Journal of Entomology and Zoology Studies 2017; 5(2): 808-813

Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(2): 808-813

Received: 14-01-2017
Accepted: 15-02-2017

Pavan Kumar Yadav
Division of Biochemistry, Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh, India

Shafiya Imtiaz Rafiqi
Division of Veterinary Parasitology, Indian Veterinary Research Institute, Izatnagar, Bareilly-243 122 Uttar Pradesh, India

Padma Nibash Panigrahi
Division of Veterinary Medicine, Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh, India

Dinesh Kumar
Division of Animal Nutrition, Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh, India

Rakesh Kumar
Division of Veterinary Pathology, Indian Veterinary Research Institute, Izatnagar, Bareilly-243122, Uttar Pradesh, India

Saroj Kumar
Division of Veterinary Parasitology, Indian Veterinary Research Institute, Izatnagar, Bareilly-243 122 Uttar Pradesh, India

Correspondence
Saroj Kumar
Division of Veterinary Parasitology, Indian Veterinary Research Institute, Izatnagar, Bareilly-243 122 Uttar Pradesh, India

Recent trends in control of ectoparasites: A review

Pavan Kumar Yadav, Shafiya Imtiaz Rafiqi, Padma Nibash Panigrahi, Dinesh Kumar, Rakesh Kumar and Saroj Kumar

Abstract
Parasitic diseases account for important health hazard in man and animal in tropical countries like India. Ectoparasites infestation causes a serious loss in health and economy every year in India. They can cause annoyance, irritation, skin infection, anaemia, tick fever as well as act as a vector for various devastating diseases. Thus, ectoparasites control is a matter of great concern. Various chemical acaricides have been prescribed since last 50 years. But, their residual effect, adverse side effect, and resistance are a matter of concern now days. Hence, biological control of ectoparasites gains prime importance in many parasite control program. The present review critically analyzes the different methods for controlling the ectoparasites with special emphasis on the newer approach of the biological, immunological, genetic and pheromone method.

Keywords: Acaricides, biological control, chemical control, ectoparasites

1. Introduction

India, as a tropical country, has a wide range of climatic zones, which make it vulnerable to a diverse range of parasites of veterinary and medical importance. Parasitic diseases pose a major health hazard in man and animal around the globe especially in tropical countries like India [1]. Arthropods, a diverse assemblage of invertebrates, consist of nearly 80% of all known animal species and occupying almost every known habitat. Among the great variety of arthropods species and lifestyle that they display, a relatively small number have developed the ability to live directly at the expense of another animal (host). Arthropods parasitize a wide range of hosts including the other arthropods. Most of the arthropods live in or burrow into the surface of their host epidermis while some of them may parasitize in the host body. In some cases they highly host specific and in some instances, they can exist only in a defined area of the host body [2]. As a result of their activity ectoparasites may have a variety of direct and indirect effect on their host. Direct injury may be caused due to blood loss (anaemia and debilitation) by sucking blood while indirect effects may be infestation of living tissue (myasis) by dipterian fly larvae, skin inflammation, pruritus and alopecia by mange mite, toxic and allergic responses by ticks, gadding by warble fly, annoyance and social boredom by large population of flies [3]. In addition to these effects, the most important role of ectoparasite is disease transmission as vectors of pathogens like bacteria, virus, protozoa and helminths. Ectoparasite either may act as a mechanical or biological vector [2]. The direct damage caused by most arthropods is directly proportional to their abundance. This doesn’t hold true in the case of disease vector, where the even very low number of the infected vector may cause considerable economic and welfare problems [3].

Arthropods play important role in their relationship with man and animals. With the advent of scientific knowledge, their role has become clear and rapidly developing medical and veterinary sciences are trying to control their damage [4]. However the problem is coming out much graver than what had been perceived by scientists, in the way they adapt to new environment and become very rapidly resistant to insecticides. This battle between man and vector goes on and will continue in the future also [4]. Despite advances in alternative methods of vector control, the rural farmers are largely dependent on chemicals for arthropod control. However, the sole reliance on chemicals is in some jeopardy because of food safety, environmental concern, insecticide resistance and lack of the commercial interest in the development of new compound [5]. The cost of developing a new drug was estimated at an average of US $230 million/compound [6], which may be manifold today.

