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ORIGINAL PAPER

Life cycle and attacks of ectoparasites on ruminants during the year in Central Europe: recommendations for treatment with insecticides (e.g., Butox®)

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Abstract The occurrence of ectoparasites on ruminants throughout the yearly seasons was compiled from the literature and from our own experiments that were based on ultraviolet trap catches during the years 2007–2009. The data were listed in tables, which also contained details on the life cycles of flies, mosquitoes, tabanids, midges, simuliids, louse flies, mallophaga, sucking lice, etc. The breeding sites of those ectoparasites were described as well as their potential activity as vector of agents of diseases. Considering the places for overwintering, proposals were made when insecticidal products such as Butox® pour-on should be used in order to obtain good rearing results.

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Introduction

Ruminants such as cattle, sheep, goats, etc. are worldwide important sources of human food and different economically important goods such as leather and/or wool, etc. Therefore, they are reared often in masses and in monocultures, which are highly attractive for many ectoparasites (Mehlhorn 2008; Eckert et al. 2009; Schnieder 2008). The latter attack their prey animals on the meadow as well as in their stables. Many of these ectoparasitic species have their breeding sites very close to their hosts, so that they are practically always present. Of course, the speed of the development of ectoparasites is temperature dependent. This implicates that their presence and numbers vary according to the different seasons during the year—especially in milder and temperate climates as they are occurring in Central Europe. Many ectoparasites harm the health of their hosts by blood sucking (e.g., ticks, mite, simuliids, midges, biting flies, fleas, lice, bugs, etc.). This leads primarily to often enormous losses of blood. Furthermore, the biting sites become superinfected with bacteria, and these wounds attract licking flies. In addition, some of the blood-sucking ectoparasites may act as vectors of agents of diseases, e.g., ticks may transmit stages of *Babesia* and *Theileria*, Rickettsiales, *Anaplasma*, several bacteria, and viruses (e.g., Crimean Congo fever), which all may introduce severe diseases or even death (Mehlhorn and Schein 1984; Mehlhorn et al. 1993; Sonenschein 1990; Raether and Harder 2008; Mehlhorn 2008; Eckert et al. 2009). Blood-sucking insects such as biting flies, simuliids, or midges are known vectors of similar agents of disease, e.g., midges turned out as vectors of the Bluetongue virus serotype 8, which overwhelmed cattle and sheep in Europe during the outbreak of 2006–2009 (Mehlhorn et al. 2007, 2009; Conraths et al. 2007; Hoffmann et al. 2009). Simuliids are known to transmit filarial worms also in Europe during their bites, which

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are so painful that cattle always rush in panic when a "cloud" of simuliid biters is approaching them (Martini 1946; Dettner and Peters 2010). But even non-blood-sucking insects may introduce severe diseases, e.g., licking flies may transport a great variety of agents of diseases on their labellae (=the terminal saliva-containing parts of their mouthparts) onto wounds or lips and nose (Förster et al. 2007, 2009a, b) and thus they may initiate severe diseases (bacteriosis, virosis, or even parasitosis). Some other ectoparasites just enter the hair of ruminants, e. g., the mallophaga feed on skin and at the basis of hair. Thus, they may pose problems when the skin is used as leather. Many mites (genera *Sarcoptes*, *Psoroptes*, *Chorioptes*) enter the skin either totally or at least in parts, thus introducing wounds and hindering the further use of the skin as leather of high quality. The same is true for the members of the so-called bot flies (e.g., genera *Hypoderma*, *Oestrus*), which leave large hollows in the skin along the backbone, where the *Hypoderma* larvae have their final breeding sites just before falling down to earth in order to pupate there.

All these different attacks of ectoparasitic and/or part-time endoparasitic ticks, mites, or insects made it necessary to block their aggressive attacks by repellents to be placed onto the animals and to decrease the number of aggressors in the surroundings of herds by application of insecticides and acaricides on the skin of farmed animals and/or on the breeding sites of the ectoparasites in the surroundings of the ruminants.

Such activities of prophylaxis or control, however, need knowledge of the developmental cycle and on the periods of occurrence of the ectoparasites as well as on their breeding sites. Unfortunately, research on entomological topics has been decreased during the last 30–40 years so that basic data of many important ectoparasites are rather old or even lacking. Thus, there is an extreme need to update such data in order to get the most efficient control and to avoid development or increase of potential resistances.

