International Journal of Entomology Research
www.entomologyjournals.com
ISSN: 2455-4758
Received: 08-09-2022, Accepted: 24-09-2022, Published: 11-10-2022
Volume 7, Issue 10, 2022, Page No. 98-101

Biological Control: The origins and the Indian scenario

Isaac L Mathew, Deepak Singh*
Department of Zoology, St. Andrew's College, Gorakhpur, Uttar Pradesh, India

Abstract
Biological control far pre-dates the modern pesticide era as one of the main pest management methods, but from around the middle of 20th century these methods fell out of favor for newly discovered pesticides that could easily manage most pests. However, it did not take long to realize that chemical pesticides were creating more problems than were supposed to solve. Rachel Carson's seminal book "Silent Spring" fueled the ongoing movement away from the pesticides and towards alternative methods of pest control. This shift helped to bring biological control in the forefront and stimulate the implementation of the concept of Integrated Pest Management (IPM) in the late 1960's, of which biological control was seen as a core component. Natural enemies of pests, such as parasitoids, predators and pathogens; are the fundamental resource of biological control. In India the history of modern classical biological control dates back to 18th century, also Indian species have also been used elsewhere as biocontrol agents. Biological control has now gained prime importance in India, with several biological control laboratories and stations presently engaged in controlling pests.

Keywords: biocontrol, biological control, biopesticide, environment, India

Introduction

Biological control can be defined as the use of an organism to supress the population of another organism to a manageable level. Biological control has been successfully adopted as a feasible alternative to the use of chemical control in many parts of the world [1]. Up to 2017, more than 350 natural enemies of insect pests were commercially available. The industry is now well organised through some 500 producers, of which 30 are major companies, and are able to mass produce, ship and release adequate guidance on a release method for users. Owing to the broader public and political support for biocontrol methods within IPM programmes, consumer preferences and demands, and shift towards organic farming has aided the rapid growth of biocontrol industry [2, 3, 4].

Chemical pesticides, although considered a boon initially, it did not take long to realise that they were creating more problems than were supposed to solve. It was "Silent Spring" by Rachel Carson (1962) which brough this issue in prominence. This fuelled the ongoing movement for safer alternative methods of pest control [5]. Now the goal of any pest control is to adopt a strategy which provides maximum benefits while causing minimum damage to the environment. Although several possible alternative methods have been developed for pest control, such as, the use of physical and mechanical agents, modified cultural practices, release of pests with genetic lesions, inserting pest resistance in crop species, and the development of narrow spectrum chemicals with the less environmental persistence; biological control stands out as the safest [4]. Biological control is a component of an IPM strategy and it is really regarded as a "systems approach" to IPM [6].

The concept of modern biological control

Biological control was one of the chief methods for prevention and reduction of pest, until around 1950, until newly discovered pesticides could easily manage almost all pests. Carolus Linnaeus, in 1752 had observed that *"Every insect has its predator which follows and destroys it. Such predatory insects should be caught and used for disinfesting crop-plants*" [7]. Biological control or biocontrol refers to direct or indirect manipulation of living natural control agent by man, to increase their attack on pest species and has been defined by several authors [8, 9, 10, 11, 12, 13]. According to De Bach (1964) [8], the term *"Biological control"* refers to a "*natural phenomenon, a field of study or an applied pest control technique, involving manipulation of natural enemies".* Other authors have defined biological control as *"any condition under which, or practice whereby, survival and activity of a pathogen is reduced through the agency of any other living organism (except man himself) with the result that there is a reduction in the incidence of disease caused by the pathogen"* [9]. *"That method of pest control that relies on natural enemies – parasitoids, predators and pathogens to reduce pest population to tolerable level"* [10], *"Biological control is the deliberate use by man of biotic agent to suppress and/or regulate a pest population"* [11], *"the use or encouragement, by man, of living organism or their products for the population reduction of pest insects"* [13], *"the use of natural enemies to control insect pest"* [12, 14, 15]. Baker & Cook [16] defined biological control as the "*reduction of inoculum density or disease producing activities of a pathogen of parasite in its active or dormant state, by one or more organisms, accomplished naturally or through manipulation of the environment, host, or antagonists, or by mass introduction of one or more antagonists*" which was subsequently revised to "*biolog9ical control is the reduction of the amount of inoculum of disease producing activity of pathogen accomplished by one or more organisms other than man"* [1]. Eilenberg *et al*. [18] has defined biological control as the strategy that uses living organisms to suppress the population of specific pest organisms, making it less abundant or less damaging than it would otherwise be. Natural enemies are the fundamental resource of biological

control, and their main categories are: Parasitoids, predators and pathogens [4].

