonyms.

Two other forms regarded by Mader (1954: 71 & 73) as 'aberrations' of *C. discoideus* have been described, namely *ruficollis* Mader (1954: 71), which has a red prothorax, and *rubrodiscus* Mader (1941: 180), which has entirely red elytra. Neither of these was found during the present study but the nature of their distinguishing characters and distribution patterns, mainly in Zaïre at the centre of the distribution area of *C. schioedtei*, suggest that they are also only colour pattern variants. A specimen in the Uganda Department of Agriculture collection at Kawanda Research Station from Nakeysanja Forest near Kawanda has both *ruficollis* and *bilineata* characters (*i.e.*, has an orange prothorax and a median black stripe on the elytra), and therefore supports this conclusion.

Chilocorus distigma (Klug)

Coccinella distigma Klug 1835: 49

Chilocorus erythrocephalus Mulsant 1850: 459. **Stat. n.**

Chilocorus solitus Weise 1899: 62. **Syn. n.** [Types not examined]

In the drier parts of Africa one of the most commonly reported species is *C. distigma*, a large species which has a black prothorax and elytra that bear a single red spot at the centre (Fig. 8). Also described, largely on the basis of larger red spots and a different arrangement of punctures, is *C. solitus*. Scanning electron microscope examination of material from various localities and with different size red spots showed that there is no clear-cut correlation of pattern variation with puncturation, so that *solitus* is a synonym of *distigma*. Mader (1954: 77) regarded *erythrocephalus* as an aberration of *distigma*, differing from it in the larger size of the red spot (Fig. 9). The distribution and variation between individual museum specimens from the same locality indicates that *erythrocephalus* is simply an extreme form of *distigma* from the southern part of its range.

Mader (1954: 78) recognises a further aberration, *famelicus* Weise, which occurs along the northern border of Zaïre (Fig. 15); this may also be a simple colour variant representing the opposite extreme to *erythrocephalus*.

Chilocorus rufoplagiatus sp. n. (To be attributed to R. D. Pope)

Male. Length 4.77–5.82 mm. Breadth 4.09–5.10 mm. General body shape very convex, almost hemispherical (1.10–1.20:1). Shining, colour mostly black above, except for discal elytral patch (Fig. 10) of light red, red head and, sometimes, very narrowly red lateral pronotal borders. Underside with elytral epipleura, mostly black, prosternum, mesosternum, metasternum, abdomen and legs reddish-testaceous to castaneous. Antennae and mouthparts reddish-testaceous. Head with punctures between eyes relatively large, close, larger than eye facets and often separated by about their own diameter; intervals between punctures with strongly-marked, reticulate microsculpture; antennae with club narrow, elongate, last segment asymmetrical, with an apically-directed projection on one side (Fig. 14). Pronotum with anterior border broadly arcuate medially, anterior and posterior angles rounded, posterior border sinuate on either side of median lobe; punctures of disc without noticeable setae, shallow, similar in size to those of head, but more widely separated, intervals with faint, reticulate microsculpture; lateral margins with punctures deeper and slightly larger than those of disc, more closely set, intervals strongly microsculptured, punctures bearing short, pale, subrecumbent setae. Scutellum small, elongate-triangular. Elytra with lateral margins scarcely explanate, except around apical third; humeral callosities moderately raised; apico-sutural angles sharply formed; punctures along apical and lateral margins more deeply impressed than those elsewhere and bearing small, but readily visible setae; punctures of disc minute, shallow, each surrounded by an irregular, roughly circular area set with even smaller punctures (the main punctures each bear an extremely small, adpressed

