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Ecological, behavioural and economic effects of insects on grazing farm animals – a review

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High populations of various insect species, especially common in the summer, may adversely affect farm animal health because of the transmission of contagious and parasitic diseases and the induction of insect allergies. Blood-sucking insects may compromise animal welfare and cause economic losses due to the annoyance and distress suffered by the animals, feeding interruptions and energy requirements for avoidance or defense behaviours initiated by the animals in response to the insects. Consequently, significant decreases in production traits, such as weight gain in beef cattle or milk yield in dairy cattle, can be expected when blood-sucking insects are numerous. There are several globally distributed families of Diptera that harass farm animals; these include the Culicidae, Ceratopogonidae, Muscidae, Oestridae, Simuliidae and Tabanidae. Large insect populations gains problems because of a lack of effective and long-lasting repellents and of the difficulty or impossibility to apply available compounds, e.g., on remote pasture areas or in free-roaming herds. Described are consequences caused by insect harassment of grazing farm animals and the main behavioral strategies used by the animals to cope with this harassment.

KEY WORDS: behaviour / Diptera / grazing animals / insects harassment / parasitic diseases

Class Insecta compose the most numerous and widespread zoological systematic group. Presently, approximately 750,000 species belonging to this taxonomic group have been described. The importance of insects to life on earth is enormous because of their contribution to the circulation and distribution of organic matter, participation in plant reproduction by pollination and in the diet of many vertebrate animals. Despite these benefits, numerous insect species are considered pests of plants, crops, animals

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and human beings. The role of insects as vectors of many contagious and parasitic diseases is well known [Horvath *et al.* 2010, King and Gurnell 2010, Little 2012, Omnaz *et al.* 2012] – Table 1. The harm to animals from insects stems mainly from insect feeding and reproductive habits and from the annoyance arising from the close proximity of insects to their hosts. Thus, harassment by insects may have an adverse effect on animal welfare and behavior [Vockeroth 2002, Górecka and Jezierski 2007]. Insect species have developed specific searching behaviours and use different cues for seeking their animal hosts, including olfaction and vision primarily other modalities.

The order Diptera (two-winged insects) derives from Mecoptera. An estimated 150,000 species of Diptera have been described [Skevington and Dang 2002, Yeates *et al*. 2007]. A characteristic and unique feature of this order is the transformation of the hind wings into short, club-shaped structures called halters, which have a stabilizing function and act as gyroscopes to inform the insect about body rotation during flight. The Diptera have only one pair of normally developed wings [Vockeroth 2002, Omnaz *et al*. 2012]. Imagos usually have licking-sucking (e.g., flies) or piercing-sucking (e.g., mosquitoes) mouthparts. Contemporary Diptera ingest only liquid food, licking it from a surface or sucking it from a host. Dipteran larvae are characterized by a reduction of the legs and the head capsule. The size of Diptera ranges from 1 mm to several centimeters, and their coloration is variable [Vockeroth 2002, Lehane 2005].

In the present review we discuss behavioral, ecological and economic effects of blood-feeding insects of the Diptera order on farm animals.

Insects' host-finding behaviour and feeding habits

The development of particular insect species is closely related to that of their animal host. Knowledge concerning the feeding habits of blood-sucking insects can be useful for preventing or alleviating insect harassment of farm animals.

Insects that suck vertebrates' blood find potential hosts using different cues, most likely use a combination of visual, thermal and olfactory cues for host-finding. For example, mosquitoes respond to moisture and temperature gradients, CO_2 titers, and host colour, preferring a dark coat [Rutberg 1987]. Black flies and horn flies are more attracted by dark colors, such as black, blue, purple and pink, than by white, yellow or green [Khan and Kozub 1985]. Also dipteran species belonging to the families Tabanidae, Muscidae and Simuliidae prefer darker colors which are more attractive for them than light colors [Duncan and Vigne 1979, Khan and Kozub 1985, Rutberg 1987, Horvath *et al*. 2010]. Furthermore, the sex and breed of animals may significantly affect their attractiveness to insects [Khan and Kozub 1985, Rutberg 1987, Wollard and Bullock 1987, Braverman 1989, Rubenstein and Hohmann 1989, Hallamaa 2009]. To facilitate finding human hosts, the antennae of female insects are equipped with receptors for 4-methylphenol, which is one constituent of human sweat [Hallem *et al.* 2004].