The origins of biological control

The history of use of biological control far pre-dates the modern pesticide era. Old Egyptian records from 2000 BC depict domestic cats as useful in rodent control [19, 20, 21]. Hieroglyph representing the Kingdom of Lower Egypt by King Menes approximately 3100 BC depicts the earliest graphic record of an insect, the hornet *Vespa orientalis*[22]. In third century Canton (China), nests of predaceous ants, *Oncophylla smaradina* were used to control foliage-feeding insects by citrus growers, even bamboo bridges were used to assist them in their movements from tree to tree [23,24,25]. Date growers in ancient Yemen used to travel North Africa to collect colonies of predaceous ants to be used in date groves to [19, 26, 27]. Thus, there is no doubt that entomophagy by predators have been rigorously used as biocontrol agents from the very beginning of human civilization [23]. Insect parasitoidism was not documented until the turn of the 17th Century. In 1602, Aldrovandi from Italy observed parasitoid, *Apanteles glomeratus* (L.) parasitizing common cabbage butterfly, *Pieris rapae* Linnaeus. In 1700, parasitism of aphids by *Aphidius* spp. was correctly interpreted by Antonie van Leeuwenhoek, the Dutch microscopist. The potential biocontrol of Aphids by Aphidivorous fly (Diptera) in 1734, biocontrol of caterpillars by *Calosoma sycophanta* (Coleoptera) in 1763, control of *Cimex lectularius* by *Reduvius personatus* (Hemiptera) in 1776, etc., are some examples of recorded observations of the early knowledge on the potential of biocontrol agents [4,28]. Latter part of the 18th century saw an increasing interest especially in parasitoid biology and its utility in biocontrol. In later development, T.R. Malthus' work helped to recognize insect pest problems as population phenomena paving way for modern understanding of biological control. Subsequently, control of several garden pests by Staphylinids and carabids (Coleoptera) in 1844, biocontrol of scale insects by *Aphytis mytilaspidis* (Hymenoptera), *Trichogramma* sp. (Hymenoptera) controlling *Nematus ribesii* in 1882, *A. glomeratus* (Hymenoptera) controlling of *P. rapae* in 1883, recognition of diseases of silkworms, etc., took place [4,30].

Early 19th century saw various studies on beneficial effects of entomophagous insects. In 1800, Erasmus Darwin noticed and recommended control of cabbage butterfly caterpillar by the small ichneumon fly, which deposits its eggs in their backs. Hartig, in 1827, Germany, proposed the gathering and storing of parasitized caterpillars in order to harvest parasitoid adults for later mass release [29]. Ratzeberg (1828) did extensive work on the parasitoids of forest insects in Germany. Kollär (1837), who first reported the existence of egg parasitoids, emphasized on the importance of entomophagous insects in nature's economy. Boisgiraud (1843) reported on the predaceous carabid beetle, *Calasoma sycophanta*, to successfully control gypsy moth larvae on poplars in rural France. He also reported on the use of predaceous staphylinid beetles against earwigs. Biological control techniques, as we know them today, emerged in the 1870s, especially in US. Distribution of parasitoids to control crop pests and the first international shipment of an insect as a biological control agent took place in this decade. In latter decades, various parasitoids and beetles were introduced across nations for biocontrol projects, and even met with some prejudice due to occasional problems [30]. Initial decades of 20th century saw renewed interest and more biocontrol projects, like The Gypsy Moth Project in New England (1905-1911), The *Lantana* Weed Project in Hawaii (1902), The Sugar-cane Leafhopper Project in Hawaii (1904-1920), etc. Biocontrol activity reached its pinnacle from 1930 to 1940 in the world with 57 different natural enemies established at various places. However, World War II and the development of relatively inexpensive synthetic organic insecticides caused decline in biocontrol activities, and entomological research switched predominantly to pesticide research. Later several National and international organizations were established to promote the development of biological control. Rachel Carson's seminal book "Silent Spring" renewed worldwide interest in ecology and the environment after 1962, fuelled the ongoing movement away from the pesticides and towards alternative methods of pest control. This shift helped stimulate the implementation of the concept of Integrated Pest Management (IPM) in the late 1960's, of which biological control was seen as a core component. Biological control is a key component of a 'systems approach' to integrated pest management, to counteract insecticide-resistant pests, withdrawal of chemicals and minimize the pesticides usage [31]. Simultaneously more emphasis was placed on conservation biological control than classical biological control [4, 30].