The scientists are working on a non-chemical method of the vector control like exploitation of natural resistance, vaccine induced resistance and biological control. With the advent of recombinant DNA technology not only the creation of new generation of bio pesticide is possible but also the control of insect vector [7]. It is now possible to modify a genome and create the transgenic vector with an objective of debilitating the individuals by way of reduced reproductive potential or vector competence and increase the vector susceptibility to existing measures [8]. The control of the ectoparasites of veterinary importance, objective should be to reduce the population below the economic threshold so that control costs are less than the anticipated benefit. The principles of insect control are correct identification of pest species, accumulation of scientific biological information related to life history and habitat of the pest species, determination of the magnitude of damage been done by the pest, estimation of amount of which could be spent profitably in reducing the damage and determination and execution of the most efficient approach to the pest control [9].

2. Current control methods of ectoparasites

2.1 Management control

It includes removal of dung and manure and provision of proper drainage to reduce the fly population by targeting their breeding places. Manure can be stacked in large heaps where the heat of the fermentation will kill the developing stage of the flies [10]. Insecticides applied over the surface of minor heap may prove beneficial to reduce the number of ticks. Vegetation should be minimized by heavy grazing and burning of weeds, periodical plowing of grazing ground, cultivation of land, which will make the environment less favourable for survival of ticks and their developmental stages [11]. In the absence of definitive pasture, ticks in India have developed homing instinct; they get shelter and develop in cracks and crevices of animal sheds, which must be minimized. The animals should be groomed frequently. There should be the provision of wire mesh or nets around animal houses. Use of fly repellent and fly traps should be encouraged [10, 11].

2.2 Chemical control

It is most practiced method throughout the globe in spite of several problems like development of resistance, public concern in terms of residue in food, environment pollution. Several types of chemicals like carbamate (aldicarb, but a carb, propoxur), chlorinated hydrocarbon (DDT, BHC, aldrin), organophosphate (Diazinon, malathion), synthetic pyrethroids (cypermethrin, deltamethrin, permethrin), formadidine (amitraz) and macrocyclic lactones (ivermectin, melbemycin, doramectine) are in use [12]. Among all these synthetic pyrethroid has been proven better residual activity against a broad spectrum of pest species and efficiency at lower dose rate. However, macrocyclic lactones are used widely. Recently some of the herbal products like neem seed oil, tea tree oil, and another plant extract etc. have also been tried against the important ectoparasites [13, 14]. A number of ectoparasites have developed resistance to various groups of insecticides. Multiple resistances have also been observed. Indiscriminate use of insecticide may result into undesirable effect on targeted species because of their wide range of action and long persistence in the environment thus a poising danger to the ecosystem [15]. It also results in an unacceptable level of chemical residue in food stock like meat and meat products, which are considered toxic to man. Development of resistance in ectoparasites necessitates the use of newer chemical thus imposing a never ending and continual increase in cost burden [15].

Insecticides and acaricides can be applied by many different methods. These includes topical sprays, hand and powdered applied dust, dips, pour on, spot on, feed additives, injectable, back rubber, tail bands and ear tags. Some species of insects can be controlled away from host cypermethrin, deltamethrin, permethrin by using mist or fog of insecticides, baits, larvicidal and residual spray. The methodology of choice depends upon the target insects, labour and current management practice and cost efficiency of the treatment proposed [16].

2.3 Biological control

Biological control consists of use, manipulation, and exploitation of one life form to suppress the population of another. The advantages of bio-pesticides are a narrow spectrum of activity due to this they kill only targeted insect [17]. Their impact on the insect is gradual, which kills about 90-100% of the target only, and also safe for the beneficial insect. Bio-pesticides are economical because of only two to three applications are required and also resistance doesn't develop against bio-pesticides. They are biodegradable, no residues and non-polluting. Biopesticides are very safe for livestock, fishes, birds as well as human beings [17]. Bio-pesticide origin may be from plants like grasses, zoological origin like bacteria, fungus, virus, and parasite and predator.