The nutritional requirements of insects vary in quantity and quality with the insect developmental stage and species, and feeding habits may differ between the sexes. In the Culicidae and Tabanidae, only adult females feed on host blood because blood meals are necessary for female survival and reproduction [Rozendaal 1997, Lehane 2005]. Without the consumption enough amount of blood, the number of eggs is reduced [Lysyk 2011]. In the Muscidae and Simuliidae families, both sexes feed on blood [Foil and Hogsette 1994].

Dipteran insects, especially those from the families Culicidae and Simuliidae prefer specific body regions of animals for feeding. For example, horses are mostly bitten around the mane and withers, at the shoulders, in the lumbar area, and on the skin around the flanks, neck, eyes, and ears. Less preferred by insects are the jaw and the nose [Dąbrowska and Wiśniewski 1995].

Animals are exposed to the attacks of insects throughout most of the day, although the activity of particular insect families varies. Muscidae feed on grazing animals throughout the day when the temperature exceeds 20°C. They prefer body regions around the eyes. Culicidae are active mostly in the morning and evening, being especially annoying shortly before and after rain. Tabanides attack host animals preferentially on warm, windless days, particularly in the evening and before a thunderstorm. The insects of the family Oestridae become active on sunny, windless days when the air temperature exceeds 22-23°C [Romaniuk 1999].

The seasonal activity of blood-sucking Diptera depends on many factors, one of which is the geographical location. Studies have shown that Muscidae are active in Europe from the middle of May to the middle of September, with a peak in July and August [Altunsoy and Kilic 2012].

Insects as vectors of disease

Blood-sucking insects carrying bacteria, viruses, nematodes, protozoa and rickettsia are vectors of numerous diseases. The most serious human diseases transmitted by insects include malaria, yellow fever, filariasis, trypanosomiasis, tularemia, encephalitis, leishmaniasis, typhus dysentery and typhoid fever. Malaria affects approximately one hundred countries in the world, particularly in tropical and subtropical regions. It has been estimated that more than one billion people are exposed to malaria [Carey *et al.* 2010, Omnaz *et al.* 2012]. The main diseases of grazing animals transmitted by insects are listed in Table 1. The insect-transmitted animal diseases include equine encephalomyelitis, West Nile fever, Japanese encephalitis, Rift Valley fever, bluetongue disease, African horse sickness, and equine infectious anemia, among others [Little 2012, Omnaz *et al.* 2012].

Blood-sucking insects can also transmit parasites and cause allergies [Kleider and Lees 1984, Rutberg 1987, Rubenstein and Hohmann 1989, Barros and Foil 2007, King and Gurnell 2010]. Wild, free-ranging and grazing animals are highly exposed to diseases transmitted by insects. Transmission occurs during blood sucking by an

Table 1. Common diseases of grazing animals transmitted by insects (Onmaz *et al*. 2012, Little 2012, Lehane 2005)

