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Authors: Hemp, Claudia, Hemp, Andreas, and Dettner, Konrad

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CANTHARIPHILOUS INSECTS IN EAST AFRICA

Claudia Hemp[1], Andreas Hemp[2], Konrad Dettner[1]
Departments of [1]Animal Ecology II and [2]Plant Physiology, University of Bayreuth
D- 95440 Bayreuth, Germany
Andreas.Hemp@uni-bayreuth.de

ABSTRACT

Cantharipholous insects, representing three different orders, were attracted to cantharidin baits in the years 1989 to 1999 in Tanzania, Kenya and Uganda. Two *Aulacoderus*, seven *Formicomus*, two *Mecynotarsus*, 11 *Notoxus*, three *Tomoderus* and one *Cyclodinus*, *Omonadus*, *Pseudoleptaleus*, *Sapintus*, and *Tenuicomus* species respectively were noted from the beetle family Anthicidae. The chrysomelid species *Barombiella vicina* and *Barombiella* sp. (Coleoptera: Chrysomelidae) were caught at cantharidin as well as *Pallenothriocera rufimembris* (Coleoptera: Cleridae) and two other up to now not identified clerid species. Also a bug species from the genus *Dieuches* (Heteroptera: Lygaeidae) was noted. Always present at the baits were a anthomyiid species (Diptera: Anthomyiidae) and ceratopogonids (Diptera: Ceratopogonidae). A cantharipholous species from the dipteran family Platystomatidae was found in an indigenous forest of Mt Kilimanjaro.

The baiting sites are briefly characterised and the knowledge about the function of cantharidin in the biology of cantharipholous insects is summarised.

INTRODUCTION

Cantharidin is a natural occurring highly toxic terpenoid (lethal dose for humans: 0,5 mg/kg, McCormick & Carrel, 1987), which has been used for over 2,000 years in Europe and China for its medicinal properties (Wang, 1989). On human skin it induces serum-filled blisters, acts as an antitumour agent (Wang, 1989; Juanjie *et al.*, 1995) and abortifacient, and may lead to priapism in humans (McCormick & Carrel, 1987). The last mentioned effect led to the abuse of cantharidin as a aphrodisiac.

On insects cantharidin acts as a contact insecticide, systemic insecticide and antifeedant. Nevertheless, so-called cantharipholous insect species of different orders are known to be attracted to the terpenoid cantharidin, for some of them it is recorded that they even feed on synthetic cantharidin crystals (Schütz & Dettner, 1992). Cantharidin is perceived by cantharipholous insects partly over great distances and especially gnats and anthomyids approach the chemical from a range of more than 500 m (Görnitz, 1937; Wirth, 1980; Young, 1984 a, b), while species as the anthicids of the flightless genus *Formicomus* gather at baits only from the immediate surroundings (Hemp *et al.*, 1997).

Known natural sources of cantharidin are the coleopteran families Meloidae (Cavill & Clark, 1971; Capinera *et al.*, 1985; Blodgett *et al.*, 1991) and Oedemeridae (Carrel *et al.*, 1986; Nicholls *et al.*, 1990; Holz *et al.*, 1994), which contain this terpenoid as a

haemolymph poison. Natural sources of cantharidin may also be found in higher plants like Meliaceae or Simaroubaceae (Dettner, 1997).

More intense studies on the function of cantharidin in the life cycles of insects have been undertaken for the beetle families Anthicidae (Görnitz, 1937; Geiler, 1953; Fey, 1954; Schütz & Dettner, 1992; Hemp, 1994; Hemp *et al.*, 1997) and Pyrochroidae (Young, 1984a; Eisner, 1988; Holz *et al.*, 1994; Eisner *et al.*, 1996a, 1996b), also for the dipteran families Ceratopogonidae and Anthomyiidae (Frenzel *et al.*, 1992; Frenzel, 1993; Frenzel & Dettner, 1994). This potent insecticide is taken up in comparatively huge amounts by these canthariphilous species and is used, as in Meloidae and Oedemeridae, as a haemolymph poison especially for the protection of the immature insects and the larval stages. In Anthicidae and Pyrochroidae external structures of the males are used to 'inform' females about the cantharidin amount ingested by the male (Eisner, 1988; Schütz & Dettner, 1992; Hemp, 1994; Eisner *et al.*, 1996a, 1996b; Dettner, 1997). In Anthicidae there are notches at the tips of male elytra while the males of pyrochroids possess grooves on the forehead. Females bite into these structures prior to copulation and thus choose their partner by its cantharidin titre.

Little is known about the function of cantharidin in the life cycles of canthariphilous insects of other groups, for example the coleopteran families Endomychidae (Young, 1984c; Young, 1989), Staphylinidae (Holz *et al.*, 1994) and Chrysomelidae (Hemp, 1994; Mafra-Neto & Jolivet, 1994), the bug families Miridae, Tingidae and Lygaeidae (Fox, 1943; Church & Gerber, 1977; Pinto, 1978; Dettner, 1997; Hemp & Dettner, in press a), the dipteran families Sciaridae (Dettner, 1997), Chloropidae (Dettner, 1997), Cecidomyidae (Dettner, 1997) and Anthomyiidae (Görnitz, 1937; Frenzel & Dettner, 1994) or the hymenopteran families Braconidae (Young, 1984b) and Diapriidae (Dettner, 1997).