Several insecticidal products are registered in European countries for use on the skin of ruminants. Among the different pyrethroids (such as cyfluthrin, cypermethrin, permethrin, cyhalothrin, deltamethrin, fenvalerate, etc.), deltamethrin (the active compound in Butox® 7.5 pour-on) is one of the most effective compounds. Different to other pyrethroids, deltamethrin is a single *cis*-isomer. *Cis*-isomers are considered as more effective than isomer combinations. Deltamethrin repels ectoparasites by the "hot foot effect," which is typical for pyrethroids. An insect then redraws its feet suddenly from treated hair after it had a "touchdown" on such an animal. Even after a very short contact for only a few seconds to treated hair, a "knock down" effect occurs since insects (and ticks) die soon after the open nerve ends at their feet got into contact with the insecticide (Eckert et al. 2009; Dettner and Peters 2010). This efficacy leads to a constantly decreasing rate of bitings or other insect attacks and reduce the number of ectoparasites close to the animals, since dead female insects do not propagate anymore. In order to find out the best periods for a treatment at a maximum of efficacy and at lowest risks for the animals and at lowest costs for the farmer, this study was done including data from several author's (Greenberg 1973a, b; Haupt and Haupt 1998; Jacobs and Renner 1988; Kano and Shinonaga 1968; Keiding 1986; Sauer 1998; Schmahl et al. 2008; Werner 1997).

Materials and methods

The epidemiological literature (older and the scarce recent papers) on the occurrence on ectoparasites in Central Europe was evaluated and compared with data given in different textbooks. Our own observations obtained during the trap catching of midges to detect of the vectors of the Bluetongue virus in the years 2006–2009 were added, since the 31 traps that had been constantly in use from August 2006 until May 2008 delivered rather deep insights in the distribution of several ectoparasites (they were also included in the trap besides the tiny midges) all over the year (Mehlhorn et al. 2009).

The insecticidal and acaricidal product Butox® 7.5 pour-on was used in several experiments, which aimed to clarify, whether Butox® is also efficacious against insects like midges or simuliids, which prefer the legs or belly of ruminants, while the product is poured onto the skin along the vertebral column of cattle and sheep depending on the claims in different countries (Schmahl et al. 2009a, b, c; Mehlhorn et al. 2008). Another topic of research had been to solve the question of whether rain leads to a decrease of the efficacy by shortening the period of protection (Schmahl et al. 2009a). Since both questions were positively answered (Butox® 7.5 pour-on protects the feet and belly and rain does not shorten considerably the period of protection), Butox® 7.5 pour-on is a useful remedy for protection which has the following characteristics:

1. It contains deltamethrin that has a rather safe LD_{50} (6,000 mg/kg) in rats.
2. It is a pure single *cis*-isomer, which is considered more effective as isomer combinations.
3. It does not have restrictions for usage or age.
4. It is a registered trademark of Intervet International BV, Boxmeer, the Netherlands.
5. Cattle should be treated with 10 ml per 100-kg body weight poured on the backside along the vertebral column (max. 30 ml); sheep were treated with a total of 10 ml in the same way.

Table 1 Periods of activity of flies that attack cattle and sheep

Species	Breeding site	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Musca domestica, house fly, typhoid fly	Eggs and larvae in and on animal feces, even in stables	$+^1$	$+^1$	$+^1$	$+^1$	+	+	+	+	+	+	$+^1$	$+^1$
Musca autumnalis, eye fly	Eggs and larvae on animal feces outdoors, adults hibernate in buildings	o^2	o^2	o^2	+	+	+	+	+	+	+	o^2	o^2
Fannia canicularis, little house fly	Eggs on feces of chicken and other animals, kitchen slops	o^2	o^2	o^2	o^2	+	+	+	+	+	+	o^2	o^2
Muscina stabulans, false stably fly	Eggs, larvae often on chicken feces, predacious as well	$+^1$	$+^1$	$+^1$	$+^1$	+	+	+	+	+	+	$+^1$	$+^1$
Stomoxys calcitrans, stable fly♀♂ suck blood every 3 days	Oviposition on plant material in stables	+	+	+	+	+	+	+	+	+	+	+	+
Haematobia irritans, horn fly	Eggs and larvae on fresh cow dung	−	−	−	−	+	+	+	+	+	−	−	−
Calliphora vicina, *C. vomitoria*, blow flies	Eggs on feces and cadavers	−	−	+	+	+	+	+	+	+	+	+	−
Sarcophaga carnaria, flesh fly	Eggs and larvae on meat, cadavers, earthworms	−	−	−	+	+	+	+	+	+	+	−	−
Lucilia sericata, gold fly	Eggs in wounds, cadavers, feces	−	−	−	−	+	+	+	+	+	+	−	−
Oestrus ovis, nose bot fly	Larvae are extruded into nose	L in nose	L in nose	L in nose	Pupa on ground	+	+	+	+	+	+	+	L in nose
Hypoderma bovis, large skin bot fly	600–800 eggs adhered to hair of cattle	L in body	L in body	L in body	Pupa on ground	+	+	+	+	+	L in body	L in body	L in body
Hypoderma lineatum, small bot fly	5–20 eggs per hair	L in body	L in body	L in body	L in body	+	+	+	L in body	L in body	L in body	L in body	L in body

