Ectoparasites of Cattle

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KEYWORDS

• Cattle • Ectoparasites • Flies • Myiasis • Lice • Mites • Ticks
• Integrated management

KEY POINTS

- Most of the approximately 1.49 billion head of cattle worldwide are susceptible to infestation with ectoparasites, several of which are also vectors of bovine pathogens.
- Diseases listed by the World Organization for Animal Health include some caused directly by ectoparasites and by ectoparasite-borne pathogens affecting cattle.
- Some ectoparasites of cattle are of One Health importance because they can be invasive and of high socioeconomic consequence, and several zoonotic ectoparasite-borne pathogens can affect public health.
- Arthropods, mainly insects, mites, and ticks, represent the most economically important group of cattle ectoparasites because of the direct effect associated with heavy infestations on health and food production.
- Integrated approaches are required to manage cattle ectoparasites in a sustainable manner.

Most of the approximately 1.49 billion head of cattle worldwide are susceptible to infestation with diverse ectoparasitic fauna. Arthropods, mainly insects, mites, and ticks, represent the most economically important group of cattle ectoparasites because of the direct effect associated with heavy infestations on health and food production.[1] Multiple species of arthropod ectoparasites are also vectors of pathogens causing bovine diseases, some of which are zoonotic.[2] Moreover, several diseases caused directly by ectoparasites or the pathogens they transmit to cattle are listed as notifiable by the World Organization for Animal Health.[3] An overview of common ectoparasites and current practices to treat or prevent ectoparasitoses in cattle is presented here.

The biology and ecology of ectoparasites are unique. Interactions between characteristics of the farming system under consideration and complex epidemiologic aspects influence the prevalence and incidence of ectoparasitoses and arthropod

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vector-borne diseases in cattle. Permutations of conventional and nonconventional beef or dairy cattle farming systems across world regions can range from extensive subsistence farming involving one resource-poor farmer to intense commercial production under ownership of multinational corporations where the latest technologies are used to manage ectoparasites.[4,5] Thus, the veterinary practitioner must consider husbandry practices to treat infestations effectively in cattle herds.[6,7] For example, grazing beef cattle, including cows and their calves, in the United States can be infested with horn flies and face flies. During the dry season or winter, hay wagons or round bale feeders used to supplement feeding operations can become stable fly-breeding sites unless hay residues are managed. Cattle-wildlife interactions in extensive farming systems can provide the medium for tick infestations and the transmission of tick-borne diseases. Biosecurity is another critical practice used to avoid the introduction of ectoparasites into a cattle herd and prevent their spread within and between farms. Practitioners must observe best veterinary drug-use practices to treat infestations, caused, for example, by latent lice or mite populations, in cattle that must be transported for managing or marketing purposes. Breeding conditions tend to be unfavorable for horn flies and face flies in properly managed cattle-feeding operations, feedlots, and feed yards. Cattle shipped from remote rangelands may be infested with cattle grubs and should be examined for warbles where these ectoparasites are endemic.

Veterinary drugs and mechanical/environmental, biological, and genetic methods have been used alone or in combination to control or eradicate ectoparasites. Veterinary products containing ectoparasiticides are used commonly by practitioners and producers to treat or prevent ectoparasitoses and mitigate exposure to vector-borne pathogens.[8] However, the intense use of ectoparasiticides in several parts of the world has selected for resistance in ectoparasite populations exposed to them continuously. Strategies combining other methods for sustainable cattle ectoparasite management are needed to address societal concerns with the massive application of ectoparasiticides in the context of food safety, global change, animal welfare, and environmental health.

Injurious ectoparasite infestations impair the productivity of cattle and, in extreme cases, result in mortality. This inflicts significant economic loss on cattle producers around the world. For example, estimates indicate that ectoparasitic flies and ticks infesting cattle in Brazil cause US$6.86 billion in economic losses annually.[9] Adopting the principles of integrated pest management to practice integrated ectoparasite management mitigates the risk for the development of resistance to ectoparasiticides while maximizing their longevity as useful tools used rationally with decreased impact on nontarget species.[10] Best ectoparasiticide use practices contribute to achieving One Health by safeguarding animal, public, and environmental health.[11]

COMMON CATTLE ECTOPARASITES

Ectoparasitic Flies

Many species of Diptera (two-winged insects, or true flies) are ectoparasites because they bite to feed on blood, that is, hematophagous, or cause nuisance to the animals during the adult stage, cause myiasis at the immature stages or larvae, invade living soft tissue, or transmit pathogens to cattle as biological or mechanical vectors.[12] Examples of common ectoparasitic flies affecting cattle health and production causing economic damage are briefly reviewed.

