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Review Article

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Biological Control of Parasites In Livestock : An Update

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Parasites are a major cause of diseases in livestock, man and crops, leading to poor yield and great economic loss Livestock parasites account for **13%** of livestock mortality leading to reduction in productivity, degrading its quality and quantity, hampering reproduction and after all food insecurity (Santos & Rebello, 2022). It has been estimated that about **$93.1** million is lost due to parasite infestation in sake of treatment costs and production. But still we are aiming to control this kind of parasites mainly through three processes: a) Mechanical b) Chemical and c) Biological method. Mechanical method mainly means removal of parasite population manually which is next to impossible and impractical. Chemical methods had already been in use for ages. Over 200 classes of chemical compounds are currently in use for the treatment of livestock parasites but now-a-days there are some limitations in chemical control eg- there is high resistance rising in drugs, some drugs are posing threat to the environment, some drugs are even acting on the non-target organisms, some are lasting long in animal products leading to health issue in human population. In context to that biological control method has been found to be a successful and sustainable method in controlling pest which has also been included in the Integrated Parasite Management strategies. Biological control methods have included human manipulation or labouratories manipulated procedures where one group of living organisms will be used to suppress the target organisms. The organism that suppresses the pest population is generally referred to as a biological control agent (BCA). DeBach, 1964 stated that the action of parasites, predators and pathogens in maintaining another organism's population density at a longer average than would occur in their absence or Alston**,** 2011 stated that "any activity of one species that reduces the adverse effect of another".

History:

In 1701, Van Leeuwenhoek was probably the first to describe insect parasitism, which he illustrated in his publication. In 1870, Charles V. Riley was the first person to conduct the successful movement of parasitoids for biological control and therefore he is considered as the "Father of Modern Biological Control".

Biological/ Bio- control Agents:

- **Pathogens:** Viruses, Bacteria, Fungi, Protozoa, Rickettsiae, Nematodes
- **Parasites:** Parasitoids
- **Predators:** Vertebrate, Invertebrate

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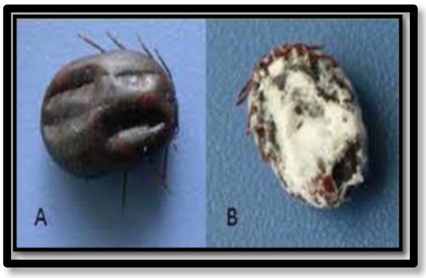
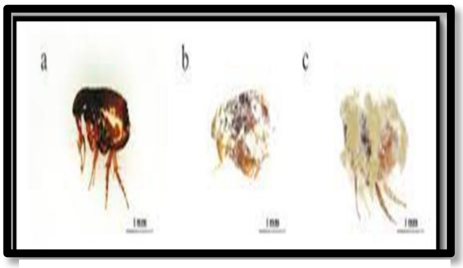


Boophilus **spp.**



Dog flea

Examples: *Metarhizium anisopliae* and *Beauveria bassiana* are effective in the control of ***Culex pepiens*** and ***Rhiphicephalus sanguineus*** where the fungal spores can be applied in outdoor attracting odour traps, on indoor house surfaces and on cotton pieces hanging from ceilings, bed nets and curtains to control adult mosquitoes.

Fungi that infect and kill nematodes (worms) are referred to as nematopathogenic fungi. Over 150 species of fungi are known to invade nematodes which can be grouped into three: Nematode-trapping fungi, Endoparasitic fungi and root-knot nematodes. Most nematopathogenic fungi of veterinary importance fall in the group of **nematode trapping fungi.** They use **constricting (non-adhesive) or non-constricting (adhesive) rings**, sticky hyphae, sticky knobs, sticky branches to trap and kill nematodes by penetration and growth of hyphal elements within the host.

Examples: ***Arthrobotrys musiformis*** has been found to be effective against *Haemonchus contortus* infective larvae (Trichostronylidae) through its predatory activity and its fungal culture filtrates. (Pérez-Anzúrez *et al.*, 2022). ***Monacrosporium thaumasium*** has also shown promising results in reduction of *Cooperia punctata*, *Oesophagostomum* sp., *Trichostrongylus* sp. and *Bunostomum* sp. (Araujo *et al.*, 2004). ***Duddingtonia flagrans*** is found to be an effective feed additives can reduce number of parasitic nematodes on pasture to the benefit of grazing animals when used at the recommended application rate (Bampidis *et al.*, 2020).