During a widespread survey insects representing seven different families from three orders were attracted to cantharidin baits at several localities in Kenya, Tanzania and Uganda. We report for the first time that members of the bug family Lygaeidae, the coleopteran family Cleridae and a member of the dipteran family Platystomatidae are canthariphilous.

METHODS AND MATERIALS

To attract canthariphilous insects 10 x 10 cm plastic boxes were used with gauze covered inlets at two sides to guarantee an exchange of air. Small plastic tubes in form of a "T" were inserted through the gauze so that insects attracted by the chemical found their way into the trap but had difficulty to escape again. Synthetic cantharidin crystals dissolved in 100% acetone and applied to filter papers in the centre of the traps served as attractant. In long term baiting experiments the bait was renewed every three to four days. In Old Moshi/Kidia control traps without bait were deployed. Not a single canthariphilous species was found in these controls (for further details about trapping methods see also Schütz & Dettner, 1992; Hemp *et al.*, 1997).

Altitude measurements were obtained by a Thommen altimeter ranging from 0 to 6,000m. UTM grid co-ordinates were taken with a GPS (Garmin 75), all given data belong to UTM zone 37.

RESULTS

A summary of the results is given in Table 1.

Table 1: Data on canthariphilous insects collected in Kenya (Ke), Tanzania (Tz) and Uganda (Ug). No. = the number of specimens attracted; males = number of males, indicating presence of notches on male elytra in anthicids; nr = not recorded.

Family (Order)	Species	Date/Locality	Altitude (m)	No.	Males
Anthicidae (Coleoptera)	*Aulacoderus chappuisi* Pic	11/91 Soitpus, Ke	1600	5	5 (notch)
	Aulacoderus inopinans Krekich	12/96 Kilimanjaro, Moshi, Tz	900	3	3 (notch)
		12/96 Kilimanjaro, Machame, Tz	1000	3	3 (notch)
	Cyclodinus basilewskyi Buck	1996 Semliki Forest, Western Ug	670	nr	nr
	Formicomus canaliculatus Laferté	12/96 Kilimanjaro, Moshi, Tz	900	10	4
	Formicomus gestroi Pic	89–97 Kilimanjaro, Kidia, Tz	1430	>1000	ca. 500
		89–97 Nairobi, Ke	1550	>500	ca. 250
		12/96 Kilimanjaro, Moshi, Tz	900	4	0
		3/97 Kilimanjaro, Siha, Tz	1260	4	0
		2/99 Usambara, Lushoto, Tz	1520	22	10
		2/99 Pangani, Tz	5	14	5
		3–4/99 Nairobi, Karen, Ke	1800	8	5
	Formicomus lacustris Krekich	2/99 Pangani, Tz	5	8	3
	Formicomus millerianus Pic	12/96 Kilimanjaro, Ngare Nairobi, Tz	1390	1	0
	Formicomus opaculus Kolbe	2/99 Pangani, Tz	5	6	3
	Formicomus rubricollis LaFerté	89–97 Kilimanjaro, Kidia, Tz	1430	>1000	ca. 500
		89–97 Nairobi, Ke	1550	>500	ca. 250
		11/92 Thika, Ke	1700	2	2
		11/92 Soitpus, Ke	1600	3	1
		12/96 Kilimanjaro, Moshi, Tz	900	2	1
		3/97 Kilimanjaro, Sanja juu, Tz	1460	2	0
		3/97 Kilimanjaro, Siha, Tz	1260	31	2
		12/98 Nairobi, Karen, Ke	1800	20	10
		3–4/99 Nairobi, Karen, Ke	1800	20	9
	Formicomus spatulatus Van Hille	11/91 Ngoliba, Ke	1700	3	1
	Mecynotarsus nigronotatus Pic	3/97 Lake Natron, Tz	620	1	0
	Mecynotarsus obliteratus Pic	1/97 Pangani, Tz	5	1	0
	Notoxus alluaudi Pic	2/99 Usambara, Lushoto, Tz	1520	4	2 (notch)
	Notoxus buraensis Uhmann	3/96 Lake Natron, Tz	620	4	4 (notch)
	Notoxus cucullatus LaFerté	1/98 Kilimanjaro, Old Moshi, Tz	1200	10	10 (notch)
		4/98 Kilimanjaro, Weru-Weru, Tz	1050	25	25 (notch)