Horn and buffalo flies

Haematobia irritans, commonly known as the horn fly, is a cosmopolitan hematophagous ectoparasite closely associated with cattle grazing in open pastures and rangeland. Adults spend most of their life on the host and tend to congregate on the back and shoulders of cattle or on their underbelly during the heat of the day. Persistent blood feeding irritates cattle and can cause significant production losses. Larvae breed in undisturbed dung pats, and adult populations build up during the warmer months of the year. Treatment is warranted when adult horn fly counts per animal exceed 200.[13] In northern Australia and Southeast Asia, the buffalo fly, *Haematobia exigua*, is an economically important biting fly closely related to the horn fly.

Horn flies are mechanical vectors of bacteria causing bovine mastitis.[14] Buffalo and horn flies are intermediate hosts of spirurid nematodes causing bleeding sores from stephanofilariasis in cattle.[15] Several classes of ectoparasiticides and formulations are used to treat infestations.[16] Insecticide resistance is a problem among these biting flies in several parts of their geographic range. Cattle-feed additives containing larvacides and insect growth regulators excreted in the dung that prevent the adult stage are used to control *Haematobia* spp. populations.[17]

Stable fly

With a worldwide distribution, unique breeding habits, strong flying ability, and transient host association to acquire a blood meal through a painful bite, the stable fly, *Stomoxys calcitrans*, is a pestiferous ectoparasite of cattle. Larvae breeding in moist decaying organic material from multiple sources including crop residues, lawn clippings, silage, and animal bedding can result in stable fly outbreaks. Stable flies tend to blood feed on the lower parts of cattle. The threshold for treatment is 5 flies per front leg.[18]

The stable fly can be a pest in open pastures or in confined cattle production facilities. Although considered a poor vector, viruses, bacteria, and protozoans pathogenic to cattle have been recovered from the stable fly. Sanitation in and around cattle-raising areas prevents fly population growth locally.[19] Ectoparasiticide treatment helps control adult flies. Biological control methods augment the effect of other stable fly interventions.

Face fly

Cattle in Europe, central Asia, and parts of Africa, the United States, and Canada are hosts for the face fly, *Musca autumnalis*. Ectoparasitism by face flies is associated with pastured cattle where, as with the horn fly, fresh cattle dung provides the immature stages the nourishment to develop.[20] Adult flies consume secretions from the eyes and nostrils, and sanguineous fluid from wounds around the host face. When face flies attempt to feed, the abrasive action of their mouthparts can create superficial skin lesions and ocular irritation and damage. The threshold of greater than 15 flies per face is generally accepted, and cattle with infestations of 20 or more flies on the face spend less time grazing and exhibit avoidance behavior.[21,22]

The face fly is the mechanical vector of *Moraxella bovis*, causing infectious bovine keratoconjunctivitis (IBK) or pinkeye. As fly feeding increases and cattle exhibit more defensive behaviors, the spread of IBK is augmented. The face fly serves as the intermediate host of *Thelazia* eyeworms, the causative agent of thelaziasis. Ectoparasiticides to aid in the control of the adults are often used in feed additives and are an effective means of preventing heavy infestations.

Mosquitoes

The adult females of several mosquito species in the insect family Culicidae blood feed on cattle. Mosquito larvae develop in many aquatic environments including ditches, ponds, open containers, tree holes, and flood-irrigated pastures. Blood feeding by female mosquitoes decreases milk production and weight gains.[23] Massive mosquito attacks can suffocate cattle and result in death.