Disease	Pathogen	Vector	Animal host	Geographical distribution
African horse sickness virus (AHS)	viruses	Ceratopogonidae, Culicidae	horse	S., Central and E. Africa; India
Bluetongue		Culicidae	sheep	Worldwide
Eastern equine encephalomyelitis (EEE)		Ceratopogonidae, Culicidae	horse (human)	N., Central and S. America; Caribbean
Equine infectious anemia (EIA)		Muscidae, Tabanidae	horse	Worldwide
Japanese encephalitis (JE)		Culicidae	horse, pig (human)	S. E. Asia
Kunjin (KUNV)		Culicidae	horse (human)	S.E. Asia, Australia
Murray Valley encephalitis virus (MVEV)		Culicidae	horse, poultry (dog)	E. Australia, Philippines, New Guinea
Ross River virus (RRV)		Culicidae	horse	Australia, Papua New Guinea, other South Pacific Islands
Venezuelan equine encephalomyelitis (VEE)		Culicidae	horse (human)	S. America, S. USA, Europe
West Nile virus (WNV)		Culicidae	horse (dog, human)	C. and N. Africa, India, Russia
Western equine encephalomyelitis (WEE)		Ceratopogonidae, Culicidae	horse (human)	America, Czech Republic, Italy
Tularemia	bacteria	Culicidae, Tabanidae	horse, pig, sheep (human)	Asia, Europe, N. America
Habronemiasis	helminths	Muscidae	donkey, horse, mule (zebra)	World with a tropical or temperate climate
Onchocerciasis		Ceratopogonidae, Simuliidae	cattle, horse (human)	Worldwide
Parafilariasis		Muscidae	cattle, horse	Africa, Eurasia, S. America
Thelaziasis		Muscidae	cattle, horse (dog, human)	Africa, Asia, Europe, N. America

infected insect but can also occur through fecal contamination at the insect puncture site or by swallowing infected insects [Lehane 2005]. Pathogens transmitted by insects can enter the host at times other than during the sucking of blood. Insects can transmit germs mechanically, e.g., on contaminated mouthparts or legs. In this case, the insects are not considered as biological vectors but as temporary mechanical vectors. In most cases, however, infections agents are spread during blood sucking when insects are acting as biological vectors, which are an important and indispensable part of the life cycle of the pathogen. Insects that are biological vectors get infected by the pathogen while feeding on an infected vertebrate, which serves as a reservoir host [Little 2012].

Particular insect families can transmit a variety of diseases or just a few specific pathogens. For example, the house fly (*Musca domestica*) is a vector of many diseases, such as typhoid fever, cholera, tuberculosis, polio and salmonellosis, but it may also spread parasitic infections. Muscidae are also intermediate hosts of parasites such as *Habronema microstoma* which is responsible for habronematosis. In addition, Muscidae can transmit *Trypanosoma* spp., polio virus, equine infectious anemia, avian flu and anthrax [Foil and Hogsette 1994, Lehane 2005]. Biting midges can transmit several diseases, the best known of which is bluetongue disease in sheep and cattle [Ruiz-Fons *et al.* 2008]. It has been established that at least 20 species of biting midges can transmit the virus responsible for this disease.

Black flies attack humans and their pets, and the female flies can transmit skin and blood parasites between host animals [Chubareva and Petrova 2007, Onmaz *et al.* 2012]. Certain species transfer pathogenic organisms, such as nematodes of the genus Filaria that cause filariasis or the genus *Onchocerca* that cause onchocerciasis (river blindness). Tabanidae can transfer *Trypanosoma evansi*. These diseases can result in serious losses of wildlife and livestock [Lehane 2005].

Insect caused allergies

Bites of piercing-sucking insects belonging to the families Culicidae and Simuliidae can result in hypersensitivity to toxic and allergenic substances contained in insect saliva (probably salivary gland proteins) [Schaffartzik *et al.* 2012]. Biting female mosquitoes inject substances into the wound that prevent blood clotting [Hellberg *et al.* 2009, Schaffartzik *et al.* 2012]. Dermatological diseases related to insect allergies in animals are particularly severe in the spring and summer and during the hottest days of the year, when insects generally develop the fastest [Hallamaa 2009, Oliveira-Filho *et al.* 2012]. A common worldwide disease of farm animals is seasonal allergic dermatitis, which mainly affects horses. Hypersensitivity to insect bites also occurs in cattle, goats and sheep [Yeruham *et al.* 1993]. Skin allergies in farm animals have different names in different parts of the world. In the USA they are termed summer dermatitis; in the UK – sweet itch; in Australia, Queensland itch; and in Norway, summer eczema [Marti *et al.*1992, Dąbrowska and Wiśniewski 1995, Schaffartzik *et al.* 2012].