Family (Order)	Species	Date/Locality	Altitude (m)	No.	Males
	Notoxus daressalaamensis Uhmann	3/97 Kilimanjaro, Sanja juu, Tz	1460	1	1 (notch)
		4/98 Kilimanjaro, Weru-Weru, Tz	1000-1100	50	50 (notch)
	Notoxus decorus Van Hille	10/89, 11/91, 11/96 Kilimanjaro, Kidia, Tz	1430	ca. 50	50 (notch)
		3/97 Kilimanjaro, Siha, Tz	1260	1	1 (notch)
		3/97 Kilimanjaro, Sanja juu, Tz	1460	2	2 (notch)
		3/97, 1/98 Kilimanjaro, Sanja juu, Tz	1430	12	12 (notch)
		3/97 Lake Natron, Tz	620	14	14 (notch)
		10/89 Nairobi, Ke	1700	8	8 (notch)
	Notoxus lunulifer Pic	1/97 Pangani, Tz	5	14	5 (notch)
		4/98 Nairobi, Karen, Ke	1800	3	3 (notch)
		12/98 Nairobi, Karen, Ke	1800	50	50 (notch)
	Notoxus pretiosus van Hille	3/96 Lake Natron, Tz	620	73	73 (notch)
		3/98 Kilimanjaro, Chala, Tz	1000	42	42 (notch)
	Notoxus rothschildi Pic	3/97 Lake Natron, Tz	620	2	2 (notch)
	Notoxus rufomaculatus Pic	2/99 Pangani, Tz	5	12	12 (notch)
	Notoxus tansanianus Uhmann	4/97 Nairobi, Ke	1580	3	3 (notch)
	Notoxus vanhillei Uhmann	1/97 Kilimanjaro, Oloitokitok-Route, Tz	1800	>1000	>1000 (notch)
		3/97 Kilimanjaro, Sanja juu, Tz	1460	13	13 (notch)
		4/98 Kilimanjaro, Old Moshi, Tz	1430	2	2 (notch)
	Omonadus bottegoi Pic	1996 Semliki Forest, Western Ug	670	nr	nr
	Pseudoleptaleus unifasciatus Desbr.	12/90, Kilimanjaro, Moshi, Tz	900	14	7
	Sapintus tavetanus Pic	12/96 Kilimanjaro, Machame, Tz	1000	3	3
	Tenuicomus babaulti Pic	12/96 Kilimanjaro, Ngare Nairobi, Tz	1390	ca. 200	ca. 200 (notch)
	Tomoderus alluaudi Pic	92, 4/98 Kilimanjaro, Kidia, Tz	1430	15	7
	Tomoderus congoanus Pic	92 Kilimanjaro, Kidia, Tz	1430	2	0
	Tomoderus kolbei Pic	11/96 Kilimanjaro, Old Moshi, Tz	1200-1500	14	7
		4/97 Nairobi, Ke	1580	1	0
Chrysomelidae (Coleoptera)	*Barombiella* sp.	10/89, 11/91, 11/94 Nairobi, Ke	1550	ca. 40	nr
		10/89, 11/92, 11/96 Kilimanjaro, Kidia, Tz	1430	ca. 40	nr
		2/97 Mt. Meru, Makumira, Tz	1100	3	nr

Family (Order)	Species	Date/Locality	Altitude (m)	No.	Males
	Barombiella vicina Lab.	10/89, 11/91, 11/94 Nairobi, Ke	1550	ca. 10	nr
		10/89, 11/92, 11/96 Kilimanjaro, Kidia, Tz	1430	5	nr
		2/97 Mt. Meru, Makumira, Tz	1100	1	nr
Cleridae (Coleoptera)	*Pallenothriocera rufimembris* Pic	11/96 Kilimanjaro, Kidia, Tz	1430	1	0
		1/97 Kilimanjaro, Oloitokitok route, Tz	1800	3	3
		12/96 Kilimanjaro, Sanja juu, Tz	1430	7	7
		12/96 Kilimanjaro, Sanja juu, Tz	1460	32	30
		12/96 Kilimanjaro, Shira route, Tz	1750	4	4
	Sp. 1	2/99 Pangani, Tz	5	8	8
	Sp. 2	12/98 Nairobi, Ke	1800	50	46
Lygaeidae (Heteroptera)	*Dieuches* sp.	89/90, 91/92 Kilimanjaro, Kidia, Tz	1430	19	nr
Platystomatidae (Diptera)	*Peltacanthina mythodes* Hendel group	1/97 Kilimanjaro, Sanja juu, Tz	1460	4	2
Anthomyiidae (Diptera)	*Anthomyia benguellae* Malloch	89–98 Kilimanjaro, Tz	800-?	>100	nr
		89–98 Nairobi, Ke	1550	>100	nr
Ceratopogonidae (Diptera)	*Atrichopogon* sp. 1	89–98 Kilimanjaro, Tz	800-3000	>1000	nr
	Atrichopogon sp. 2*				
		89–98 Nairobi, Ke	1550	>1000	nr

*The new gnat species trapped in Kidia / Old Moshi were morphologically investigated by Frenzel (1993), solely species name mentioned in Frenzel *et al.* (1998) as *A. mittmannii* and *A. ruediger* without published species description to present.

Baiting sites

Sanja juu and Shira route (West Kilimanjaro, Tanzania)

At two localities near Sanja juu (UTM 2.84,7/96.54,7, figure 1), at 1,430 m and 1,460 m in an *Olea europaea* ssp. *africana*-rich indigenous forest, traps were put out on 18 December 1996 from 10 a.m. to 6 p.m.