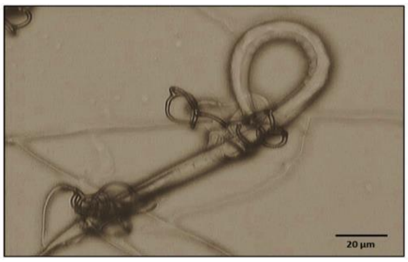


Fig: *Arthrobotrys musiformis* trapping *Haemonchus contortus* infective larvae

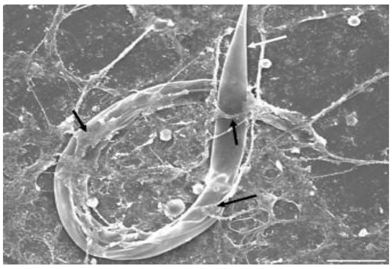


Fig: *Monacrosporium thaumasium* trapping GI nematodes

Fig: *Duddingtonia flagrans* trapping worms

Bacteria:

The most important entomopathogenic bacteria belong to the genus ***Bacillus*** of which ***B. thuringiensis*** (Bt) is the most widely used agent in the biological control of insects. Within Bt, there are a number of serovars (including *israelensis, jega thesan, darmstadiensis, kyushensis, medellin, fukuokaensis, higo*), each containing proteins with parasicidal activity and ***Bt* ser. i*sraelensis*** (Bti) was the first to be found toxic against **dipteran larvae.**

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Examples: ***B. sphaericus*** is effective in killing larvae of *Culex* spp., *Anopheles* spp and certain species of sand fly (vector for *Leishmania* spp.), ***Paenibacillus glabratella***, a recently discovered biocontrol agent showed positive results in controlling snails. ***Streptomyces avermitilis*,** produces toxins collectively called "avermectins" which are highly effective against classes Insecta, Arachnida and Nematodes.

An updated list of Bt genes encoding proteins with demonstrated anti-dipteran activity encompasses cry1, cry2, cry4, cry10, cry11, cry19, cry20, cry24, cry27, cry30, cry39, cry44, cry47, cry50, cry54, cry56. Several products of *Bacillus thuringiensis* are available in the market- **Dipel 2x** (*B. thuringiensis* var *kurstaki*), **VectoBac** (*B. thuringiensis* var. *israeliensis*) and **HD 703** (*B. thuringiensis* var *thuringiensis*) (Valtierra-de-Luis *et al*., 2020)

Viruses and virus-like particles:

Viruses belonging to the families **Entomopoxviridae, Reoviridae and Baculoviridae** have shown successful result in controlling pest population of which **Baculovirus** is the most widely exploited virus group for biocontrol. At present, there are approximately **16 biopesticides** based on baculoviruses available for use or are under development.VLPs are self-assembled with viral protein and devoid of genetic material, making them non- infectious and safe to use.

Protozoa:

Some protozoa such as *Haemogregarina, Babesia* and *Theileria* are pathogenic to some arthropods like ticks. Predatory soil amoeba *Theratromyxa weberi* is capable of ingesting nematodes

Nematodes:

Nematodes belonging to the genera ***Steinernema*** and ***Heterorhabditis*** have been proven as effective BCAs to control insect pests like houseflies, fleas and other non-biting flies.

Others:

Rickettsia, a diverse group of bacteria, mostly transmitted by arthropods such as ticks, fleas and so on. During their stay, rickettsial organisms lead to alterations in tick behavior, interfere with their development and cause pathological changes in salivary glands and ovarian tissues leading to their death.

Earthworm consume a large volume of soil along with animal faeces containing nematodes present in the soil and faeces which acts as a dominating role in removal of cattle dung from pastures, reducing infective larvae of trichostrongyle nematodes on the pasture.

Predators: feeds on other animal (i.e., prey) for their development, sustenance, and reproduction and generally larger than their prey.

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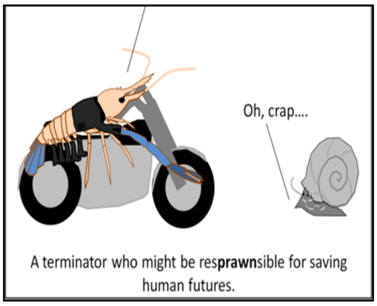
Invertebrates:



Spiders: Spiders trap their prey by making typical web and sometimes they will use larva silk to make "capture nets" and are capable of consuming *Ascaris* ova in the soil. River prawns have been observed to prey on snails.