Insect growth regulators block or regulate the growth of insect. They also produce sterility, ovicidal effect, reduce reproduction, and reduce emergence and deformity due to the mortality and disturbed metamorphosis [18]. These may be of chemical origin (chryomizine, methoprim, chymoprim) or plant origin (azarone, azadirachrin). Bacteria like *Bacillus sphaericus* and *Bacillus thuringiensis* are among the most widely used antagonistic and have been developed against the mosquitoes, culicoides and tick [18]. *Bacillus thuringiensis* (Bt) is gram-positive, spore-forming bacteria with entomopathogenic properties. Bt produces insecticidal protein during sporulation phase as the parasporal crystals, predominantly comprised of one or more proteins (Cry and Cyt toxins), also known as δ-endotoxins [18]. Cry proteins are parasporal inclusion proteins of *Bacillus thuringiensis* that exhibit an experimentally verifiable toxic effect to a target organism. These toxins are highly specific to their target insect, and are innocuous to livestock, plants, and humans, and are completely biodegradable. Therefore, Br is an alternative for the control of insect pests in agriculture and important human disease vectors [18]. Fungi can multiply and grow on the insect cuticle causing damage and mortality of insects. *Beauveria bassiana* and *Metaregium anisopeliae* have been found to cause mortality in some ticks and insects. *M. Anisopheles* have been successfully tried against the *Boophilus microplus* and is giving encouraging results [19, 20]. Parasite such as *Hunterellus hookeri* is the natural enemy of the tick. Fire ants predate on the ambylomma tick and the bird like- *Bubulcus africanus* and *B. erythrhynchus* destroy large number of ticks. *Gamusia affinis* predates on larvae of mosquito. Similarly, guppy fish has been used against the culicoides and mosquito. Certain plants like *Anropogona gayanius* and *Melinus minutiflora* have tick repellent property. Various extract of *Stylosanthes* has been found to have acaricidal property [20].

2.4 Immunological control

Vaccines have several advantages over conventional chemical acaricides. They offer sustained action, usually free of residues, intrinsically specific, cheaper and resistance is unlikely to develop. Several antigens derived from ticks have been tested as vaccine candidates. Various experiments lead to the isolation and identification of concealed BM86 antigen that has been expressed in *E. coli* and Pichia *pastoris* to produce recombinant tick vaccine Tick GARD and Gavac respectively against *B. microplus* [21]. The second generation *B. microplus* vaccine TickGARD^{PLUS} has also been developed which provides higher and long lasting immunity [22]. Another recombinant antigen Bm95 isolated form *B. microplus* tick has been used for control of resistant ticks along with Bm86 and it is suggested it could be a universal antigen to protect against infection by *B. microplus* strain from different geographical areas [23, 24].

Immunization of the animal with synthetic peptides derived from Bm86 glycoprotein of *B. microplus* gut revealed that synthetic peptide is effective in tick control [24]. Recently, the study pertaining to dual action anti-tick vaccine targeting exposed and concealed antigen has shown encouraging results. The ticks fed on immunized animal induced a continuous inflammatory response and increased antibody titre, while engorged ticks died following damage of their mid-gut [26]. Monoclonal antibodies against *Haemophyselis longiconrnis* mid-gut protein have been produced and characterized [27]. Vaccines against sheep blow fly *Lucillia cuprina* are under development, where a series of proteins have been isolated from peritrophic membrane and shown to be effective antigens [28]. Encouraging result has been obtained in the case of *chrysomia bezziana* [29]. In Hypoderma, hypodermin A has shown good efficacy and same has been cloned successfully and expressed in *E.coli*. In the excretory-secretory product of *oestrus ovis* larvae six major serine proteases have been identified that may be potential vaccine targets [30]. The attempts towards concealed antigen approach have focused upon the peritrophic membrane of *Haematobia irritant* and other flies [31]. Immunization trials with concealed antigen from the mid gut of lice and fleas have also been carried out [32].

2.5 Pheromone-mediated control

Certain pheromones are important in mating of arthropods and attraction of female to susceptible host. Certain aggregation attachment pheromones (AAP) enhance the aggregation or attachment of unfed nymph and adult tick [33]. AAP can be used in controlled strategies by incorporating the pheromone tick compounds into plastic tag infiltrated with insecticides. Tag release pheromone slowly attracts tick, acting as 'tick decoys' [33].