The first external symptom of hypersensitivity to insect bites is local hair loss because of itching and rubbing or scratching off the hair coat. The developing disease is characterized by numerous oozing pimples and papulae, which are painful and itchy. The animal is permanently scratching, nibbling, licking, and rubbing its body on objects in its surroundings, which leads to more hair loss over larger areas and to injuries that result in secondary infections. The skin on the affected areas becomes red and is often covered with scabs [Schaffartzik *et al.* 2012, Schurink *et al.* 2011, Oliveira-Filho *et al.* 2012]. Subsequently, hyperpigmentation and thickening of the affected skin may occur. Additionally, in particularly sensitive animals, systemic symptoms including anaphylactic shock may occur along with the skin symptoms. The symptom severity depends on the number of insect species existing in the geographical region, the degree of injury and also on the individual sensitivity of the host [Dąbrowska and Wiśniewski 1995, Greiner 1995].

Hypersensitivity to insect bites is characterized by two types of immune system responses. The immediate type I hypersensitivity response appears approximately 15 minutes after the insect bite and is characterized by a high level of serum IgE antibodies and a migration of circulating eosinophils from the bloodstream into the inflamed tissues. The delayed type IV hypersensitivity reactions are inflammatory reactions initiated by mononuclear leukocytes. The term delayed is used to differentiate a secondary cellular response, which appears 48-72 hours after the antigen exposure [Dąbrowska and Wiśniewski 1995, Oliveira-Filho *et al.* 2012, Schaffartzik *et al.* 2012].

Hypersensitivity to the bites of mosquitoes of the family Culicoidae increases with the age of the animal [Braverman 1989]. The frequency of hypersensitivity responses differs depending on the horse breed. For instance, Icelandic, Arab, Friesian, Shire, Quarter and Warmblood horses, Connemara and Shetland ponies are relatively more sensitive to insect bites than other breeds e.g. American saddlebred, Belgian or Standardbred [Scott and Miller 2011, Schaffartzik *et al.* 2012]. Notably, as there are no mosquitoes in nature in Iceland, when Icelandic horses became popular in European countries in the sixties, more than 50% of the horses imported to the Europe suffered from skin allergies, especially in the summer. About 5 years after their arrival into the European continent, the hypersensitivity rate decreased to 6%, which is similar to that in the endemic horse breeds in Europe. In Icelandic horses born in Europe and exposed to insect bites from birth, the frequency of hypersensitivity to insect bites is approximately 5%. This pattern suggests that immune tolerance can be developed during the life span of an animal in a given environment [Marti *et al.* 1992, Schaffartzik *et al.* 2012].

Changes of animal behaviour caused by insects

Insect bites are painful or at least cause discomfort and annoyance to animals from the presence of insects on and around them. Large insect populations may disturb feeding, resting and other important host activities and thus negatively influence animal well-being [Rutberg 1987, King and Gurnell 2010]. Animals use various behavioral strategies to protect themselves against insect harassment. One of these strategies is moving to and staying within areas where insects are less active. Horses, bison, caribou and reindeer often rest in open, windy areas without vegetation [Rutberg 1987, Rubenstein and Hohmann 1989, King and Gurnell 2010]. Horses spend more time on hills and slopes if insects are extremely active. In free-roaming Polish Konik horses maintained in a forest sanctuary, the Koniks were observed on hot summer days when harassing insects are most active to stand motionless in the forest almost all day in particular spots beneath spruce trees in a circle close to one another with their heads towards the middle of the circle [Górecka and Jezierski 2007]. King and Gurnell [2010] observed that on hot days horses sought refuge in forests or afforestations; however, more insects were observed there than in open areas, and the animals were seeking shade rather than protection against insects. It has been shown that insects are more active on sunny days without clouds or wind [Górecka and Jezierski 2007]. As a consequence, farm animals spend less time grazing under these weather conditions and more time defending themselves against insects. Conversely, horses are more likely to spend more time grazing on windy days.