Mosquito biting activity is mostly crepuscular or nocturnal, but some species will blood feed during the day.[24] Mosquitoes are vectors of pathogens that affect cattle, some of which are zoonotic, including Rift Valley fever virus, which has caused outbreaks in several African countries and in the Arabian Peninsula. Breeding-site management and the use of products targeting larvae prevent the local buildup of large mosquito populations. Ectoparasiticides, including those with repellent activity, can be used to protect cattle from mosquito bites.

Black flies

The distribution around the world of black fly species of the family Simuliidae is determined by the presence of flowing water where the larvae develop. Herd health and productivity are affected when cattle are attacked by swarms of adult female black flies. Significant blood loss and exposure of the host, including cattle, to considerable amounts of bioactive salivary factors at feeding sites associated with persistent biting by swarms of black flies results in a syndrome called simuliotoxicosis. Cattle can die in large numbers from severe blood loss in areas where population explosions of black flies occur.[25]

Black flies are vectors of vesicular stomatitis virus–New Jersey in North America, and filarial nematodes causing bovine onchocerciasis in various parts of the world. The microfilaria of *Onchocerca lienalis* infect the umbilical region of cattle, where feeding black flies acquire the nematode for transmission to other susceptible hosts. This parasitic nematode is suspected to cause zoonotic ocular onchocerciasis.

In large geographic areas where black flies are problematic, engineered manipulation of stream flow is an effective management tool. Treating the larval habitat with *Bacillus thuriengiensis israelensis* is an effective means of controlling local populations. Additional protection can be afforded by treating cattle with ectoparasiticides, which have repellent activity. In the presence of black fly swarms, ruminants should be provided shelter in stables or barns to relieve cattle from heavy black fly attack, and in extreme cases thorough coverage spraying with an ectoparasiticide can prevent mortality caused by simuliotoxicosis.

Tabanids

Tabanidae is the family of flies that includes several species in the genera *Tabanus* and *Hybomitra* commonly known as horse flies, and deer fly species in the genus *Chrysops*. The vermiform larvae develop in aquatic or semiaquatic environments where they prey on other insects or feed on decaying organic matter depending on the species. Adults are most abundant in open areas along the edge of woods and only the females are hematophagous, which results in persistent attacks on cattle.[26] Horse flies inflict painful bites to take a blood meal, in part caused by the action of their cutting-lapping mouthparts.

Blood-feeding activity by tabanids can alter daily cattle movement patterns and influence herd structure. As strong fliers and painful biters that are frequently interrupted during blood feeding, tabanids are efficient mechanical vectors of pathogens given their tendency to return to the same host or attempt to feed on another host nearby.[27] Traps and repellent ectoparasiticides can be used for tabanid control. However, local conditions and seasonal phenology can make it challenging to manage large tabanid populations.

Biting midges

In contrast to their tiny size, biting midge species in the *Culicoides* genus of the Ceratopogonidae family are of considerable economic impact on cattle health and production worldwide. The adult females are hematophagous, feeding from blood in a pool formed by the scissor-like action of their mouthparts that lacerates the skin. Larvae hatching from the eggs laid by the females in semiaquatic or aquatic environments rich in organic matter feed on the environmental microbiota to develop and continue the life cycle. Adults are minute, measuring ~2 mm in body length and difficult to detect until they inflict their painful bite.

Bluetongue and epizootic hemorrhagic disease viruses are economically important groups of arboviruses transmitted by *Culicoides* spp. that affect cattle in several parts of the world.[28] Some parasitic nematode and protozoan species are suspected to be transmitted to cattle by biting midges. *Culicoides* spp. are among the group of biting flies incriminated as vectors of vesicular stomatitis viruses in the Americas. Vector control remains the primary approach to attempt the interruption of transmission of *Culicoides*-borne bluetongue and epizootic hemorrhagic disease viruses to cattle in the absence of commercial vaccines against these arboviruses. Although challenging, environmental management to prevent breeding sites is an effective way to prevent large biting midge populations. Ectoparasiticide treatment aids in the control of biting midges.