The forest community was dominated in the tree layer by *Olea europaea* ssp. *africana*, *Diospyros abyssinica*, *Croton megalocarpus*, *Calodendron capense*, *Rawsonia lucida* and *Strychnos usambarensis*. The shrub layer consisted of *Teclea simplicifolia*, *Hibiscus calyphyllus*, *Clausena anisata*, *Vangueria apiculata* while in the undergrowth the herbs *Isoglossa laxa* and *Celosia schweinfurthii* prevailed. The forest community of the baiting site at the Shira route was much related to the lower situated forests of Sanja juu with some species of higher altitudes coming in. Due to the altitude precipitation is higher at Shira route and this was reflected in the richer epiphyte layer.

Apart from innumerable ceratopogonids and some *Anthomyia benguellae* (Diptera: Anthomyiidae), two females of *Formicomus rubricollis* (Coleoptera: Anthicidae), four specimens of the *Peltacanthina mythodes* group (Diptera: Platystomatidae) and 39 *Pallenothriocera rufimembris* (Coleoptera: Cleridae) were attracted to cantharidin. On 18 March at the same two localities cantharidin was put out again between 11 a.m. and 4 p.m. This time specimens of *Notoxus decorus, N. vanhillei* and *N. daressalaamensis* (Coleoptera: Anthicidae) approached.

On the 19 December cantharidin was exposed along the Shira route (UTM 2.87,4/96.69,9) at 1750 m from 10 a.m. to 6 p.m. Four *Pallenothriocera rufimembris* (Coleoptera: Cleridae) were found in the trap, as well as some ceratopogonids.

Ngare Nairobi (West Kilimanjaro, Tanzania)

The dry area of West Kilimanjaro around Ngare Nairobi is characterised by grasslands or large cultivated fields. Only individual shrubs of *Acacia drepanolobium*, *Balanites aegyptiaca* and *Maerua angolensis* were scattered in the grassland community. Frequent herbs were *Solanecio goetzii, Hibiscus parviflorus*, *Albuca abyssinica*, *Aspilia pluriseta*, *Aloe myriacantha* and *Scilla kirkii*. Most abundant were the grasses *Themeda triandra*, *Pennisetum stramineum* and *Pennisetum mezianum*.

In December a trap was placed in grassland (UTM 2.90,6/96.70,4) when herbs and grasses were in flower after rainfall. After exposing cantharidin for approximately an hour from 10 to 11 a.m. about 200 *Tenuicomus babaulti* were collected, and one specimen of *Formicomus millerianus* (Coleoptera: Anthicidae).

Siha (South-West Kilimanjaro, Tanzania)

On 18 March below the village Siha (UTM 2.86,7/96.49,7) at an altitude of 1,260 m a cantharidin bait was left for about one and a half hours from 9 to 10.30 a.m. The bait was placed at the rim of indigenous forest bordering cultivated land (maize, bananas). The forest type was the same as described for the baiting site at Sanja juu.

Ceratopogonids appeared immediately as soon as cantharidin was exposed, and some minutes later specimens of the anthicid species *Formicomus rubricollis* and *F. gestroi* (Coleoptera: Anthicidae) were gathering at the bait. One male *Notoxus decorus* (Coleoptera: Anthicidae) was detected in the trap as well.

Machame route (South Kilimanjaro, Tanzania)
In the savannah along the tarmac road to Machame (UTM 3.3,8/96.34,5, 1,000 m) cantharidin was put out several times during the daytime from November 1996 to March 1997. A nearby swampy area was cultivated intensively with beans and other crops. The trap was placed into dry grass in the road ditch.

Three specimens of *Aulacoderus inopinans* and three *Sapintus tavetanus* (Coleoptera: Anthicidae) were noted at the bait in December. Also two bugs, an adult specimen and a nymph were found in the trap. Unfortunately the adult bug escaped when opening the trap. The nymph probably belongs to the family Lygaeidae.

Along the banks of the river Weru-Weru numerous *Notoxus daressalaamensis* and some *N. cucullatus* (Coleoptera: Anthicidae) were attracted to cantharidin baits.