The history of biological control in India

In India the history of modern classical biological control dates back to 18th century when the first unintentional outstanding success was the biological control of weed prickly pear by cochineal insects, in 1795. As the first ever instance of biocontrol of weeds, in 1863, mealy bugs from North were introduced in South India to control cactus [20]. In 1930 biological control of Cottony Cushion Scale, *Icerya purchasi* Maskell (Margarodidae) was achieved by the coccinellid beetle, *Rodolia cardinalis* introduced from Australia. In 1982 *Cyrtobagous salviniae*, weevil native to Brazil was introduced from Australia for biological control of Water Fern, *Salvinia molesta* (Salviniaceae). Biological control of Water Hyacinth, *Eichhornia crassipes* (Pontederiaceae) was achieved by introduction of three exotic natural enemies *viz*., hydrophilic weevils – *Neochetina bruchi* (Ex. Argentina) and *N. eichhorniae* (Ex. Argentina) and galumnid mite *Orthogalumna terebrantis* (Ex. South America) from their original native place via USA in 1982. Similarly, effective biological control of Mealybugs was achieved during the last several decades by introducing Coccinellid beetles. Biological control of common Mealybug, *Planococcus citri* (Risso) (Pseudococcidae) was achieved by encyrtid parasitoid *Leptomastix dactylopii* introduced from Brazil in 1983 [32]. In the 1960s the biological control of Woolly Aphid, *Eriosoma lanigerum* (Hausmann) (Aphididae), at Saharanpur (Uttar Pradesh) and later to other parts of India, was achieved by introduction of exotic aphelinid parasitoid, *Aphelinus mali*, a native of North America. Control of Spiralling whitefly, *Aleurodicus dispersus*, a native of Caribbean region and Central America, unintentionally introduced into India in 1995, was achieved by exotic aphelinid parasitoids, *Encarsia guadeloupa*e and *E*. sp. nr. *meritoria* (Origin: Carribbean region/Central America) [33]. Recently biological control of several weeds has been

achieved to some extent by introduction of appropriate biocontrol agents [4, 32, 34].

Similarly, Indian species have also been used elsewhere as biocontrol agents. The first attempt of biocontrol in this regard was made in 1762 when mynah bird, *Acridotheres tristis* Linnaeus, was introduced from India to the island of Mauritius for the control of red locust, *Nomadacris septemfasciata* Serville. In 1872, the small Indian mongoose (*Herpestes auropunctatus*) was introduced in several parts of the world primarily for rat control and to some extent snakes [25, 35].

Current status of biological control

Originally founded by British in 1926 as the Imperial Institute of Biological Control to promote the development of biological control, the institute was later called the Commonwealth Bureau of Biological Control (CBBC) in 1947. In 1951 it was renamed as Commonwealth Institute for Biological Control (CIBC) with headquarters currently in Trinidad, West Indies. Similarly, in 1955 the Commission Internationale de Lutte Biologique contre les Enemis des Cultures (CILB) was established, which was later renamed to the Organisation Internationale de Lutte Biologique contre les Animaux et les Plants Nuisibles in 1962. Also known as the International Organization for Biological Control of Noxious Animals and Plants (IOBC). In 1969, under the auspices of the International Union of Biological Sciences (IUBS), an agreement was reached among organizations to merge IOBC and the "International advisory committee for biological Control" (active in English-speaking countries) into a single international organization under the name IOBC. Initially having consultative status in the Food and Agricultural Organization (FAO) of the United Nations, it later affiliated with the International Council of Scientific Unions [36, 37].

In India systematic biological control research commenced with the establishment of the Indian station of Commonwealth Institute of Biological Control (CIBC) at Bengaluru in 1957 with need based 23 substations at various places in different states. Later, the All-India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds (AICRP-BC&W) was established in 1977 with 10 centres, which increased to 16 under the aegis of Project Directorate of Biological Control (PDBC), an institute of Indian Council of Agricultural Research. During, PDBC was later upgraded as National Bureau of Agriculturally Important Insects (NBAII) in the XIth plan to act as a nodal agency for biological control of crop pests. In the XIIth five-year plan, NBAII was re-named as National Bureau of Agricultural Insect Resources (NBAIR) with changed mandate [38]. As of 2022, at least 361 active Bio-control Laboratories in India, out of which there are 35 Central Integrated Pest Management Centres (CIPMCs), 38 State Bio-control Laboratories (SBCLs) in States/UTs established under Grants-in-Aid by Government of India during Xth & XIth Plan, 49 Indian Council of Agricultural Research (ICAR) labs, 98 State Bio-control Laboratories (SBCLs), and 141 Private labs [39].