Mites: Some mites are nematode predators, for example, *Phytoseiid* spp. are capable of consuming *Ascaris* ova in the soil. They are also voracious predators of eggs and larvae of houseflies and other flies that develop in manure and faeces of livestock. ***Macrocheles muscae domesticae*** can eat up to 10 housefly eggs per day.

Macrocheles muscae domesticae

Flies: Predatory fly, ***Hydrotaea (Ophyra) aenescens***, presents a breakthrough in the indoor control of the housefly, *Musca domestica*. Small flies such as ***Mutilla glossinae*** are promising BCAs against the tsetse fly.

Insect herbivores: Insect herbivores like the cell-content feeder ***Liothrips ludwigi*** (Thysanoptera), the stem borers ***Merocnemus binotatus*** (Boheman) and ***Tyloderma* spp**. have shown promising results in the control of weeds. ***Scolothrips sexmaculatus*** prefers spider mite eggs but adult females will consume various mites of animals.

Ants: Around 27 species of ants from 16 genera mainly *Aphaenogaster, Iridomyrmex, Monomorium, Pheidol , Solenopsis* etc. are known to prey on ticks, horn flies and different other pests. Application of the fire ant, ***Solenopsis*** spp.in the USA markedly reduced the population of ticks, *Ixodes* spp. transmitting anaplasmosis in cattle.

Solenopsis spp

Dragonflies and water bugs: They are known to feed on mosquitoes larva, thus acting a promising agent in malaria control.

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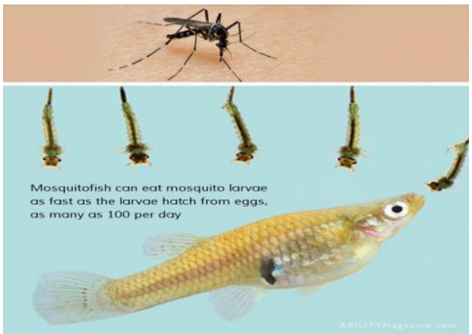
Beetles: Dung beetles of the family Scarabaeidae are useful in the control of pasture livestock flies since they breed primarily in cow pats. ***Onthophagus ganelle*** and ***Euniticellus intermedius*** when introduced from Africa to Australia, showed reduction of ***Musca*** spp. upto 80–100% and the buffalo fly ***Haematobia exigua*** by 95%. It can also play a role in the biocontrol of bovine gastrointestinal nematodes (Trichostrongylidae).

Dung beetles

Vertebrates:

Amphibians and fishes:

Water tortoise ***Pelomedusa subrufa*** has been reported to be able to remove ticks from black rhinos. Edible fishes such as ***Gambusia affinis, Guppy poecilia*** and carp fishes have tremendous potential as a larvivorous predator of mosquito and showed 98% reduction in the larval density of ***Anopheles*** spp**.** when introduced into water wells. ***Cyprinus carpio, Aplocheilus blocki, Tilapia spp, Catla catla, Labeo rohita*** and ***Cirrhinus mrigala*** have also shown promise in the control of mosquitoes.



A study showed that ***Gambusia affinis*** preferred live larvae than commercial food and consumes about **100- 150** larvae per fish per day. They prefer **live larvae over dead larval** stuff and prefers to eat larva in the **presence of light.** (Noreen *et al.*, 2017)

Reptilians: Australian gecko ***Gehydra dubia*** and the exotic Asian house gecko ***Hemidactylus frenatus*** have been observed to prey on mosquitoes and is therefore a promising tool for the biocontrol of malaria.

Avian and domestic fowls: Birds are natural predators of insects. Some bird species are known to pick off ticks from the host during flight or collect them from the ground and also eat the larvae of dung flies. Domestic fowls and birds are good predators of snails i.e., intermediate host of trematodes.

Parasites (parasitoids):

It is an organism that lives in close association with its host which sooner or later kills the host and is stenoxenous. The parasiotid wasp**,** ***Ixodiphagus hookeri*** (Hymenoptera) is the natural enemy of a many hard and soft tick species but shows promising result in control of the American dog tick ***Dermacentor variabilis (***Buczek *et al*., 2021). Braconid wasps have shown control over caterpillars other insects including greenfly.

Fig: ***Ixodiphagus hookeri*** in close association with American dog tick ***Dermacentor variabilis.***

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Rearing Systems for Biocontrol Agents:

1) Natural rearing systems: It uses the natural or target prey for production of the parasitoids and predators.