Another defense strategy against insects is to form larger animal groups or temporary aggregations. It was observed [Schmidtmann and Valla 1982] that there are fewer insects per animal in larger animal groups than in smaller animal groups. Dairy cattle tend to aggregate into groups when the number of insects increases to approximately 9-12 per individual animal; however, there is no relation between the tendency to aggregate and the grazing or feeding time [Schmidtmann and Valla 1982]. The aggregation of animals into groups facilitates mutual protection by tail swishing against insects gathering around sensitive body areas such as the eyes [Duncan and Vigne 1979, Rubenstein and Hohmann 1989, Mullens *et al.* 2006, King and Gurnell 2010].

Although it has been proven in several studies that animal aggregation into larger groups is effective for decreasing insect harassment, there are also observations that show no relation between the size of the animal group and insect harassment [Rutberg 1987]. Furthermore, it was observed in horses that particular individuals within a group are not evenly attacked by insects. Social hierarchy may play a role because higher-ranking females tended to be more harassed by insects than lower-ranking females [Rubenstein and Hohmann 1989]. In natural horse herds, this could also result from the greater proximity of the high-ranking mares to stallions, which are usually more frequently attacked by insects than are mares. In addition, flies more frequently attack lactating females than nonlactating ones and one-year-old foals are more attractive to insects than infant foals [Rubenstein and Hohmann 1989]. The fact that adult animals are more likely to be bitten than young ones could be explained by the use by insects of carbon dioxide concentrations to locate their hosts. Because the production of CO_2 by animals depends on the metabolic rate, which increases with age and is higher in males than in females [Rubenstein and Hohmann 1989, King and Gurnell 2010], differing CO_2 concentrations may be a reason why adults are attacked more than infants and males more than females.

Table 2. Mean (±SD) frequencies of individual protective behaviours in Konik horses in relation to age and environmental factors (Górecka and Jezierski 2007; modified)

Item	Frequency per minute			
	tail swishing	skin twitching	head shaking	leg lifting
Age group				
adult horses	29.2±18.7	$11.4±9.6^{A+}$	$2.8±5.4^{A+}$	$0.8±2.7^{A}$
foals	29.1±21.3	$5.6±5.3^{B+}$	$1.1±1.6^{B+}$	$0.7±1.2^{B}$
Maintenance				
forest reserve	$33.3±21.0^{A+}$	$10.5±10.0^{a}$	$1.7±3.0^{A+}$	$1.1±3.1^{A+}$
pasture, stable group	$24.9±16.8^{B+}$	$8.8±7.5^{b}$	$2.9±5.8^{B+}$	$0.5±0.9^{B+}$
Ecosystem within the reserve				
forest area	$36.0±21.1^{A+}$	$11.8±10.4^{A+}$	2.0±3.6	$1.6±4.0^{A+}$
open grassland	$26.7±18.2^{B+}$	$8.9±8.2^{B+}$	2.4±5.0	$0.5±1.0^{B+}$
Weather conditions				
hot weather, sunshine	$29.9±21.0^{A+}$	$9.7±8.8^{A}$	$2.5±4.9^{A+\,A}$	$0.8±1.4^{A+}$
cloudy	$26.1±22.0^{B+}$	$9.7±9.7^{B+}$	$1.3±1.8^{B+}$	$1.1±5.3^{B+}$
rainy, cool weather	$6.3±17.8^{C+}$	$2.4±5.2^{C\,C+}$	$0.2±0.5^{C}$	0.7±0.2
Wind				
strong wind	$15.3±12.5^{A+}$	$5.6±5.0^{A\,A+}$	0.5±0.7	0.2±0.5
weak wind	$25.6±16.5^{B+}$	$8.0±7.2^{B}$	2.2±4.1	0.5±0.8
windless	$30.7±20.2^{C+}$	$10.3±9.4^{A+\,C}$	2.4±4.8	0.9±2.6

Within columns means bearing different superscripts differ significantly at: $^{ab}P<0.05$; $^{ABC}P<0.01$; $^{A+,B+C+}P<0.001$.