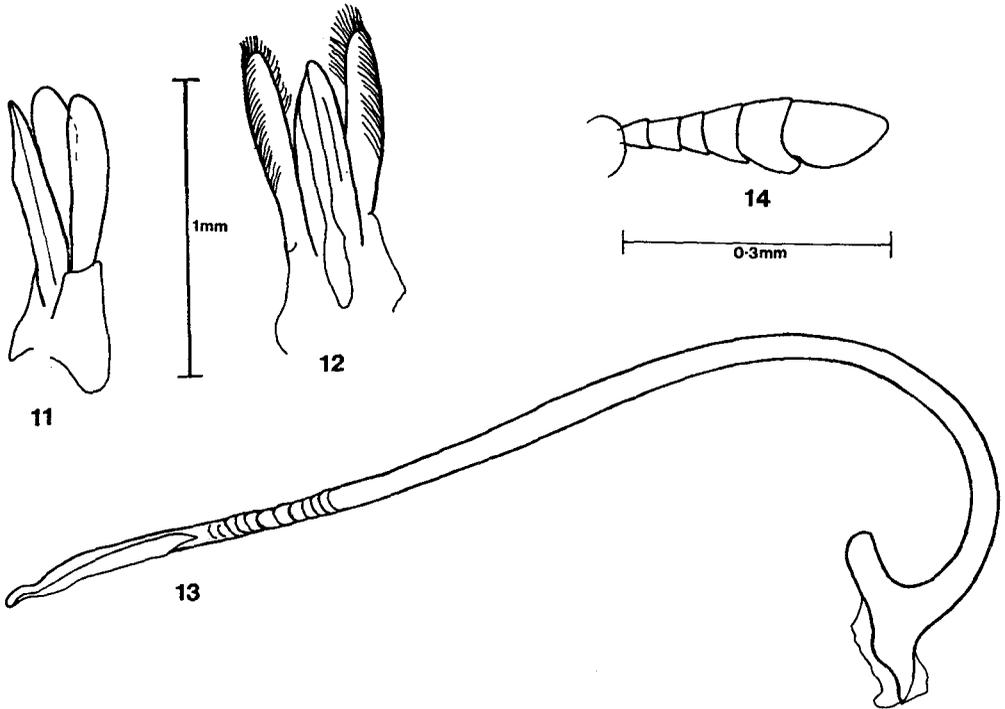


Fig. 11-14.—*Chilocorus rufoplagiatus*. 11-13, male genitalia; 11, median lobe and parameres, lateral; 12, same, dorsal; 13, siphon; 14, antenna.

seta, but this is very difficult to detect other than by means of the scanning electron microscope), intervals between discal punctures smooth, shining; epipleura strongly descending externally, well-marked to apicosutural angles, foveae for reception of middle and hind femoro-tibial junctions clearly marked. Prosternum with intercoxal process clearly convex transversely. Mesosternum with a more or less distinct median carina running backward from raised anterior border. Metasternum with faint, transverse microsculpture on disc, microsculpture finer, more distinct and sometimes reticulate toward lateral borders. Abdomen with reticulate microsculpture between punctures, punctures of first segment between hind coxae fine, very sparse, punctures of fifth segment much closer, often separated by little more than one diameter. Legs with tibial excavations sharply edged at basal ends on middle and hind legs, anterior tibiae with excavations having a raised, but rounded basal border.

Male genitalia. (Fig. 11-13)

Female. Externally indistinguishable from the male.

Distribution. Uganda.

Material. Holotype ♂ (and 7 ♂ + 10 ♀ paratypes), UGANDA: Kakira, ex *Aulacaspis tegalensis*, 8.v.1969 (D. J. Greathead) (All deposited in BMNH).

Comments. When first noticed in the field, *C. rufoplagiatus* was thought to be the form 'erythrocephalus' of *C. distigma*. It was, however, found to be of a consistently smaller maximum size than *distigma* and, in live specimens, to have a distinctly darker

underside. The distribution was also found to be disjunct from that of *C. distigma erythrocephala* since the museum specimens of the former are all from the north-eastern shores of Lake Victoria. As it proved impossible to distinguish the sexes externally, single pair laboratory crosses were not made. However, because of the absence of intermediates in mixed culture and in the field, the differences in the life-cycle (see below), the discrete distribution (Fig. 16) and the slight, but constant morphological differences, it was concluded that *C. rufoplagiatus* is a distinct species.

The male genitalia are very similar to those of *distigma*, so similar as to be of little use in distinguishing between the two species. However, the two taxa are easily separable by the colour pattern (see above), by the punctures on the head, which are much smaller and sparser in *distigma*, and by the presence of a median mesosternal carina in *rufoplagiatus* but not in *distigma*. The new species also resembles *C. schioedtei*, which also has very similar male genitalia, but is generally larger than *rufoplagiatus*, has a more sparsely punctured head and lacks a median longitudinal mesosternal carina.