The new liberal trade policies of the government, especially since the 90s, has resulted in the introduction of several exotic insect pests in the country *viz*., subabul psyllid, *Heteropsylla cubana* on subabul, *Leucaena leucocephala* (1988); leaf miner, *Liriomyza trifolii* complex on several plants (1990); coffee berry borer, *Hypothenemus hampei* on coffee (1991); spiralling whitefly, *Aleurodicus dispersus* on several plants (1993); coconut eriophyid mite, Aceria guerreronis on coconut (1998) and whitefly, Bemisia argentifolii (1999) on tomato and other hosts[40]. These pests are being taken into consideration for biological control. Until 2004, 166 exotic biological control agents have been introduced in India, of which 33 could not be released in the field, 71 recovered after release, 6 provided excellent control, 7 showed substantial control and 4 partial control [40].

Discussion

Pests cause significant loss in crop yield all over the world. If crops and its yields are not protected against the ravages of pests the goal of ensuring food security cannot be fully realized. India, with its diversified agro-ecosystems, embraced technologies of green revolution spontaneously and reaped the benefits, which is reflected in the shape of production of 200 million tonnes of food grains, 25 million tonnes of oil seeds and 15 million tonnes of fibres per annum. Financial losses due to pests to farmers in developing nations like India will be a huge setback for the economy and society as a whole. Therefore, it is undoubtedly inevitable to reduce these losses by protecting the crops and its products from pests through appropriate techniques [41]. Biological control has now gained prime importance with several biological control laboratories and stations presently engaged in controlling pests.

The use of biological control agents to control insect pests has many advantages over traditional chemical controls. They leave no harmful chemical residues and continue to reproduce as long as the host is available and environmental conditions are suitable thus mostly requiring a single inoculation. They are fairly specific in the range of prey that they will attack, moreover, they actively seek out their prey and can increase the level of control over time. Chances of developing resistance to a control agent are slim and the control can be self-perpetuating over long periods of time. However, the main limitations of biological control include, comparatively slower suppression of pest populations, regulation instead of eradication in most cases resulting in many partial rather than complete successes, need for extensive and comprehensive understanding of the biology and ecology of the pest and the natural enemy complex, and less cost effectiveness in many cases [31]. Taking this into consideration, modern IPM evaluates and consolidates all available techniques, with biological control at its core, into a unified program to manage pest populations below economic injury level and minimise adverse side effects on the environment.

References

1. Van Lenteren JC, Bolckmans K, Köhl J, Ravensberg WJ, Urbaneja A. Biological control using invertebrates and microorganisms: plenty of new opportunities. BioControl, 2017, 1-21.
2. Van Lenteren JC. Biological control for insect pests in greenhouses: an unexpected success. Biological control: a global perspective. CAB Int, Wallingford, 2007, 105-117.
3. Solà Cassi M. Approaches for the biological control of stored product pests. [PhD Thesis], Universitat Autònoma de Barcelona, 2017.