2.6 Sterile insect technique

Sterile insect technique is a method of biological control, whereby large numbers of sterile insects are released [34]. The released insects are generally male as it is the female that causes the damage, usually by laying eggs in the crop, or, in the case of mosquitoes, taking a blood meal from humans. The sterile males will compete with wild males for female insects. If the female mates with a sterile male then it will have no offspring, thus reducing the next generation population. Repeated release of sterile insects can eventually wipe out a population, though it is often more useful to consider controlling the population rather than eradicating it [34]. This technique has been successfully been used to eradicate the Screw-worm fly (*Cochliomyia hominivorax*) in areas of North America. There have also been many successes in controlling species of fruit flies, most particularly the Mexican fruit fly (*Anastrepha ludens*), and the Med fly (*Ceratitis capitata*) [34]. The sterilization of insects with radiation, which may be weakening the newly sterilized insects, if doses are not correctly applied, makes them less able to compete with wild males [34].

2.6.1 Sterile fly for African trypanosomiasis

The African trypanosomiasis or sleeping sickness is a parasitic disease in humans, caused by Trypanosoma which is transmitted by the Tsetse fly; the disease is endemic in some part of Sub-Saharan Africa [35]. A study on the tsetse flies shows that females generally only mate once in their lifetime and very rarely mate a second time. Once female fly has mated, she can produce continual offspring throughout her life [35]. The sterile fly is an innovative solution to the problem of the African trypanosomiasis. Specially bred male tsetse flies are sterilized through irradiation process. After sterilization male flies are then released into regions where sleeping sickness is prevalent, which mate with the females [35]. Because the male is sterile, and the females mate only once, the population of Tsetse flies in the affected area will reduced. Several studies have proved that this process has been very effective in preventing sleeping sickness in people who live in these areas [35].

2.6.2 Success stories

Cochliomyia hominivorax (Screwworm fly) has been eradicated from USA, Libya, and Mexico. Anastrepha ludens (Mexican fruit fly) has been eradicated from several parts of northern Mexico [36]. Tsetse fly has been eradicated from Zanzibar, *Ceratitis capitata* Wiedemann (Medfly) eradicated from northern part of Chile, southern part of Mexico and southern part of Peru. *Bactrocera cucurbitae* Coquillett (Melon fly) has been eradicated from Japan [36].

2.6.3 Current targets

The following mosquitoes are currently targeted for their control like anopheles mosquito which acts as malaria vector, eg. *Anopheles arabiensis*, sleeping sickness vector, Tsetse fly (*Glossina spp*), vectors for filariasis, dengue and yellow fever aedes mosquitoes [37].

2.6.4 Drawbacks

As for insecticide treatment, the repeated treatment is sometimes required to suppress the population before the use of sterile insects. Sex separation may be difficult for some species although this can be easily performed on screw worm and med fly. Radiation treatment in some cases, over doses, affects the health of males and sterilized male in such cases may not be compete with wild male for mating with females. The technique is species specific, for instance; there are 22 species of Tsetse fly in Africa, and the technique must be implemented separately for each species. The standard operating procedures of mass rearing and irradiation [38] do not leave room for mistakes. Since fifties, when SIT was first used as a means for insect control, several failures have occurred at several places of the world where non-sterilized artificial produced insects were released before the problem was spotted. Application to large areas should be long lasting, otherwise migration of wild insects from outside the control area could repopulate. And also the major disadvantage to this technique is that the cost of producing such a large number of sterile insects is often prohibitive in poor countries.