Chilocorus nigrinus (Fabricius 1798: 79)

This oriental species was introduced into the Seychelles (Vesey-FitzGerald, 1941) and Mauritius (Jepson, 1941) and has recently been introduced to Madagascar (J. R. Williams, personal communication). It has been taken on Aldabra, but has not hitherto been found on the African continent nor are there any records of its deliberate introduction. It was found for the first time on *Aulacaspis tegalensis* at Ramisi on the Kenya coast (by DJG) in 1968, and in 1969 it was the dominant species at Arusha Chini in Tanzania. In 1970 it was also found as the only species at Gonza (Tanzania).

KEY TO SPECIES OF *Chilocorus* FEEDING ON SUGAR-CANE SCALES IN EAST AFRICA

The following key separates the four species dealt with in this paper.

- 1 Smaller species (<4.00 mm long); lateral margins of pronotum broadly yellow; elytra unicolorous black with sparse, simple punctures *nigrinus* (Fabricius)
- Larger species (>4.5 mm long); lateral margins of pronotum dark, extreme lateral borders occasionally reddish; elytra in part red, or yellow-red, punctures sparse, each main puncture surrounded by an irregular ring of micropunctures 2
- 2 Frons set with small punctures separated by several diameters; elytral colour pattern variable from a small, pale, more or less centrally-placed spot on each elytron to elytra with lateral and apical margins black, surface elsewhere pale red (Fig. 1-9) 3
- Frons set with larger punctures, often separated by no more than their own diameter; elytral colour pattern characteristically black with a large, pale red spot on the disc of each elytron (Fig. 10) *rufoplagiatus* sp. n.
- 3 Elytral colour pattern as in Fig. 1-7; lateral pronotal borders unevenly arcuate, lowermost point nearer hind border *schioedtei* Mulsant
- Elytral colour pattern as in Fig. 8 and 9; lateral pronotal borders more or less symmetrically arcuate *distigma* (Klug)

Biology of *Chilocorus* species

The four species were bred in the laboratory on pieces of sugar-cane infested with *A. tegalensis*. For experimental purposes, single pairs for genetic investigations, or five pairs for life-cycle studies were kept in 1-lb Kilner jars with a moist filter paper in the bottom and the top covered with nylon organdie held in place with the threaded part of the lid. To obtain eggs, sections of cane about 5 cm long and completely coated in scale were placed in the jars and changed every two days. The mean temperature in the laboratory was 21°C and the relative humidity in the jars was 70-80%.

The life-cycle of the four species is similar. At maturation, unfertilised females begin to lay eggs on the surface of the scale and fertilised females lay eggs beneath the scale.

As the eggs are fragile and tend to adhere to the scale it was not possible to count the number of eggs laid without damaging them, hatchling larvae were therefore counted to estimate egg production. The rate of oviposition fluctuates from day to day, but the means for different groups of individuals of the same species were similar. Larvae were kept at initial densities of 20–30 per jar and allowed to remain on the same piece of cane until the scale was consumed or had dried up.

The life-cycles are summarised in Table III. All species are long-lived. The females continue to reproduce from maturity to a few days before death, providing a male is present; otherwise fertile eggs cease to be laid after a few days. Copulation begins

TABLE III. *Summary of life-cycles and reproductive potential of Chillocorus spp. at 21°C mean ambient temperature in the laboratory at Kawanda*