4. Mathew IL, Singh D. Bacillus thuringiensis and Parasitoids: Integrated biocontrol of stored grain pests. White Falcon Publishing, 2020.
5. Sexton SE, Lei Z, Zilberman D. The economics of pesticides and pest control. International Review of Environmental and Resource Economics,2007:1(3):271-326.
6. Holmes L, Mandjiny S, Upadhyay D. Biological control of agriculture insect pests. European Scientific Journal, ESJ, 2016, 12(10).
7. Resh VH, Cardé RT. (Eds.). Encyclopedia of insects. Academic Press, 2009.
8. DeBach P. Biological control of Insect pest and weeds. Reinhold pub corp. New York, 1964, 844.
9. Garrett SD. Toward biological control of soil-borne plant pathogens. Ecology of soil-borne plant pathogens, 1965, 4-17.
10. Bosch R, Van Den, Messenger PS. Biological Control. Intext Educational, New York, 1973.
11. Rabb RL, Stinner RE, Carlson GA. Ecological principles as a basis for pest management in the agroecosystem. In: F. G. Maxwell & F. A. Harris (eds), Proceedings of the Summer Institute on Biological Control of Plant Insects and Diseases, Univ. Press of Mississippi. 1974, 19-45.
12. Lenteren JC Van. The potential of entomophagous parasites for pest control. Agri. Ecosyst. Env.,1983:10:143-158.
13. Coppel HC, Mertins JW. Biological insect pest suppression Springer Science & Business Media, 2012, 4.
14. Smith HS. On some phases of insect control by the biological method. J Econ Entomol.,1919:12(4):288-292.
15. Lenteren JC Van. Biological Pest Control: Passing fashion or here to stay? Organorama,1983:20:3-9.
16. Baker KF, Cook RJ. Biological control of plant pathogens. WH Freeman and Company, 1974.
17. Cook RJ, Baker KF. The nature and practice of biological control of plant pathogens. American Phytopathological Society, 1983.
18. Eilenberg J, Hajek A, Lomer C. Suggestions for unifying the terminology in biological control. BioControl,2001:46:387-400.
19. Liu G. Some Extracts from the history of entomology in China. Psyche.,1939:46:23-28.
20. Wilson F, Huffaker CB. The philosophy, scope and importance of biological control. In: Huffaker, C.B., Messenger, P.S. (Eds.), Theory and Practice of Biological Control. Academic Press, 1976, 788.
21. Johansson C. Origin of the Egyptian Domestic Cat, Uppsala Univ, 2012.
22. Harpez I. Early entomology in the Middle East. In: Smith, R.F., Mittler, T.E., Smith, C.N. (Eds.), History of Entomology. Annual Reviews Inc., Palo Alto, California, 1973, 21-36.
23. van Lenteren JC. Early entomology and the discovery of insect parasitoids. Biol. Control., 2005:32:2-7.
24. van Lenteren JC, Godfray HCJ. European science in the Enlightenment and the discovery of the insect parasitoid life cycle in The Netherlands and Great Britain. Biol. Control.,2005:32:12-24.
25. Omkar O. Ecofriendly Pest Management for Food Security. Elsevier Science, 2016.
26. Coppel HC, Mertins JW. Biological pest suppression (Advanced series in agricultural sciences 4). Springer-Verlag Berlin, Heidelberg, 1977, 314.
27. Bellows TS, Fisher TW. Handbook of Biological Control. Academic Press, Elsevier, 2005, 1046.
28. Huffaker CB, Simmonds FJ, Laing JE. The theoretical and empirical basis of biological control. In: Huffaker, C.B., Messenger, P.S. (Eds.), Theory and Practice of Biological Control. Academic Press, New York, 1976, 41-78.
29. Howard LO. A History of Applied Entomology. Smithsonian Misc. Coll.,1930:84:1-564.
30. https://ucanr.edu/sites/W2185/files/109429.pdf
31. Bale JS, Van Lenteren JC, Bigler F. (). Biological control and sustainable food production. Philosophical Transactions of the Royal Society B: Biological Sciences,2008:363(1492):761-776.
32. Singh SP. A biological suppression technique for mealy bugs. Indian Horti,1996:41(3):62-65.
33. Ramani S, Poorani J, Bhumannavar BS. Spiralling whitefly, *Aleurodicus dispersus*, in India. BNI,2002:23(2):55N-62N.
34. Jayanth KP, Singh SP. Biological control of aquatic weeds. Indian Famg.,1993:42:25-30.
35. Simberloff D. Risks of biological control for conservation purposes. BioControl,2012:57:263-276.
36. Anonymous. International Institute of Biological Control, Annual Report 1990. Cambrian News Ltd., Aberystwth, Wales, England, 1991, 80.
37. Bellows TS Jr, Fisher TW. (eds). Handbook of Biological Control: Principles and Applications. Academic Press, San Diego, CA, 1999, 1046.
38. Kumar S. History, progress and prospects of classical biological control in India. Indian J Weed Sci.,2015:47(3):306-320.
39. http://ppqs.gov.in/divisions/integrated-pest-management/bio-control-labs
40. Singh SP. Some success stories in classical biological control of agricultural pests in India (No. C044. 006). Asia-Pacific Association of Agricultural Research Institutions (APAARI); FAO, 2004.
41. Gulbadher A. Crop protection. Retrieved from http://cropinfo.in /agriinfo / crop-protection/, 2010.