2.7 Genetic modification

Genetically modified insects called Release of Insects carrying a Dominant Lethal (RIDL) have been developed by a company known as Oxitec using recombinant DNA technology [39]. The method is based on insertion of a repressible "Dominant Lethal" gene into the insect's genome. The inserted gene kills the insects but the gene can be repressed by an external additive, which allows the insects to be reared in manufacturing facilities. This external additive is most commonly given orally and so can be an insect feed additive [39]. In the insect the reported gene can also be given as genetic markers, such as fluorescence, that make monitoring the progress of eradication easier [40]. There are many RIDLs available, but the most advanced forms are female-specific dominant lethal gene. This form avoids the requirements for a separate sex separation step, as the repressor can be withdrawn from the final stage of insect rearing, leaving only males. Then these males are then released in large numbers into the affected areas. The released males are not sterile, but when female mates with these males producing offspring, having the dominant lethal gene expressed, they die [40]. The population of females in the wild will therefore decline, leading to the overall decline in population. Using RIDL technique, the males will not have to be sterilized by radiation before release; male has to be making healthier when they need to compete with the wild males for mates [40, 41].

2.7.1 Genetic control

The genetic resistance is mostly lifelong and heritable. The resistance vary between individuals however; expression can be affected by external factors such as nutrition and stress [42]. African taurine breeds, and the South American criollo breeds are a rich resource from which to identify specific breeds with high average resistance to particular tick species. Although there hasn't been any systematic attempt towards ranking the tropical breeds for resistance either to a single species or to multiple species of ticks, there are many evidences for tick resistant breeds [42]. The Brahman and Nelore have high resistance to both *Boophilus microplus* and *B. decoloratus*, and all Indian zebus may have high resistance to all *Boophilus* spp [42]. Resistances of the Brahman and Boran (East African zebu) are similar. However, the Brahman is less resistant to *B. decoloratus* than the Nguni (southern African sanga-*B. taurus*) and less resistant than Zimbabwean sanga to *Amblyomma hebraeum* [43]. Boran is less resistant to several species, including *Amblyomma variegatum* and *B. decoloratus* than is a related zebu, the Arusi. Borans and Brahmans are more resistant to *B. microplus* than are Tulis (southern African sanga-*B. taurus*) [43]. The Gobra zebu from West Africa has lower resistance to *A. variegatum* and *Hyalomma* spp. than the N'Dama (West African-*B. taurus*). There is considerable anecdotal evidence that some South American criollo breeds (*B. taurus*) may also have high resistance to *B. microplus* [43, 44]. Breeds that have been exposed to particular species of tick for a long period are likely to have evolution genes, each of minor effect, affecting resistance to that species. For zebu cattle breeds, resistance to *B. microplus* is due to polygenic effects [44]. While polygenic resistance will respond commonly to selection in breeds of moderate to high resistance, it is impractical to select for, or to introgress polygenic resistance into lowly resistant breeds. Australian scientists have successfully exploited the difference in susceptibility to parasite by developing the Belmont Adaptaur breed [45]. A major gene for *B. microplus* resistance has been identified in Belmont Adaptaur breed and this finding will enhance the use of host resistance in control of tick [46]. With the development of high regulation genetic linkage map of highly polymorphic satellite DNA makers, it is now feasible to identify chromosomal location for gene contributing to resistance. Such gene with a sufficiently large effect can be identified [47]. Integrated strategies for control of ectoparasites concerned with veterinary importance are already being implemented for selected insect species in many part of the world. Within the next decade, the integration of technologies for the management of arthropod pests will become the norm rather than the exception.

2.8 Integrated Pest Management (IPM)

The key concepts particularly important to this approach to pest management are use of two or more techniques, cost-effectiveness, control of pest populations (rather than individual pests) and environmental compatibility [48]. Within a modern IPM programme, technologies are applied systematically and deliberately (rather than randomly) to manage a problem in such a way that the procedures complement each other [48]. As the profit margins continually decrease, integrated control strategy should be cost-effective for the producer; for the strategy to be acceptable there must be a financial return on the investment. Within the IPM approach, the purpose is to reduce pest populations, not individual pests, up to acceptable tolerance level [48]. Finally, the integrated strategy should be compatible with the environment so that, in the future, the applied procedures do not cause environmental imbalance which are more detrimental than the original problem. Integrated pest control requires many technologies for incorporation into specific insect management systems. Individual components include new delivery systems and chemicals formulations, biological control, mechanical control, immunological control, genetic control, and regulatory control [49]. Computer simulation models based on a quantitative ecological database which is invaluable in devising and monitoring IPM program to controlling ectoparasites which affect poultry and livestock. IPM strategies have been developed for pests of veterinary importance, but finally these must be incorporated into total livestock production systems. For implementation the IPM, a number of major impediments must be overcome. These problems can best be solved by the vigorous technology transfer programme [49]. In addition to face-to-face meetings between extension workers and producers, and the implementation of IPM can be further encouraged at the producer group level meetings, through education of animal health professionals through the publication of articles in producer magazines, and by radio talk and television broadcasts to the agricultural sector. Research focusing on the development of environmentally compatible and cost-effective IPM systems is necessary for future progress [49].