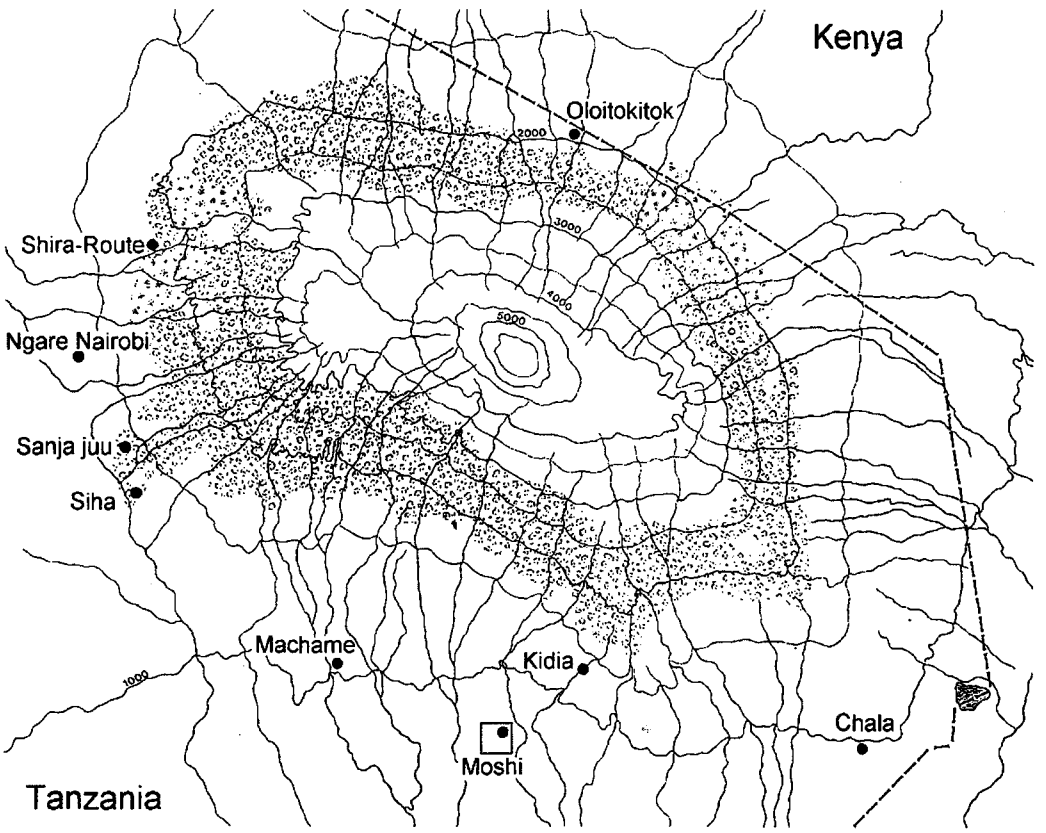

Figure 1: Baiting sites at Mt Kilimanjaro

Old Mosh /Kidia (South Kilimanjaro, Tanzania)
At Old Moshi/Kidia (figure 1, UTM 3.23,6/96.35,4) long-term baitings with cantharidin were made in the plantation belt at an altitude of 1,430 m. From October 1989 to April 1990, November 1991 to March 1992, November 1995 to March 1996, November 1996 to March 1997, and October 1997 to April 1998, traps were continuously put out at that locality. Further data on the collection at Old Moshi/Kidia are given in Hemp *et al.* (1997).

Due to the long period of cultivation by the tribe of the Wachagga in this zone only few relics of the original vegetation were still present. The area has been intensely cultivated,

mostly with coffee and bananas. Only single indigenous trees were intermingled such as *Albizia schimperiana, Olea capensis*, *Tabernaemontana holstii* or *Syzygium guineense*.

Traps with the cantharidin baits were put into a dense hedge with *Tabernaemontana holstii*, *Syzygium guineense*, *Bougainvillea spectabilis*, *Caesalpinia decapetala*, *Rubus steudneri* and *Euphorbia pulcherrima* bordering a meadow with sparse vegetation.

Many records of canthariphilous species are from this locality due to the regular exposure of cantharidin. From October to April both sexes of the anthicids *Formicomus rubricollis* and *F. gestroi* were attracted to the traps. Few *Tomoderus alluaudi, T. congoanus* and *T. kolbei* (Coleoptera: Anthicidae) have also been found in this altitude. Especially in November during a short period, *Notoxus decorus* males were attracted from the surroundings, and *Notoxus cucullatus* and *N. vanhillei* (Coleoptera: Anthicidae) were present occasionally. The chrysomelids *Barombiella vicina* and *Barombiella* sp. occurred also in Old Moshi/Kidia. All specimens of these two species were trapped in October or November. Also the clerid species *Pallenothriocera rufimembris* was found in Kidia. Restricted to December and January was a bug species from the family Lygaeidae. Specimens of the genus *Dieuches* were caught in this period of the years 1989/90 and 1991/92. At least three species of the dipteran family Ceratopogonidae are present on Mt Kilimanjaro, and two of them proved to be new species (Frenzel 1993, Frenzel *et al.* 1998). Finally, *Anthomyia benguellae* (Diptera: Anthomyiidae) was always present at cantharidin baits.

Moshi (South Kilimanjaro, Tanzania)
In December 1996 a baited trap was put out at midday for about 2 hours in cultivated savannah east of Moshi town (figure 1, UTM 3.20,5/96.27,8). The trap was placed near a tomato field under the shade of *Acacia albida*. Nearby was a small ditch providing water for the crops.

Very soon several *Formicomus* (Coleoptera: Anthicidae) species approached from the immediate surroundings. They proved to be *F. rubricollis*, *F. gestroi* and *F. canaliculatus*. Three *Aulacoderus inopinans* males (Coleoptera: Anthicidae) were seen flying to the bait.