Sand flies

Several species of Old World sand flies in the genus *Phlebotomus* and New World sand flies in the genus *Lutzomyia* of the family Psychodidae are ectoparasites of cattle in tropical and subtropical regions of the world. Adult flies are characteristically small insects <5 mm in length and brown to yellow in color, with hairy wings and bodies. Gravid female sand flies lay their eggs in humid terrestrial habitats with highly organic soils including leaf litter, animal burrows, barns, livestock pens, and shelters where decomposing cattle manure may accumulate. The recently emerged adults rest near the larval site until old enough to seek food. Being weak fliers, adult females disperse through a series of short hopping flights to find a host.[29]

Females will take blood meals from a variety of vertebrate hosts including cattle. Feeding activity can distress cattle, resulting in avoidance behaviors leading to decreased productivity. In addition to skin irritation from their bite, some *Lutzomyia* species are vectors of vesiculoviruses in the Rhabdoviridae family, including vesicular stomatitis viruses.[30] Protection of cattle from nuisance and hematophagy by sand flies must be practiced because breeding-source reduction for population control is challenging. Repellent ectoparasiticides can be used to control adult sand flies attacking cattle.

Tsetse flies

Tsetse fly species in the genus *Glossina* are of great economic importance as ectoparasites and vectors of pathogens that affect cattle health in a significant portion of sub-Saharan Africa spanning savanna, forest, and riverine ecosystems. Tsetse flies transmit *Trypanosoma* spp. causing African animal trypanosomiasis, or nagana, in cattle and other domestic animals. Some of these fly ectoparasites are of One Health relevance because they are also cyclical vectors of trypanosomes causing human African trypanosomiasis or sleeping sickness. African animal trypanosomiasis is a major impediment to the development of cattle production in Africa, where the disease is endemic.[31] Male and female tsetse flies are obligate blood feeders. Adenotrophic viviparity is a unique reproductive mode evolved by tsetse flies whereby maternal nourishment of the progeny is provided by glandular secretions within viviparous females, which is followed by live birth.

Tsetse flies can detect moving cattle 180 m away, attracted to host odors from 100 m, and disperse approximately 1 km per day.[4] These ecologic characteristics have influenced the development of control methods targeting the adult stage. Area-wide integrated pest management has been adapted, taking a phase-conditional approach to control tsetse flies in Africa.

Myiasis-causing flies

Myiasis is an infestation with the immature stages, generally referred to as maggots, of several fly species that feed on living or necrotic tissue of a live animal to develop and complete their life cycle. Most myiasis-producing fly species make up the superfamilies Muscoidea and Oestroidea. Members of the Calliphoridae (blow flies) and Sarcophagidae (flesh flies) are generally some of the most damaging to cattle. The winged adult females do not bite but are opportunistic and generally exploit open wounds in cattle produced by common farm practices, including branding, dehorning, and castration, to lay their eggs from which the maggots emerge. They are also a nuisance and can induce cattle to injure themselves.

The list of notifiable diseases by the World Organization for Animal Health includes infestation with the invasive New World screwworm (*Cochliomyia hominivorax*) and Old World screwworm (*Chrysomya bezziana*).[3] These myiases are of One Health importance because they can affect warm-blooded animals including humans, cattle, and other domesticated animal and wildlife species. When a myiasis is left untreated it generally results in host mortality. New World and Old World screwworms cause millions of dollars in loss annually for cattle producers wherever these pests remain endemic. Experiences eradicating the New World screwworm from North and Central America applying the sterile insect technique, followed by elimination of outbreaks first in Libya starting in the late 1980s and then one occurring in Florida in 2016, are testament to the scientific and technical complexities of area-wide efforts to protect cattle from high-consequence foreign livestock pests requiring national and international multiagency coordination through public-private partnerships.[32] In endemic areas, ectoparasiticides can be applied in several ways to treat myiasis in cattle and other domestic animals.

Economically important fly species in the family Oestridae causing myiasis in cattle include *Hypoderma lineatum*, also known as the common cattle grub, *Hypoderma bovis* or the northern cattle grub, and *Dermatobia hominis*, commonly called the torsalo or human bot fly. The cutaneous ulcer caused by the developing oestrid larva, or bot, appears as an open cyst termed a warble—hence the name warble flies. Cattle bots are also called grubs. Adult flies have a bumblebee-like appearance and are commonly known as heel flies or gadflies. Cattle grubs are found on all continents of the northern hemisphere, whereas *D hominis* affects cattle in tropical and subtropical regions of the Americas.