3. Conclusion

Each of control strategies has limitations for high level sustainable control of ectoparasite. The management of insecticide resistance, strategic use of chemical and manipulation of host resistance, in combination with suppressing ectoparasite population are all important components as well as host breeding for increasing resistance. In IPM programme the chemical insecticides are used as a last resort due to their increased application cost and hazard associated with their use. Whenever used, they strive to maintain pest population below the level of causing injury to livestock. Further, the environmental consideration is fully undertaken and it's advised to use eco-friendly benign chemicals which are effective against the target species. In present scenario, IPM is important as it protects human health by minimizing toxic residues of chemicals that may produce cancer or neurological disorder, manage resistance in vector, conserve biodiversity comprising of beneficial pollinator parasite/predator insect, reduce environmental pollution, and avoid loss of export. In India huge losses are incurred in terms of export as 25% of Indian food product contain pesticide residue above the tolerance level.

4. Acknowledgement
We apologize to those researchers whose important work we were not able to cite and we also declare that we have no conflicts of interest.

5. References
1. Panigrahi PN, Gupta AR, Behera SK, Panda BSK, Patra RC, Mohanty BN *et al.* Evaluation of gastrointestinal helminths in canine population of Bhubaneswar, Odisha, India: a public health appraisal. Veterinary World. 2014a; 7(5):295-298.
2. Wall R, Shearer D. Veterinary entomology: Arthropod Ectoparasites of Veterinary Importance. Edn 1, Chapman and Hall, London, 1997, 439.
3. Wall RL, Shearer D. Veterinary Ectoparasites: Biology, Pathology and Control, Edn 2, Wiley-Blackwell, London, 2001, 304.
4. Institute of Medicine (US) Forum on Microbial Threats. Vector-Borne Diseases: Understanding the Environmental, Human Health, and Ecological Connections, Workshop Summary. Washington (DC): National Academies Press (US), 2008.
5. Pruett JH. Immunological control of arthropod ectoparasites- A review. International Journal for Parasitology. 1999; 29(1):25-32.
6. De Alva R. Creating new products for animal health. Edn 3, Seminario Internacional de Parasitología Animal, Acapulco, Mexico, 1995, 86-87.
7. Narayanan K. Role of Biotechnology in effective utilization of insect pathogens in integrated pest management programme in India. Aditya Book Pvt. Ltd., New Delhi, 1996, 153-196.
8. Miller LH, Sakai RK, Romans P, Gwadz RW, Kantoff P, Coon HG. Stable integration and expression of a bacterial gene in the mosquito *Anopheles gambiae*. Science. 1987; 237:779-781.
9. Knipling EF. The Basic Principles of Insect Population Suppression and Management. U.S. Department of Agriculture, 1979, 659.
10. Casida JE, Quistad GB. Golden Age of Insecticide Research: Past, Present, or Future? Annual Review of Entomology. 1998; 43(1):1-16.
11. Curtis CF, Jana-Kara B, Maxwell CA. Insecticide treated nets: impact on vector populations and relevance of initial intensity of transmission and pyrethroid resistance. Journal Vector Borne Disease. 2003; 40(1-2):1-8.
12. Maxwell CA, Msuya E, Sudi M, Njunwa KJ, Carneiro IA, Curtis CF. Effect of community-wide use of insecticide-treated nets for 3-4 years on malarial morbidity in Tanzania. Trop Med Int Health. 2002; 7(12):1003-8.