Chala area (East Kilimanjaro, Tanzania)
The Chala area is dominated by grassland and remnants of the indigenous savannah woodland as agriculture is of minor importance due to the dry conditions in this region. Dominant species of the savannah grassland were the grasses *Cymbopogon caesius*, *Chloris roxburghiana*, *Hyparrhenia hirta*, *Heteropogon contortus*, *Eragrostis superba* and the herbs *Oldenlandia wiedemannii*, *Chascanum hildebrandtii*, *Stathmostelma rhacodes* and *Tephrosia reptans*. Among the single trees and bushes were *Sclerocarya birrea*, *Euphorbia scheffleri*, *Acacia mellifera, Rhus natalensis* and *Omocarpum trachycarpum*.

Numerous male *Notoxus pretiosus* (Coleoptera: Anthicidae) were attracted in March 1998 to cantharidin baits at that locality (UTM 3.47,3/96.29,5).

Oloitokitok route (North Kilimanjaro, Tanzania)
The baiting site along the Oloitokitok route (figure 1, UTM 3.34,2/96.72,1) was near a river at 1,800 m where the vegetation was much disturbed. The trap was put into denser forest with almost undisturbed forest close by.

The riverine forest community at the baiting site was dominated by *Euphorbia obovalifolia, Albizia gummifera* and *Cussonia holstii*. Obvious in the shrub layer were *Vangueria apiculata*, *Clerodendron myricoides*, *Ochna holstii*, *Bersama abyssinica* and

Dracaena laxissima. Characteristic undergrowth herbs were *Aneilema aequinoctiale*, *Justicia diclipteroides* and the fern *Asplenium strangeanum*.

The bait was put out at 10 a.m. and checked again at 5 p.m. Three specimens of *Pallenothriocera rufimembris* (Coleoptera: Cleridae) and thousands of the anthicid *Notoxus vanhillei* approached the bait; also many ceratopogonids and few anthomyiids were noted.

Makumira/Usa River (Mt Meru, Tanzania)

One *Barombiella vicina* and three *Barombiella* sp. (Coleoptera: Chrysomelidae) were trapped in a garden at Makumira (UTM 2.58,5/96.27,8) at the end of February 1997. The garden was situated between other gardens, all of them characterised by ornamental trees and bushes and hedges of *Bougainvillea spectabilis*.

Cantharidin was put out in the morning at about 9 a.m. but the beetles were noted only in the evening hours, flying around the bait. When opening the trap most of the very active beetles escaped.

Lake Natron - Ol Donyo Lengai (Tanzania)

At a tourist camp at the foot of Mt Ol Donyo Lengai, cantharidin was exposed for two days at the end of March 1996. The trap was placed near a shallow ditch filled with water in the shade of an *Acacia xanthophloea* tree. The undergrowth consisted only of sparse dry grass and herbs, with a little more vegetation along the ditch.

Numerous specimens of *N. pretiosus* and *N. decorus* as well as some *N. rothschildi* and *N. buraensis* and one *Mecynotarsus nigronotatus* (Coleoptera: Anthicidae) came to the bait, especially in the evening hours. Ceratopogonids were also noted.

Pangani-Mwera (Tanzania)

Between Pangani and Mwera on the Indian Ocean, cantharidin baits were placed on the beach about 30 m away from the edge of the water, in sparse dry grass under the shade of coconut palms. The trap was checked about every two hours during two days.

Due to the strong wind blowing most of the day from 26 to 29 January 1997 only few anthicids approached the bait, and those were mostly in the evening hours when the wind was not so fierce. Specimens of *Notoxus lunulifer* and one *Mecynotarsus obliteratus* (Coleoptera: Anthicidae) were caught from the trap. From 14 to 15 February 1999 specimens of the anthicids *Formicomus gestroi*, *F. lacustris* and *F. opaculus* gathered in the cantharidin traps as well as eight up to now unidentified male clerids (sp. 1 in Table 1).

Usambara Mountains (Tanzania)

Near the town Lushoto in the West Usambara Mountains cantharidin baits were exposed on 16 February 1999 on a mowed meadow of a farm cottage. In the evening hours the anthicids *Notoxus alluaudi* and *Formicomus gestroi* were collected from the traps.

Nairobi (Kenya)

In a garden on the compound of Kenyatta University cantharidin was exposed at the end of October/beginning of November in the years 1991 and 1995, and in February 1992, in March 1992 and March 1996. The garden consisted mainly of succulent plants (*Aloe* sp., *Euphorbia* sp. and others) and areas of grass and herbs. The trap was placed between the planted succulents on open ground.

Apart from many *Formicomus gestroi* (Coleoptera: Anthicidae) appearing whenever traps were put out, in November of 1991 and 1995, the chrysomelid beetles *Barombiella vicina*

and *Barombiella* sp. were attracted to the cantharidin bait in the evening hours. These species were especially abundant in November 1991, with numerous beetles flying around the trap, finally entering through the gauze openings and gathering at the bait. Ceratopogonids and *Anthomyia benguellae* (Diptera: Anthomyiidae) were always present.