Frantic behavior by cattle to avoid hovering female grub flies attempting to lay their eggs on them, known as gadding, is observed generally in response to *H bovis*. This can result in reduced weight gains, lowered weaning weights, and reduced milk production. After burrowing into the skin, larvae then translocate to development sites in the host and migrate to superficial tissue, where the warble is formed to eventually drop off through the exit pore. Dropped larvae pupate in the ground to complete the life cycle. In addition to tissue damage, warbles diminish the value of hides from infested cattle. Macrocyclic lactones can be used to control cattle grubs by treating in autumn and spring.[33] However, ensure treatment is avoided when *H lineatum* and *H bovis* grubs cluster along the esophagus and the spinal column, respectively. Otherwise components leaking from dead grubs can trigger respiratory distress, paralysis, and shock in treated cattle.

Lice

Lice, representing the insect order Phthiraptera, are relatively small (≤2.5–3.0 mm) with a dorsoventrally flattened body, and are morphologically divided into sucking and chewing groups. *Bovicola bovis*, commonly known as the cattle biting louse, is the chewing louse associated with cattle. The main species of cattle sucking lice are: *Haematopinus eurysternus*, or short-nosed cattle louse; *Haematopinus quadripertusus*, or cattle tail louse; *Linognathus vituli*, or long-nosed cattle louse; and *Solenopotes capillatus*, or little blue cattle louse. Lice complete all the stages of their life cycle on the host. Sucking lice are hematophagous and typically have a narrow, pointed head, whereas biting lice feed on skin and hair and have a broad head. Unlike the cattle tail louse that can be more abundant in the summer, burdens are low on cattle with other louse species during the summer months but typically increase during the winter and early spring.[10]

Heavy lice infestation is associated with signs of pruritus, can cause severe anemia, and may also be an indicator of other underlying conditions in affected cattle. Infested animals will scratch and rub the skin, trying to relieve themselves of the irritation.[34] Dip or spray ectoparasiticide treatment of cattle can control lice infestations. Macrocyclic lactones are also used but are more effective against sucking lice than chewing lice. However, they are inactive against lice eggs, or nits, so additional treatments may be required to ensure that newly hatched nymphs are killed. Ectoparasiticide application can be part of the schedule to treat lice and other parasites when cattle are prepared for the winter months.

Mites

Mites are arachnids in the subclass Acari and are approximately 1 mm long. Acariasis describes an infestation with mites that complete their life cycle on the host by feeding on the skin and its secretions or by ingesting fluids oozing from lesions inflicted with their mouthparts.[35] Severe dermatitis caused by cutaneous acariasis is called mange. Cattle can be affected by 5 types of mange according to the mite species causing it. Ectoparasite biology and ecology influence the clinical picture of mange—for example, whether the mite burrows into the skin or whether it inhabits the hair follicles or sebaceous glands.

Sarcoptic mange, or scabies, caused by *Sarcoptes scabiei* var. *bovis*, a skin-burrowing mite, is highly contagious and zoonotic, causing intense pruritus and papules. If left untreated the skin thickens, forming large folds, and the entire outer body surface can be affected in a few weeks. *Psoroptes ovis* is a nonburrowing mite causing psoroptic mange that pierces the skin to imbibe the fluids emanating from the wound, which can form a thick crust. Exudative dermatitis, alopecia, and intense pruritus characterize psoroptic mange that can kill untreated calves.[36] *Chorioptes bovis*, the chorioptic mange mite, typically inhabits the skin surface of the tail and lower legs and therefore the condition may be called tail, foot, or leg mange. Although *C bovis* can survive off the host for up to 3 weeks, chorioptic mange is relatively less pathogenic to cattle than sarcoptic or psoroptic mange. *Demodex bovis* is the most common of 3 *Demodex* species that can infest the hair follicles and sebaceous glands of cattle where they feed on sebum, oozing plasma, and epidermal debris. Cases of demodectic mange occur frequently during late winter and early spring; lesions are susceptible to secondary bacterial infection. Young cattle appear to be more susceptible to heavy infestations, which can also result in hide damage. The cattle itch mite, *Psorobia bos*, can cause psorergatic mange of limited pathogenicity. Cases involve slight skin thickening and some scaling where low-grade pruritus can occur. Cattle are also susceptible to infestation by the ear mites *Raillietia auris* and *Raillietia flechtmanni*. In addition to subclinical otitis, ear mite cases include the accumulation of wax and the involvement of neurologic symptoms. Early detection and diagnosis using the proper sampling method are important for the control of infestations and prevention of mite transmission to the herd.