Other defense behaviours used by individual animals against insects involve body movements, such as walking in circles, tail swishing, skin twitching, head and mane shaking, ear flapping, leg lifting, scratching, licking, and wallowing in sand or mud [Schmidtmann and Valla 1982, Romaniuk 1999]. The frequency of these animal behaviours may vary with such factors as the maintenance conditions, ecosystem, animal age and weather conditions (Tab. 2).

Economic effects of insect harassment

High numbers of various insect species, especially common during the summer, negatively affect the health, well-being, activity and, ultimately, the productivity of grazing animals.

Decreased productivity in terms of lower weight gain or less milk production is related to blood losses from insect bites, energy losses from repeatedly performing defensive behaviours, reduced feeding time and reduced intake of important nutrients [Rubenstein and Hohmann 1989, Gerry *et al.* 2007, Dougherty *et al.* 1993]. A significant decrease in milk production by dairy cattle caused by insects feeding on cattle blood was ascertained by Mullens *et al.* [2006], Taylor and Berkebile [2006], Gerry *et al.* [2007] and Altunsoy and Kilic [2012]. According to Campbell *et al.* [2001] and Gerry *et al.* [2007] high numbers of the stable fly *Stomoxys calcitrans*, may decrease weight gains in cattle. The same fly species can cause a decrease in milk production by cows of up to 1.49 kg per day [Gerry *et al.* 2007]. Decreased milk production in lactating females has negative consequences for offspring development [Sykes 1994, Mullens *et al.* 2006, Gerry *et al.* 2007, Taylor *et al.* 2012].

Weight gains in cattle may be reduced by 0.1 kg per day when the animal is daily attacked by approximately 66 individuals of blood-sucking tabanids insects [Altunsoy and Kilic 2012]. Other studies [Steelman *et al.* 1993, Dougherty *et al.* 1993, Sykes 1994] estimated that attacks by dipteran flies can reduce cattle weight gains by up to 18% per year. Insects need not fly to cause production losses in farm animals. Some studies have shown reduced weight gain in cattle during migration of the larvae of *Hypoderma bovis* from the skin surface on the legs or sides of hosts to positions under the skin of the back. Animals which were not infected with larvae of *Hypoderma bovis* over a 12-month period achieved weight gains approximately 20 kg higher than those of infected animals [Romaniuk 1999]. Another species belonging to the family Muscidae, *Haematobia irritans*, causes a decrease in not only weight gain but also milk production by cattle [Kaufman 1999].

One of the reasons for decreased production caused by insects is host blood loss. As an example from the Tabanidae, 25-30 *Hybomitra sonomensis* individuals feeding for 6 hours can withdraw approximately 100 ml of blood from their host [Foil and Hogsette 1994]. *Tabanus bovinus* females, which frequently attack pastured horses, can each consume 0.2 ml of blood per meal. The blood meal volumes of one mosquito female range from 5 to 12 μl [Lysyk 2011].

In the USA, the total economic losses in livestock production caused by flies are estimated in millions of US dollars. In Saskatchewan, Canada, the total losses caused by *Simulium luggeri* (Simuliidae) in 1978 on an area of 5700 km^2 were estimated at 2.9 million dollars [Freeden 1985]. Another estimate showed that losses in the USA in 1965 from insects of the family Tabanidae were nearly 100 million dollars [Foil and Hogsette 1994]. The total North America economic losses in cattle caused by *Stomoxys calcitrans* (Muscidae), a species associated with cattle, were estimated at nearly 1 billion dollars per year [Taylor and Berkebile 2006]. In conclusion, the value of animal products can be substantially decreased because of insect harassment [Sykes 1994, Michalski 2007, Taylor *et al.* 2012].