In the suburb Karen of Nairobi several *Formicomus rubricollis* and *Notoxus lunulifer* (Coleoptera: Anthicidae) were found at cantharidin baits, probably attracted from the surrounding patch of indigenous forest, which was similar in structure and species composition to the West Kilimanjaro *Olea*-forests of Sanja juu of 1,400 to 1,500 m. Also from this indigenous *Olea*-forest about 50 specimens of a up to now unindentified clerid species (sp. 2 in Table 1) were found flying to cantharidin baits from 4–8 December 1998. Resting on the cantharidin impregnated paper the beetles attacked other canthariphilous insects, especially anthicids of the genus *Notoxus* and fed on them. Clerid beetles mating in the cantharidin traps were also noted. Comparision of the clerids with material of the insect collection of the National Museums of Kenya, Nairobi suggests that the beetles might belong to a species labelled as *Thriocera pectoralis* Klg. var. *mystica* Boh. also collected around Nairobi[1]. End of March/beginning of April 1999 during five days only about 20 *Formicomus rubricollis* and few *F. gestroi* (Coleoptera: Anthicidae) were gathered from cantharidin traps at the same locality in Karen, Nairobi. Clerids were not attracted to the cantharidin traps during that period.

Further baiting sites in Kenya

In November 1989, in the garden of a Nairobi hotel (Boulevard), ceratopogonids and anthomyiids and a few *Notoxus decorus* (Coleoptera: Anthicidae) were attracted to cantharidin. In the area of Kasarani in the north-eastern suburbs of Nairobi, *Notoxus tansanianus*, *Tomoderus kolbei* and *Formicomus rubricollis* and *gestroi* (Coleoptera: Anthicidae) were trapped in the rainy season of April 1997. Cantharidin was also laid out at the Blue Posts Hotel in Thika. A trap placed into the flower beds of the hotel garden attracted *Formicomus rubricollis* (Coleoptera: Anthicidae). Baiting with cantharidin on a trip to Mt Soitpus near Emali, on the Nairobi-Mombasa road, some specimens of *Aulacoderus chappuisi* and one of *Formicomus rubricollis* (Coleoptera: Anthicidae) were caught in bushland savannah. To a trap put out in bushland near Ngoliba, specimens of *Formicomus spatulatus* (Coleoptera: Anthicidae) were attracted.

Western Uganda

In western Uganda baits were put out in the Semliki National Park into moist indigenous forest (670 m). Specimens of *Omonadus bottegoi* and *Cyclodinus basilewskyi* (Coleoptera: Anthicidae) were attracted into cantharidin traps.

[1] However, the species identity is questionable (Dr Gerstmeier, München, pers. comm.). More detailed studies of the insufficient types of this species described by Pic, and that collected from the Tanzanian coast near Pangani, have to be undertaken to confirm the species identity.

DISCUSSION

Notes on the possible function of cantharidin in the life cycles of cantharipbilous insects:

Anthicidae

Anthicid beetles probably are the best known group of cantharipbilous insects. The phenomenon of cantharipbilous insects was first noted by Görnitz (1937) on *Notoxus monoceros* and other cantharipbilous species of Diptera. Geiler (1953) and Fey (1954) also contributed to the biology of *Notoxus monoceros*. This anthicid species is strongly attracted to cantharidin and feeds readily even on pure synthetic crystals (Schütz & Dettner, 1992). As in many other *Notoxus* species, the males have notches at the tips of their elytra. After intake by the males, cantharidin is firstly secreted into the notches. A large amount of this terpenoid is stored in testicles and accessory glands. A small amount is present in the haemolymph (Schütz & Dettner, 1992). Females test through the elytral notches of the males whether the would-be partner has taken up a sufficient amount of cantharidin. Males often show courtship behaviour to attract females. They protrude anal sacs at the tips of their abdomen that seem to have strong effects on females. Females approach readily and try to bite into these sacs, which are withdrawn when the female is close by. The male then presents his elytral notches to the female, who eagerly bites into them. Females choose their sexual partner by the content of this terpenoid as they receive most of the cantharidin stored by the male during copulation (Hemp 1994). A high concentration of cantharidin is found in the receptacula seminis of the females after copulation. The females themselves secrete the transferred cantharidin into their eggs. Cantharidin thus is used in that species to protect the offspring. Cantharidin taken up by females is used only as a haemolymph poison for the female herself and is not secreted into the reproductive organs as in males (Schütz & Dettner, 1992; Hemp, 1994). This cycle is probable for all those anthicid species having elytral notches, e.g. *Aulacoderus* and *Microhoria* species (Hemp, 1994). Some *Mecynotarsus* species are also known to be cantharipbilous (Schütz & Dettner, 1992; Hemp, 1994; Hemp & Dettner, in press b). Numerous males and few females of *Mecynotarsus nevermanii* Werner were attracted in Costa Rica (Tamarindo, Atlantic Coast) in a similar habitat as *M. obliteratus* at the beach near Pangani in Tanzania. Almost nothing is known up to now about the biology of *Mecynotarsus* species. As *Mecynotarsus* belongs to the same tribe as *Notoxus* (Notoxini), notches are known for two cantharipbilous species (Schütz & Dettner, 1992) and mainly males are attracted to cantharidin (in case of the two females attracted in Tanzania at Pangani and Lake Natron the trap was probably placed by chance in the immediate surrounding of the two specimens), a similar function of cantharidin for cantharipbilous *Mecynotarsus* species is suggested.