Ticks

Ticks are larger and close relatives of the mites in the arachnid subclass Acari. Their obligate blood-feeding habit requires that ticks subvert innate and acquired host immune responses through bioactive factors secreted in their saliva to remain attached at the bite site for days at a time, sometimes on multiple occasions parasitizing the same host.[37] Besides having direct effects on their hosts, ticks are also the most important parasitic arthropod group as vectors of pathogens affecting domestic animals and wildlife. Ticks are remarkable in their vector ability to transmit diverse pathogens including protozoa, bacteria, and viruses. Tick-borne pathogens are the cause of transboundary cattle diseases. Bovine babesiosis, anaplasmosis, theileriosis, and heartwater are among the diseases listed as notifiable by the World Organization for Animal Health caused by tick-borne pathogens that affect cattle.[3]

Ticks of veterinary relevance belong to the family Ixodidae, also known as hard ticks, and the family Argasidae, which are known as soft ticks. Ixodid tick species in the genera *Ixodes*, *Dermacentor*, *Amblyomma*, *Haemophysalis*, *Hyalomma*, and *Rhipicephalus* affect cattle health and production around the world. Depending on the species, ixodid ticks will parasitize 1, 2, or 3 hosts to complete the larval, nymphal, and adult stages. Mated adult females drop off the host to lay their eggs on the ground. Compared with ixodid ticks, argasid ticks are faster feeders and nidicolous, living in or near shelters used by their hosts. Argasid genera with species that are ectoparasites of cattle include *Ornithodoros* and *Otobius*.

The importance of ticks in animal agriculture is reflected in efforts by different countries spanning more than a century trying to control or eradicate ticks and tick-borne diseases. The southern cattle fever tick, *Rhipicephalus microplus*, is considered to be the most economically important ectoparasite of livestock worldwide.[5] This invasive tick species is the vector of *B bovis* and *Bovicola bigemina*, causing babesiosis in cattle in tropical and subtropical parts of the world. Estimates place bovine babesiosis at the top of arthropod-borne diseases causing financial losses for cattle producers.[37] As a result of the intense use of ectoparasiticides against it, *R microplus* is ranked sixth among the most resistant arthropods globally. The detection of *Haemaphysalis longicornis* in several states of the United States by 2019 is an emerging disease threat for cattle, other domesticated animals, wildlife, and humans in North America, which highlights the One Health importance of invasive ticks and associated tick-borne diseases.[38] Several research groups are investigating alternative technologies that could ease the dependence on ectoparasiticide treatments to deal with the problem of ticks and tick-borne diseases of cattle.

ADVANCING INTEGRATED ECTOPARASITE MANAGEMENT

Compounds from several chemical classes with insecticidal and acaricidal activities are marketed as cattle ectoparasiticides.[39] The macrocyclic lactones represent another important group of chemicals that because of their mode of action also have activity against endoparasites and thus are defined as endectocidal. Their administration requires attention because of the relative susceptibility of endoparasites and ectoparasites. This, for example, can result in the exposure of ticks infesting treated cattle to a sublethal dose when the macrocyclic lactone product is applied as indicated on the label for an endoparasite infection, which in this scenario will select for resistance in that tick population.[40] In addition, it is unlawful to use an ectoparasiticide product in a manner inconsistent with the label instructions. Farmers should consult a veterinarian, extension agent, or local veterinary entomologist to obtain information on products authorized for use in their area to ensure they are handled safely. Overuse and misuse of ectoparasiticides selects for resistance to the veterinary drug in the product and can be hazardous to animals, food, and the environment.