+ activity of adult flies in nature and in stable, $+^1$ activity of fly stages in stables, o^2 overwintering in buildings or stables, − in winter rest, *L* larva

Table 2 Developmental data of flies attacking cattle and sheep

Species	Size/adult (mm)	Eggs	Hatch of larvae	Larval development	Pupal rest	Life span of adults
Musca domestica	6–7	600–1,000 of 0.25 mm on feces (pig, horse, cattle)	15°C: 50 h 20°C: 23 h 30°C: 10 h	15°C: 10 20°C: 8 30°C: 4	15°C: 18 20°C: 10 30°C: 4	60–70 days in stables
Musca autumnalis	5–7	600–900 on feces	Temperature dependent	4–7 generations per year	4–7 generations per year	♀ of last generation hibernates
Fannia canicularis	4–6	Feces and putrescent material	25°C: 20–48 h	6 days	7–10 days	6–7 generations per year
Muscina stabulans	6–8	Eggs, larvae on chicken feces	Life cycle in summer about 2–3 weeks	Life cycle in summer about 2–3 weeks	Life cycle in summer about 2–3 weeks	4–5 generations per year
Stomoxys calcitrans	6–7	800 in groups of 25–500 in silage, in stables with urine and feces	1–2 days, temperature dependent: 14 days up to month	6–8 days, temperature dependent: 14 days up to month	6–8 days, temperature dependent: 14 days up to month	♀ live about 70–90 days
Haematobia irritans	4.5–4.5	In fresh cattle dung	Temperature dependent: 24 days up to month, optimum 27–30°C	Temperature dependent: 24 days up to month, optimum 27–30°C	Temperature dependent: 24 days up to month, optimum 27–30°C	3–4 generations per year
Calliphora species	9–11 10–14	Eggs on feces with cadavers	Temperature dependent	Temperature dependent	10–40 days	1–2 months
Sarcophaga carnaria	10–19	Eggs on cadavers, agent of myiasis	Temperature dependent	Temperature dependent	10–40 days	1–2 months
Lucilia sericata	5–11	Eggs on feces, wounds, meat	24 h	4–7 days	1–2 w on the ground	1–2 months
Oestrus ovis	8–15	Larvae are deposited at the nose or eyes	Immediately after laying	Larvae hibernate in the nose	2–4 weeks on the ground	4 weeks
Hypoderma bovis	13–15	600–800 on hairs	4–7 days, then invading the skin	Inside the body until March	15–65 days on the ground	3–5 days
Hypoderma lineatum	11–13	5–20 eggs per hair	3–6 days, then invading the skin	Inside the body until March	23–28 days on the ground	3–5 days

Results

According to the literature and our own observations, the insects that may harm ruminants occur during the following periods throughout the year.

Diptera—flies

In temperate climates, flies (order Diptera—Brachycera, group Cyclorrhapha) show a temperature-dependent occurrence throughout the year. However, in any case, several stages—varying according to the species—survive cold periods at protected places and may initiate a mass production under favorable conditions (e.g., humidity, sufficient food, and high temperatures). Then they may molest humans and animals and threaten their health in case of transmission of agents of diseases. The main periods of fly activities are listed in Table 1, while the data of their development are compiled in Table 2. Among the flies sensu stricto, there are species with a licking activity (e.g., *Musca domestica*); others obtain their food by blood sucking (e.g., *Stomoxys calcitrans*), while again others live as endoparasites during their larval phase after the short living females had deponed their egg load onto cattle or sheep (e.g., bot flies). Of course, all of those fly specimens require different conditions in order to survive during the winter.