13. Panigrahi PN, Giri BN, Biswal S, Mohanty BN, Gupta AR, Patra RC. Acaricidal efficacy of aqueous and alcoholic extract of Cleistanthus collinus against Boophilus microplus of cattle. Indian Journal of Veterinary Medicine. 2014b; 35(I):15-19.
14. Abdel-Shafy S, Zayed AA. *In vitro* acaricidal effect of plant extract of neem seed oil (*Azadirachta indica*) on egg, immature, and adult stages of *Hyalomma anatolicum excavatum* (Ixodoidea: Ixodidae). Veterinary Parasitology. 2002; 106(1):89-96.
15. Graf JF, Gogolewsk RI, Leach-Bing N, Sabatini GA, Molento MB, Bordin EL *et al*. Tick control: an industry point of view. Parasitology. 2004; 129(S1):S427-S442.
16. Mondal DB, Sarma K, Saravanan M. Upcoming of the integrated tick control program of ruminants with special emphasis on livestock farming system in India. Ticks and Tick-borne Diseases. 2013; 4:1-10.
17. Hogsette JA. Management of ectoparasites with biological control organisms. International Journal of Parasitology. 1999; 29:147-151.
18. Bravo A, Gill SS, Soberon M. Mode of action of *Bacillus thuringiensis* Cry and Cyt toxins and their potential for insect control. Toxicon. 2007; 49(4):423-35.
19. Lezama-Gutiérrez R, Alatorre-Rosas R, Bojalil-Jaber LF, Molina-Ochoa J, Arenas-Vargas M, González-Ramírez M *et al*. Virulence of five entomopathogenic fungi (Hyphomycetes) against, Spodoptera frugiperda (Lepidoptera: Noctuidae) eggs and neonate larvae. Vedalia. 1996; 3:35-39.
20. Ment D, Gindin G, Rot A, Soroker V, Glazer I, Bare S *et al*. Novel Technique for Quantifying Adhesion of Metarhizium anisopliae Conidia to the Tick Cuticle. Applied and Environmental Microbiology. 2010; 3521-3528.
21. Rodriguez M, Rubiera R, Penichet ML. High level expression of the *B. microplus* Bm86 antigen in the yeast *Pichia pastoris* forming highly immunogenic particles for cattle. Journal of Biotechnology. 1994; 33:135-146.
22. Jonsson NN, Matschoss AL, Pepper P, Green PE, Albrec ht MS, Hungerford J. *et al*. Evaluation of tickGARD (PLUS), a novel vaccine against *Boophilus microplus*, in lactating Holstein-Friesian cows. Veterinary Parasitology. 2000; 88:275-285.
23. García-García JC, Montero C, Redondo M, Vargas M, Canales M, Boué O. *et al*. Control of ticks resistant to immunization with Bm86 in cattle vaccinated with the recombinant antigen Bm95 isolated from the cattle tick, *Boophilus microplus*. Vaccine. 2000; 18(21):2275-2287.
24. de la Fuente J, Almazán C, Canales M, Pérez de la Lastra JM, Kocan KM, Willadsen P. A ten-year review of commercial vaccine performance for control of tick infestations on cattle. Animal Health Research Review. 2007; 8(1):23-28.
25. Patarroyo JH, Portela RW, De Castro RO, Couto Pimentel J, Guzman F, Patarroyo ME. *et al*. Immunization of cattle with synthetic peptides derived from the *Boophilus microplus* gut protein (Bm86). Veterinary Immunology and Immunopathology. 2002; 88:163-172.
26. Trimnell AR, Hails RS, Nuttall PA. Dual action ectoparasite vaccine targeting 'exposed' and 'concealed' antigens. Vaccine. 2002; 20:3560-3568.
27. Nakajima M, Kodama M, Yanase H, Iwanaga T, Mulenga A, Ohashi K. *et al*. Production and characterization of monoclonal antibodies against midgut of ixodid tick, *Haemaphysalis longicornis*. Veterinary Parasitology. 2003; 115(4):355-363.