Insect control

A variety of methods have been developed to control and combat insects. There are hundreds of chemical repellents, insecticides, and insect traps based on pheromones or other attractants available on the market. Additionally, mechanical methods have been used to protect animals from insects; for example, specially designed nets can be worn by animals (mainly horses) to prevent insects from contacting their most sensitive body parts, such as the eyes, ears, head, or even the whole body. However, there are questions concerning the effectiveness and applicability of all of these methods used to control and combat insects. Repellents applied to animals are usually only of short-term effectiveness, and their application is problematic for farm animals kept on remote pastures or for free-ranging herds. Other important strategies to control and combat animal harassing insects include the understanding and promotion of natural control methods, such as the protection of fly-catching birds, the control or removal of insect reproduction sites and the disruption of insect reproductive cycles.

The most popular and widely used chemical to protect animals from insect harassment is the synthetic compound N,N-diethyl-meta-toluamide (DEET). This repellent has been used for more than 50 years, and it was estimated that there are about 200 million users of this chemical worldwide. DEET is an effective repellent for mosquitoes and other blood-sucking Diptera [Lee *et al.* 2010, Mikulak *et al.* 2012]. The advantages of DEET derive from its relatively low toxicity and persistence for only several hours when used at the highest concentration. Unfortunately, the DEET mode of action has yet to be elucidated [Syed and Leal 2008]. DEET appears to be effective at close range and as a contact chemorepellent by acting on insect gustatory receptors and at long range by acting on the olfactory system [Pellegrino *et al.* 2012].

Blume *et al.* [1971] tested six DEET concentrations ranging from 3.75 to 75% and applied as aerosols for their effectiveness in protecting cattle and horses. The protective effect was found to be proportional to the concentration of the repellent. Moreover, high concentrations of DEET afforded the best protection for both cattle and horses. The 50-75% solutions effectively protected cattle and horses from stable flies and tabanids for approximately 4 hours. However, when sprayed with DEET at higher concentration, cattle salivated excessively and produced a nasal discharge, and horses exhibited skin exfoliation on certain body parts [Blume *et al.* 1971]. Mikulak *et al.* [2012] tested the effectiveness of a number of repellents containing DEET (10-15% titer) that were marketed in Poland and demonstrated that these DEET-based repellents show effective deterrence, but their efficacy decreased after 4 hours [Mikulak *et al.* 2012]. The efficacy of fly control using cattle ear tags impregnated with chemical repellents has been well established. Block and Lewis [1986] used ear tags impregnated with such pesticides as permethrin, decamethrin, and fenvalerate and several repellents to determine the effects of these chemical controls on milk performance in dairy cows. More flies were observed on the control animals (91% of the total number of flies observed on the cattle) than on animals fitted with the ear tags (9%). However, the ear tags were not equally repellent to the different species of blood-sucking insects [Block and Lewis 1986].

Summary

This review article shows the huge global problem of insect harassment and described most important information on this topic. Insects are vectors of many contagious and parasitic diseases and also caused allergies. Blood-sucking Diptera infestation can have detrimental effects on welfare and behaviour, daily activity, health and productivity of grazing animals by causing chronic irritation and pain through biting. Animals use various behaviour strategies e.g. individual (tail swishing, head shaking, leg lifting) and social protective behavior (form larger groups or temporary aggregations) to protect themselves against insects attacts.

Furthermore, important is that economic losses in livestock production caused by flies are estimated in millions of US dollars. Insects significant decrease in milk production by dairy cattle or weight gains. An important from an economic point of view, there are also huge financial cost on repellents and insecticides. However, there are questions concerning the effectiveness and applicability of all of these methods used to control insects, because many of this repellents applied to animals are usually only of short-term effectiveness and also the application of them is sometimes problematic.

The main problem to be solved is to find methods which will be more effective to protect animals from insect harassment in different conditions as well as to get more knowledge about insects host-seeking behaviour and feeding habits.

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