Blood-sucking or skin-feeding insects

Simuliids, midges, tabanids, mosquitoes, louse flies, and blood-sucking lice need constantly the blood of their hosts. Blood sucking may occur at intervals of several days (e.g., mosquitoes) or is repeated after a few hours (e.g., lice, Anoplura in sensu stricto). On the other hand, the chewing lice (Mallophaga) feed constantly at the skin and/or hair, while sitting lifelong in the hair of their hosts. Since blood-sucking mosquitoes, tabanids, midges, and simuliids leave their hosts after each blood meal and breed—depending on the species—in different biotopes, they all have developed different strategies for survival during the winter. Therefore, they had to adapt their life cycles to the potentially bad conditions during winter time. This permanent stationary parasitism affords of course other activities than those that are needed in the case of the temporary and short-time parasitism of mosquitoes. The activity phases of those temporary and permanent ectoparasites are compiled in Table 3.

Ectoparasites—independent whether they suck blood, lick body fluids, or whether they feed on skin or hair—may

Table 3 Periods of activity of blood-sucking simuliids, midges, tabanids, louse flies, lice, and skin/hair-feeding mallophages on cattle and sheep

Species	Breeding sites	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Simulium, *Odagmia*, *Boophthora*, simuliid species, 1–4 mm	Quick lotic waters	–	–	–	+	+	+	+	+	+	+	–	–
Culicoides, midges species, 0.8–3 mm	Silage, feces, often in stables	+	+	+	+	+	+	+	+	+	+	+	+
Tabanus bovinus 18-20 mm tabanid species	Tarns, ditches, humid soil	L	L	L	+	+	+	+	+	+	L	L	L
Haematopota pluvialis, 12–15 mm, tabanid species	Tarns, ditches, humid soil	L	L	L	+	+	+	+	+	+	+	L	L
Anopheles maculipennis, 5.5 mm, fever mosquito	Water	o	o	o	+	+	+	+	+	+	+	o	o
Culex pipiens, 5–7 mm, louse mosquito	Water	o	o	o	o	+	+	+	+	+	+	+	o
Aedes cantans, 6–8 mm, meadow mosquito	Water	E	E	L	P	+	+	+	+	+	+	E	E
Culiseta annulata, 6–9 mm	Water	E, L	E, L	L	L	+	+	+	+	E	E	E, L	E, L
Mansonia richiardii, 6–8 mm	Water	L	L	L	L	L	+	+	+	+	L	L	L
Melophagus ovinus, 4–5 mm, sheep louse fly	Hair of hosts	+	+	+	+	+	+	+	+	+	+	+	+
Lipoptena cervi, 3–5 mm, cervid louse fly	Hair of hosts	+	+	+	+	+	+	+	+	+	+	+	+
Linognathus vituli, 3 mm, louse	Hair of hosts	+	+	+	+	+	+	+	+	+	+	+	+
Haematopinus species, 3 mm, sucking lice	Hair of hosts	+	+	+	+	+	+	+	+	+	+	+	+
Mallophaga 1.2–1.6 mm, biting lice	Hair of hosts	+	+	+	+	+	+	+	+	+	+	+	+

o ♀♀ overwinter, *E* egg, *L* larva, *P* pupa, + present

Table 4 Ectoparasites: transmission of agents of diseases to ruminants and symptoms of the disease

Ectoparasites	Symptoms of disease
House flies: *Musca domestica*, etc.	Mechanical vector for more than 100 animal and human pathogenic viruses, bacteria, and parasites. In case of ruminants, the following symptoms may occur besides restlessness, reduced food uptake, and even loss of weight: mastitis, diarrhea, and eye diseases due to bacteria and *Thelazia* worms
Cadaver flies: *Calliphora*, *Lucilia* species	Myiasis in wounds or in the hair and nostrils; transportation of viruses, bacteria, or parasitic eggs/larvae to mouth, eye, udder, or wounds
Stable flies: *Stomoxys calcitrans*	Inflammation of biting sites, restlessness, hypersensitivity, anemia, loss of weight, potential mechanical transmission of viruses or bacteria (e.g., paratyphus)
Bot flies: *Hypoderma* species, *Oestrus ovis*	Restlessness, hypodermosis, inner edema, paralysis during larval wandering, poss. death, loss of the leather due to skin bots and nose bots, nose and eye problems, wrong turning syndrome in sheep, general loss of weight
Simuliids: *Simulium*, *Odagmia*, *Boophthora* species	Painful, burning bite sites with considerable subcutaneous hemorrhages, shock reaction in case of numerous bites, heart and blood circulation problems, paralysis of breathing activities, poss. death in case of mass infestation, transmission of filarial worms
Tabanids: *Tabanus*, *Haematopota* species	Painful bites introduce restlessness and severe itching and therefore loss of weight follows. Mechanical transmission of *Anaplasma* stages, bacteria, filarial worms, and probably also viruses
Blood-sucking lice: *Haematopinus*, *Linognathus* species	Restlessness, itching, loss of hair and weight, anemia, reduced activity
Mallophaga: *Bovicola*, *Lepikentron* species	Restlessness, itching, loss of hair, skin infections, loss of weight
Louse flies: *Lipoptena*, *Melophagus* species	Restlessness, itching, loss of hair and weight, dermal myiasis
Mosquitoes: *Aedes*, *Culex*, *Anopheles* species	Itching, potential transmission of viruses and worms, restlessness, and skin edema
Midges: *Culicoides* species	Vectors of Bluetongue virus, possible death, painful bites, skin edema, especially at the udder, loss of weight, restlessness