		<i>schioedtei</i>	<i>distigma</i>	<i>rufoplagiatus</i>	<i>nigritus</i> *
Life-span of adults in days (mean and range)	♂	214(49–401) n = 16	167(63–294) n = 20	79(2–166) n = 12	110(10–217+) n = 9
	♀	170(49–282) n = 16	122(75–223) n = 21	116(2–220) n = 15	210(39–217+) n = 16
Pre-oviposition period in days (mean and range)		46(42–53)	50(45–55)	25.5(25–26)	23(21–24)
Oviposition rate (mean daily no. of larvae)		6.9	4.2	2.9	2.2
Duration (days, mean + range) of:					
Egg		10.8(10–14)	11.4(10–14)	11.6(10–14)	9.5(9–11)
Larval stages		21.3(19–24)	22.4(19–25)	23.3(19–27)	18.7(16–23)
Larval + pupal stages		35.1(29–44)	34.3(28–43)	34.6(32–40)	27.6(24–32)
% survival in larval + pupal stages		59.8%	48.9%	71.7%	57.4%
Total offspring per ♀:					
Hatching		856	301	261	370+
Reaching adult stage		512	147	184	212+

* Experiment stopped before all were dead, mean life-span estimated from plots on arithmetic probability paper.

about one week before fertile eggs are laid. Evidence that it has occurred (in the absence of direct observation) is provided by the appearance of empty spermatophores (Fisher, 1959) on the substrate.

Total egg production per female and potential offspring per female, based on these data, have been calculated and included in Table III. The chief initial interest was to determine the reason for the much higher reproductive rate of *C. schioedtei* than of *C. distigma* in the mass-rearing cages. The calculated result is of the same order as that noticed in mass-rearing. These data also provide a guide to the relative efficiency of the four species in the laboratory. Of the four, *C. schioedtei* appears to be the most efficient, but in the field in East Africa, although it is the only species or the dominant species on diaspidid infestations in the high rainfall areas lacking a dry season, *C. distigma* is the only species or the dominant species in areas with a dry season (Fig. 16). To attempt to discover possible reasons for this the rearing conditions were altered experimentally. When the two species were kept as before in jars in an enclosure heated to 30°C, with a consequent reduction of humidity to less than 50%, the life-cycle was speeded up and the survival rate of larvae and pupae fell (Table IV), but not in ways that would eliminate *C. schioedtei*. However, the fertility was profoundly affected. Adults of this species, placed in the enclosure after their last moult, matured and laid for up to two weeks and then ceased laying fertile eggs but did continue oviposition (infertile eggs on the surface of the cane pieces). Laying of fertile eggs recommenced in one batch two months after removal to room temperature but other batches held for only six weeks after removal produced no further offspring. Two batches kept in

TABLE IV. *Summary of life-cycles and survival rate of C. schioedtei and C. distigma at 30°C, for comparison with Table III*

	<i>schioedtei</i>	<i>distigma</i>
Oviposition rate	a few eggs over two weeks	2-4 per day
Duration (in days) of:		
Egg	7-10	8-10
Larval stage	13.4(12-16)	14.4(12-17)
Larval+pupal stages	20.6(18-25)	20.7(19-23)
Survival larval+pupal stages	22.3%	10.0%

the enclosure but with the humidity raised to over 70% (by placing a piece of sphagnum moss kept saturated with water in the jar) laid fertile eggs for a longer period (3-4 weeks) but also ceased to lay eventually. Two further batches kept at room temperature in a desiccator, which reduced the relative humidity in the jar to under 60%, were not affected. Further, the F₁ generation reared in the heated enclosure laid no fertile eggs. Thus, there is evidence that raised temperature affects fertility, possibly through the males, as eggs continue to be produced and laid. Owing to the difficulty of controlling humidity, the evidence on the effects of humidity is less reliable. Although humidity appeared unimportant in the experiments it would seem likely that it does play some part in regulating fecundity.