2) Systems using factitious prey: Organism that is unlikely to be attacked by a natural enemy in its natural habitat, but that supports its development and/or reproduction. They donot occur in natural habitat but can sustain in laboratory condition.It is easier and less expensive to rear. Examples: Storage mites for predatory mites (Phytoseiidae, Laelapidae), Eggs of lepidopterans for insect predators, etc.

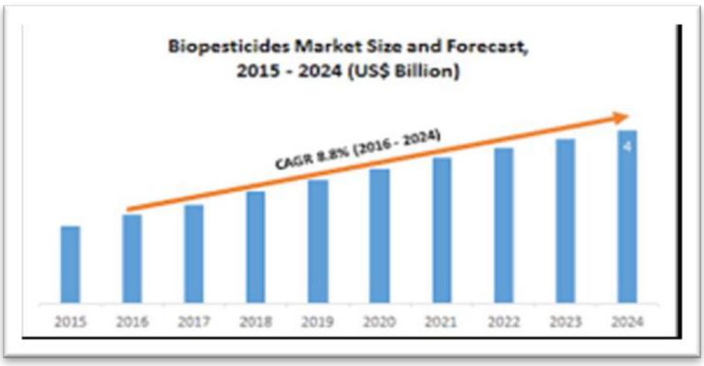
3) Artificial rearing systems: It uses artificial foods and preferably no plant materials. It may be tissues, haemolymph, protein, amino acids, cells etc.

IDEAL LOCATIONS FOR BIO-CONTROL UNITS:

- Care should be taken to set up biocontrol production units in areas which have **appropriate climatic conditions.**
- Location of biocontrol **production units** and **consumer market** (farming areas) should be close to each other
- Care should be taken so that the surrounding farming areas should not get any harmful effects from the biocontrol units.
- **Air pollution** can damage biocontrol agents, the production unit should be located away from industrial and urban areas

Present Status of BCA:

- The global market of bio agents is expected to reach $4 billion by 2024 from $2 billion in 2016, growing an increase with 8.8% from 2016 to 2024. The USA accounts for 40% of the global bio pesticide followed by Europe (20%) and Oceania (20%).
- In India, biopesticides industry shows a growth rate of 20.2 % since 2010 -2020.



At present there are total **361 biocontrol laboratories/un**its in India of which **141** are under the private sector laboratories, **98** nos. are under state biocontrol laboratories, **49** nos. are under ICAR/SAUs/DBT laboratories, **38** nos. are under private sector getting grant from Government of India., **35** nos. under Central

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Integrated Pest Management Centers (CIPMC). In **2022,** India has made its first announcement on 7th National Conference on Biological Control from **5-7** August in Bengaluru.

Approaches to Biocontrol:

1) **Importation:** It involves introduction, screening and release of natural enemies to permanently establish effective natural enemies in a new area which will target the native pest to control.

2) **Augmentation:** It typically involves the purchase and release of natural enemies that are already present in an area but not in quantity, enough to adequately keep in check the pest population in a particular location.

3) **Conservation:** This includes avoidance of measures that destroy natural enemies and the use of measures that increase their longevity and reproduction in an environment.

Challenges:

- If a BCA attack any native non-target species, its persistence and ability to spread to areas far from the site of release become a serious liability.
- Non-native BCA can carry non-native parasites and commensal species.
- BCA are easily influenced by environmental factors such as temperature, humidity and oxygen extremes, which determine the success of the biological control strategy.
- Distribution of BCAs product, especially those containing living organisms are not easy.
- Most industries producing BCA products are often situated a considerable distance away from where the BCA is to be used.
- There is no information available on the economic viability of those strategies; biological products must have competitive costs relative to chemicals to allow their use by farmers.
- Lukewarm attitude among who find it difficult to forego their fast-acting chemical pesticides over the sluggish BCA.

Conclusion

- Biological control approaches hold promise as the most suitable alternative to the chemical pesticides and are now a core component of IPM (Integrated Parasite Management).
- A good number of promising BCAs including predators, parasites (parasitoids) and patho- gens (fungi, bacteria, viruses and virus-like particles, protozoa and nematodes) have been identified and proven to be efficacious against many parasites of medical, veterinary and agri- cultural importance
- With the recent advances in biotechnology and the application of most recent technologies such as nanotechnology and microencapsulation, there are many opportunities for the continued use and expanded role of natural enemies in biological control.
- Newer BCAs are being identified and older ones are being genetically engineered to make them more efficacious in their antagonism of parasites.
- In the future, biological control will develop to overcome many of the challenges, and BCAs will become the mainstay for the control of parasites

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