transmit agents of diseases (Table 4). The intensity of such a vectorship is depending on the frequency of their host changing. In cases of midges, mosquitoes, or simuliids, which may suck daily at several hosts, the potential of the establishment of a vectorship is surely higher than it is in the case of blood-sucking or chewing lice, which change their host only in rare cases. Therefore, the numbers of pathogens that are adapted to often host-changing ectoparasites are considerably larger than those in mainly permanent parasites (Tables 4).

Discussion

The comparison of consideration of ectoparasites of ruminants and their periods of activities during the year as well as their importance as vectors of agents of diseases or as initial agents of severe symptoms of diseases clearly showed that farming of ruminants without control of ectoparasites will not be economically successful, if at all possible. Thus, protection against ectoparasites is strongly needed in order to avoid losses in body weight or in the

Table 5 Overview on the yearly occurrence of ectoparasites as larval or adult stages on ruminants on meadows or in stables

Parasites	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
House fly, *Musca*	+	+	+	+	++	++	+++	+++	++	+++	++	+
Stable fly, *Stomoxys*	P	P	+	+	++	+++	+++	+++	+++	++	P	P
Nose bot fly, *Oestrus*	L	L	L	P	+	+	+	+	+	+	+	L
Skin bot fly, *Hypoderma*	L	L	L	P	+	+	+	+	+	L	L	L
Midges, *Culicoides*	+	+	+	+	+	++	+++	+++	+++	+++	+	+
Simuliids, *Simulium*	−	−	−	+	++	++	+++	+++	++	+	−	−
Tabanids, *Tabanus*	−	−	−	+	+	++	+++	+++	+++	++	−	−
Mosquitoes	−	−	−	−	+	+	+++	+++	+++	++	−	−
Louse flies	++	++	+	+	+	+	++	+++	++	+	+	+
Sucking lice	+	+	+	+	+	+	+	+	+	+	+	+
Biting mallophages	+	+	+	+	++	++	+++	+++	+++	+	+	+

+ few adults, ++ many adults, +++ huge amounts of adults, *L* larvae, *P* = pupae

quality of goods produced from farmed animals (leather, wool, etc.). Table 5 shows the months wherein attacks of several ectoparasites must be expected in Europe. Thus, measurements (e.g., treatments of the animals with the deltamethrin-containing insecticidal product Butox® 7.5 pour-on or with similar insecticides) should be scheduled regularly. Since the period of the efficacy of each insecticidal product depends on the way of formulation and the way of application, treatment should be done exclusively according to the claims of the product, e.g., ear tags with insecticide have a shorter phase of activity against insects that suck in the region of the belly than products with a pour-on application (Liebisch and Liebisch 2008). Tests with the deltamethrin-containing product Butox® showed that it protects sheep and cattle against midges, which suck blood at the legs or at the belly for at least 4 weeks, even if the animal becomes wet several times during these 4–5 weeks (Mehlhorn et al. 2008, 2009; Schmahl et al. 2009a). However, such a treatment is only effective, if it is done consequently throughout the year. With respect to the data of the life cycles of the most important ectoparasites of ruminants (see Tables 1, 2, 3, 4, and 5), the following scheme of treatment is recommended: beginning from November until April, treatment all 8–10 weeks; beginning from May until October, all 4 weeks. This handling will reduce the activity of harmful ectoparasites considerably.

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