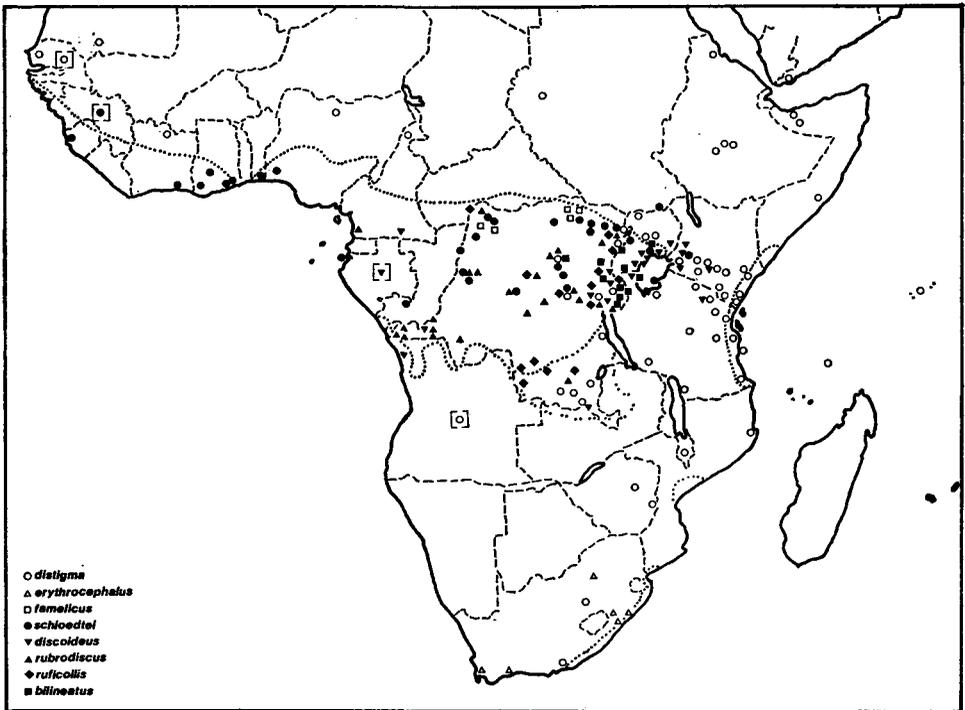


Fig. 15.—Distribution of *Chilocoriscor schioedtei* (black symbols) and *C. distigma* (open symbols) and of colour forms. Symbols in square brackets indicate no locality known, only country. The dotted line indicates the limit of lowland forest and forest savanna mosaic and the paired dots enclose an additional area in Zaire and Zambia where pockets of forest occur in the savanna (after Keay, 1959).

Less detailed studies with *C. rufoplagiatus* showed no evidence that reproduction is interrupted by raised temperature. No studies were carried out using *C. nigritus* but its dominance at Arusha Chini (Tanzania) under conditions of low humidity and rainfall and high temperature (mean annual rainfall <500 mm, mean monthly maximum temperature about 32°C, mean monthly minimum temperature about 20°C) suggest that it is not affected adversely by severe drought or heat.

Geographical distributions

The geographical distributions of *C. distigma* and *C. schioedtei* and their colour forms, plotted from records supplied by the British Museum (Natural History); Musée Royale d'Afrique Centrale, Tervuren; National Museum (Nairobi) and published records, is shown in Fig. 15. The two species have complementary distributions with *C. schioedtei* more or less confined to the forest areas and the adjoining zones of forest