Mostly males are attracted to cantharidin in species with elytral notches. Females approach only if the bait is placed directly into the habitat. All *Notoxus decorus*, and *Notoxus tansanianus* caught in Kenya, especially around Mt Kilimanjaro in Tanzania, were males, as well as all *Aulacoderus inopinans*, *Tenuicomus babaulti* and *Aulacoderus chappuisi* (see Table 1). They were seen flying to the bait from a distance of more than 20 m. At Pangani, Tanzania the trap was probably placed directly into the habitat of *Notoxus lunulifer* in January 1997 as the number of attracted females was even higher that that of males (Table 1). Due to the strong wind blowing at that locality it is unlikely that the trapped specimens flew to the bait, but were approaching it from the immediate surroundings.

Formicomus species comprise a second group of anthicids with respect to their behaviour to cantharidin. Both sexes are equally attracted to cantharidin. The ratio of males to females

at the baits depends only on their life cycles. The end of a reproduction cycle is marked by a surplus of females. At that time, mostly females are still to be found at cantharidin while males are scarce (Hemp, 1994; Hemp *et al.*, 1997).

Cantharidin is taken up by both sexes of the *Formicomus* species, an anthicid genus whose members are also strongly protected by iridoids of the secretion of their mesothoracic glands (Hemp & Dettner, 1997). Most of this terpenoid is stored in the testicles by the males and transmitted during copulation to the ovaries of the females. Receptacula seminis are not present. Compared to species with notches little cantharidin is consumed and stored. The behaviour of these species at the cantharidin bait is very conspicuous. Specimens coming to cantharidin are very ready to mate. Males jump on every beetle of the same species passing by. If a fitting partner has been found copulation takes place and the pair stay together mounted for some time. Neither courtship behaviour nor pre-copulatory testing of cantharidin concentration by females occurs, in contrast to *Notoxus monoceros*. Cantharidin might function as an aggregation pheromone in these species, since it helps to aggregate partners that normally meet only by chance in their habitat (Hemp, 1994; Hemp *et al.*, 1997). *Pseudoleptaleus unifasciatus* and the caught *Tomoderus* species (see Table 1) probably belong to this second group of anthicids as well.

Ceratopogonidae

Ceratopogonids are an ever-present group as soon as cantharidin is put out. Studies on the function of cantharidin in the biology of canthariphilous ceratopogonids have been undertaken by Frenzel (1993) and Frenzel & Dettner (1994). Both sexes of the investigated canthariphilous gnats are attracted by cantharidin and readily ingest this terpenoid. Concentrations in tissues of ceratopogonids are similar to those detected in the cantharidin-producing species of the beetle families Meloidae and Oedemeridae. High concentrations of cantharidin in the haemolymph of European ceratopogonids proved to deter Empididae, which prey on these gnats (Frenzel, 1993).

Chrysomelidae, Cleridae, Lygaeidae, Anthomyiidae, Platystomatidae

Little or no investigations have been made on canthariphilous Chrysomelidae, Cleridae, Lygaeidae, Anthomyiidae and Platystomatidae. Only the phenomenon that certain species of these families are attracted has been noted.

It seems likely that the canthariphilous species of these groups use cantharidin as a haemolymph poison for self-protection and for the protection of their offspring, as is known for anthicids, pyrochroids and ceratopogonids. Saliva stains left by Miridae on filter paper impregnated with cantharidin suggests the intake of cantharidin by the bug family (Hemp & Dettner, in press a).

Some analyses on the European canthariphilous anthomyiid *Anthomyia pluvialis* were made by Frenzel (1993). Both sexes of this species ingest cantharidin. However, a concentration of this terpenoid in any part of the body, e.g. the reproductive organs, could not be observed. This suggests that ingested cantharidin is used directly as a haemolymph poison. Also, in East Africa, both sexes of *Anthomyia benguellae* always came to the cantharidin baits.

In Cleridae, it is possible that cantharidin functions as a kairomone to lead the predator to its hosts, as is known for the braconid *Perilitus plumicornis* (Hymenoptera: Braconidae), a parasite of the anthicid *Notoxus monoceros* (Görnitz, 1937). Many clerids prey upon larvae of wood-boring beetles. Maybe the canthariphilous clerids feed on a canthariphilous or a cantharidin-producing species, which it perceives by its cantharidin and thus is attracted to

this terpenoid (Hemp *et al.*, 1999). Specimens of a clerid species occurring around Nairobi, Kenya were observed to attack living anthicids at the cantharidin baits and feeding on them. On the other hand, secretary glands on the elytra of the cantharíphilous clerid species (in the area of the shoulders paired tufts of hairs are present and single gland cells are spread all over the elytra) and the presence of mostly males at the baits suggest strongly that a similar cycle as in anthicids with notches at the tips of the elytra may be present.

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