28. Tellam RL, Vuocolo T, Eisemann C, Briscoe S, Riding G, Elvin C. *et al*. Identification of an immuno-protective mucin-like protein, peritrophin-55, from the peritrophic matrix of *Lucilia cuprina* larvae. Insect Biochemistry and Molecular Biology. 2003; 33 (2):239-252.
29. Sukarsih PS, Satria E, Wijffels G, Riding G, Eisemann C, Willadsen P. Vaccination against the Old World screwworm fly (*Chrysomya bezziana*). Parasite Immunology. 2000; 24:545-552.
30. Tabouret G, Bret-Bennis L, Dorchies P, Jacquiet P. Serine protease activity in excretory-secretory products of *Oestrus ovis* (Diptera: Oestridae) larvae. Veterinary Parasitology. 2003; 114:305-314.
31. Wijffels G, Hughes S, Gough J, Allen J, Don A, Marshall K. *et al*. Peritrophins of adult dipteran ectoparasites and their evaluation as vaccine antigens. International Journal for Parasitology. 1999; 29:1363-1377.
32. Ochanda JO, Mumcuoglu KY, Ben-Yakir D, Okuru JK, Oduol VO, Galun R. Characterization of body louse midgut proteins recognized by resistant hosts. Medical and Veterinary Entomology. 1996; 10:35-38.
33. Abdel-Rahman MS, Fahmy MM, Aggour M. Trials for control of ixodid ticks using pheromone acaricide tick decoys. Journal of Egypt Society of Parasitology. 1998; 28:551-557.
34. Dyck VA, Hendrichs J, Robinson AS. Sterile Insect Technique: Principles and Practice in area-wide integrated pest management. Edn 1, Springer, Dordrecht, The Netherlands, 2005, 787.
35. Takken W, Weiss M. The Sterile Insect Technique for Control of Tsetse Flies in Africa. IAEA Bulletin, 1978; 20(3):20-24.
36. NAPPO Phytosanitary Alert System. http://www.pestalert.org/main.cfm. 18 January, 2012.
37. Benedict MQ, Robinson AS, Knols JG. Development of the sterile insect technique for African malaria vectors. Malaria Journal. 2009; 8(Suppl 2):1.
38. FAO/IAEA, Manual for mass-rearing Tsetse flies, Version 1.0. International atomic energy agency, Vienna, Austria. 2006, 239.
39. Thomas DD, Donnelly CA, Wood RJ, Alphey LS. Insect population control using a dominant repressible lethal genetic system. Science. 2000; 287:2474-2476.
40. Hogenboom M. Genetically modified flies could save crops BBC News Science and Environment, Retrieved, 2014.
41. Leftwich PT, Koukidou M, Rempoulakis P, Gong HF, Zacharopoulou A, Fu G e*t al*. Genetic elimination of field-cage populations of Mediterranean fruit flies. Proceedings of the Royal Society. 2014, 281.
42. Frisch JE, O'Neill CJ. Comparative evaluation of beef cattle breeds of African, European and Indian origins. 2. Resistance to cattle ticks and gastrointestinal nematodes. Animal Science. 1998; 67(1):39-48.
43. Frisch JE. Towards a permanent solution for controlling cattle ticks. International Journal for Parasitology. 1999; 29:57-71.
44. Gomes A, Honer MR, Schenk MAM, Curvo JBE. Populations of the cattle tick (Boophilus microplus) on purebred Nellore, Ibage and Nellore x European crossbreds in the Brazilian savanna. Tropical Animal Health and Production. 1989; 21:20-24.
45. Frisch J. Identification of a major gene for resistance to cattle ticks. In: Proceedings of the 5th world congress on genetics applied to livestock production, Guelph, 1994, 293-295.
46. Kerr RJ, Frisch JE, Kinghorn BP. Evidence for a major gene for tick resistance in cattle. In: Proceedings of the 5th world congress on genetics applied to livestock production. International committee for world congress on genetics applied to livestock. Canada. 1994; 20:265-268.
47. Sonstegard TS, Gasbarre LC. Genomic tools to improve parasite resistance. Veterinary Parasitology. 2001; 101:387-403.
48. Burn AJ, Croaker TH, Jepson RC. Integrated pest management. Academic Press, San Diego, 1987, 474.

Bram RA. Integrated control of ectoparasites. Rev Sci Tech. 1994; 13(4):1357-1365.