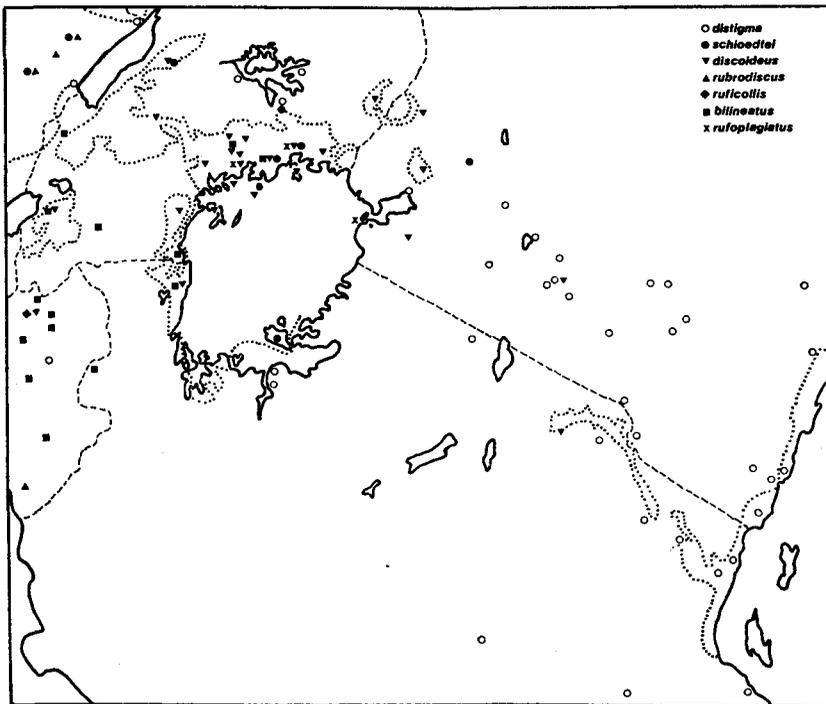


Fig. 16.—Distribution of *Chilocorus schioedtei* (black symbols), *C. distigma* (open circles) and *C. rufoplagiatus* (crosses) in part of East Africa. The dotted lines enclose areas of lowland to medium altitude forest and derived communities (from vegetation map in Russell, 1961).

savanna mosaic whilst *C. distigma* has been found throughout the savanna and steppe zones. Some exceptions are evident but are difficult to assess without detailed vegetation maps. The most conspicuous of these are *C. distigma* at Stanleyville and Kindu in the heart of the Congo Forest zone, possibly from introductions on produce, and *C. schioedtei* in the southern Sudan, possibly as a relict on one of the forested mountains in the area. Fig. 16, showing the distribution in the northern part of East Africa, shows

more clearly the association with vegetation. The only two conspicuous exceptions are the presence of *C. schioedtei* at Nairobi and Usa River, near Arusha; the former, a single specimen, may have arrived on produce or on transport from the west. The Usa River record, in a moist forested area, may represent a natural population as a series of specimens was collected. The most notable aspect of the distribution is the absence of *C. schioedtei* from the east coast forest zone, presumably because it is isolated by arid country from the western forests, which seem to be the centre of evolution and dispersal of this species.

Hosts

Host records of *C. distigma* and *C. schioedtei* are listed in Table V. *C. schioedtei* is principally associated with Diaspididae and *C. distigma* is associated almost exclusively with this family. Both have been found feeding on the same host species and hosts having similar food plant preferences in the complete range of crops from trees to annuals, indicating that there is little if any preference for particular hosts or particular habitats within the areas of distribution of the two species.

C. rufoplagiatus has only been reported on *Aulacaspis tegalensis* so far. *C. nigrinus*, like the larger African species, has a wide range of recorded hosts, principally Diaspididae (e.g., Vesey-FitzGerald, 1953; Rao *et al.*, 1954).

TABLE V. *Host records of Chilocorus schioedtei and C. distigma, excluding records from Seychelles. (Many East African records have been listed by Le Pelley (1959), in which the references to the original publications will be found.)*

Host	<i>schioedtei</i>	<i>distigma</i>
PSEUDOCOCCIDAE		
<i>Antonina bambusae</i> (Maskell)		Tanzania (Le Pelley, 1959)
<i>Planococcus citri</i> (Risso)	Kenya (Dept. Agric.)	
<i>P. kenya</i> (Le Pelley)	Kenya (Le Pelley, 1959)	
COCCIDAE		
<i>Coccus africanus</i> (Newstead)	Zaire (Buckyx, 1962)	
	Kenya, Tanzania, Uganda (Le Pelley, 1959)	
<i>Inglisia conchiformis</i> (Newstead)	Uganda (new record)	
ASTEROLECANIIDAE		
<i>Asterolecanium coffeae</i> (Newstead)	Uganda (Le Pelley, 1959)	
DIASPIDIDAE		
<i>Africaspis chionaspiformis</i> (Newstead)	Kenya (E. Afr. Agric. For. Res. Org.)	Kenya (Le Pelley, 1959)
	Uganda (new record)	
<i>Aonidiella aurantii</i> (Maskell)	Zaire (Ghesquière, 1927)	Kenya (Le Pelley, 1959)
		Uganda (new record)
<i>Aonidomytilus albus</i> (Cockerell)		S. Africa (Searle, 1964)
		Tanzania, Uganda (Le Pelley, 1959)
		Zaire (Lefèvre, 1944)
		Malawi (Smee, 1942)
<i>Aspidiotus destructor</i> (Signoret)	Sierra Leone (Patterson, 1926)	Somalia (Chiaramonte, 1933)
	Ghana (Forsyth, 1966)	Tanzania (Le Pelley, 1959)
	Uganda (Le Pelley, 1959)	
	Angola (Valles, 1965)	
<i>A. nerii</i> Bouché	Kenya (Le Pelley, 1959)	Ethiopia (new record)
<i>Aulacaspis tegalensis</i> (Zehntner)	Uganda (new record)	Kenya (Le Pelley, 1959)
		Tanzania (new record)
<i>A. tubercularis</i> Newstead	Uganda (new record)	
<i>Lepidosaphes olivina</i> Leonardi		Ethiopia (Silvestri, 1915)
<i>Hemiberlesia lataniae</i> (Signoret)		Tanzania (Le Pelley, 1959)
<i>Inchoaspis dentilobis</i> (Newstead)		Uganda (Le Pelley, 1959)
<i>Ischnaspis longirostris</i> (Signoret)		Tanzania (Le Pelley, 1959)
<i>Lepidosaphes beckii</i> (Newman)		Uganda (new record)
<i>Pinnaspis minor</i> (Maskell)	Nigeria (Lambourn, 1914)	
<i>Pinnaspis strachani</i> (Cooley)	Uganda (new record)	