The combined use of emerging technologies is being tested. However, habitat reduction and sanitation must remain key management goals. Where commercially available, the integrated use of antitick vaccines can reduce the frequency of ectoparasiticide applications and diminish the total amount of product used.[41] Research on vaccines against other cattle ectoparasites such as the horn fly must be resumed now that its genome is sequenced and bioinformatic tools that can accelerate the development process are available.[42] Botanic ectoparasiticides that could be used to treat cattle continue to be commercialized. The combined use of biopesticides, such as acaropathogenic fungi, with ectoparasiticides can result in synergistic effects to control cattle tick populations resistant to the widely applied pyrethroid ectoparasiticides. Additional research in this area is facilitated by testing samples available at entomopathogenic fungal collections. An example is the US Department of Agriculture Agricultural Research Service collection, which maintains more than 130,000 isolates and provides information and taxonomic services on the characterization and identification of fungi.[43] This collection contains 188 records of fungi pathogenic to mosquitoes, 91 records for muscoid flies, and 47 records for black flies. Continued research is needed to assess the integrated use of traps to manage biting and nuisance fly populations.[44,45] The strategic use of barriers impregnated with ectoparasiticides for fly control and foot baths to manage tick infestations enhances integrated strategies.[46]

Organic cattle farming continues to grow in some parts of the world. Methods to control cattle ectoparasites in organic farms have been developed.[47] Preventive practices are also paramount for the management of ectoparasites in organic operations.[48] These practices include selecting species and types of cattle suitable for local conditions and resistant to endemic parasites, providing adequate nutrition, establishing housing with proper pasture conditions, observing sanitation practices to minimize predisposing conditions for ectoparasitoses, and keeping stress low.[49] Natural enemies serve as a focal point for the biological control of pests. Naturally occurring populations of parasitoids are amenable to augmentative releases, which significantly enhance the biological control effort for cattle production. Parasitoids prey on fly pupa wherein their offspring develop.

Research on livestock genomics is being applied to advance the breeding of cattle resistant to ectoparasites, especially ticks. Likewise, biotechnology-enhanced sterile insect technique approaches are being enabled by advances in ectoparasite genomic science.[50] These include progress with genetic pest management for ectoparasites of cattle. For example, RNA interference (RNAi) affords protection by silencing mRNA, resulting in the suppression of critical gene functions. RNAi technology is being developed for the control of bluetongue viruses in *C sonorensis*.[51] Lethal gene and gene drive technology could be developed for cattle ectoparasite management.[52] Lethal gene technology demonstrated yellow fever mosquito control in small studies and on islands without the use of insecticides. Gene editing using CRISPR (clustered regularly interspaced short palindromic repeats)/Cas9 relies on the insertion of another sequence into the genome of the male. Once introduced into the population all offspring inherit the altered gene sequence, and within a few generations the population becomes dominated by the transgene constructs, eliminating or neutralizing the population.[53]

SUMMARY

Diverse groups of ectoparasitic arthropods cause significant morbidity and mortality in cattle globally. Ectoparasites affect cattle health and production through the different ways that they infest their hosts to obtain nutrients and complete their life cycle, and as vectors of pathogens. Some ectoparasites and ectoparasite-borne pathogens affecting cattle are listed by the World Organization for Animal Health as notifiable. Hematophagous flies, myiasis-causing flies, lice, mites, and ticks are the most important groups of cattle ectoparasites. Several of these ectoparasitic species are of One Health relevance because of their impact on public health. The intense use of ectoparasiticides to treat infestations in cattle has selected for ectoparasite populations that are resistant to this treatment method. Although ectoparasiticide resistance is prevalent in most of the important arthropods infesting cattle, the alternatives currently available for cattle producers are limited. This limitation of cost-effective control measures should be evaluated in relation to current cattle-management systems. Approaches integrating the use of different technologies are required to manage cattle ectoparasites effectively while addressing societal expectations regarding food safety and environmental health.[54] Assessing the status of coparasitism with ectoparasites and endoparasites in cattle across agroecosystems is critical for the advancement of integrated parasite management.

DISCLOSURE

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