Discussion

The two large African species, *C. schioedtei* and *C. distigma*, are similar in their size, life-histories and hosts but have almost mutually exclusive distributions. This suggests that they are in direct competition and, because of the association of their distribution areas with vegetation zones rather than particular habitats, the factors determining their distribution are probably climatic. The laboratory experiments suggest that high temperature, possibly associated with lower humidity, prevents successful reproduction of *C. schioedtei*, whilst under relatively cool, moist laboratory conditions this species has a much higher reproductive potential. Thus, it seems that, in areas where the climate does not prevent reproduction, *C. schioedtei* is able to displace *C. distigma*, whilst in areas with a more severe climate *C. distigma* replaces *C. schioedtei*. Were it not for the continued ovarian activity, the reaction to raised temperature resembles the adult dormancy exhibited by many Coccinellidae in reaction to the onset of unfavourable conditions (reviewed by Hagen, 1962). Possibly it represents a vestigial dormancy response, which, in the absence of competition, might allow *C. schioedtei* to colonise the savanna regions, but which in practice reverses the reproductive advantage in its favour that was observed under continuously favourable laboratory conditions.

The foregoing suggests that, in selecting species of coccinellids for biological control, *C. schioedtei* should be preferred for trial in areas with an equable moist climate and *C. distigma* for areas with a more severe climate including high temperatures and a dry season.

C. distigma has been used in biological control on several occasions. The first time was in 1936 against a complex of scales on coconuts in the Seychelles (Vesey-FitzGerald, 1941) where it became established and was initially abundant. Unsuccessful attempts were made to establish it in California and Bermuda at the end of the 1940's (reviewed by Greathead, 1971). More recently it was released against the date palm scale *Parlatoria blanchardii* (Targioni Tozzetti) in Mauritania (Iperti & Brun, 1969). It and *C. schioedtei* were shipped to Mauritius between January and July 1969 and released against *A. tegalensis*, but, although both bred in the field during the season in which they were released, they have not been recovered subsequently.

It is of interest that *C. distigma* was replaced as the most important predator in the Seychelles by *C. nigrinus* (Vesey-FitzGerald, 1941; 1953), which was introduced in 1938, partly because it also thrived on *Pinnaspis buxi* (Bouché), a member of the scale insect complex neglected by *C. distigma*. Table III suggests a possible additional explanation in the higher survival rate of offspring, at least in the laboratory. It is noteworthy that in East Africa *C. nigrinus* is less abundant than *C. distigma* as a predator of *A. tegalensis* on the coast at Ramisi but the position is reversed at Arusha Chini. Thus, the factors determining the relative abundance of *C. distigma* and *C. nigrinus* when in competition need further clarification but suggest that *C. nigrinus* may be the species better adapted to the drier savanna areas.

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(Received 10 August 1976)