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Biological Control of Castor Semilooper, *Achaea janata* L. in Castor Agroecosystems in India- A Review

***Puneet*[1], *Balbir Singh*[2], *Deepak Kumar*[3*] *and Lokesh Yadav*[4]**
[1]*Ph.D. Scholar, Department of Entomology,*
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana), India.
[2]*District Extension Specialist (Entomology), Krishi Vigyan Kendra, Bawal (Rewari),*
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana), India.
[3]*Ph.D. Scholar, Department of Nematology,*
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana), India.
[4]*Ph.D. Scholar, Department of Plant Pathology,*
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana), India.

(Corresponding author: Deepak Kumar)*
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ABSTRACT: Castor is an important oilseed crop grown all around the globe with a wide range of industrial applications. Castor though being a hardy crop is still attacked by a large number of pests but the dominant ones are the insects. Insects are found to attack almost every growth stage of castor crop and cause severe yield losses. Among the insect pests, castor semilooper, *Achaea janata* L. is one of the major defoliators causing severe damage to the crop ultimately leading to drastic reductions in yield. A number of natural enemies are reported to be present invariably associated with the field populations of castor semilooper in castor agroecosystems. Among them the braconid endoparasiotid, *Microplitis maculipennis* is a major regulator of castor semilooper larval populations. *Trichogramma* spp. causes parasitisation of the semilooper eggs to a fair extent. Predatory birds also contribute a lot as far as natural control of castor semilooper is concerned.

Keywords: Castor, *Achaea janata*, biological control, natural enemies.

INTRODUCTION

Castor (*Ricinus communis* L.) is an important non-edible oilseed crop cultivated all around the globe in both arid as well as semi-arid areas (Govaerts *et al.*, 2000). The primary use of castor crop is to extract non-edible oil from its seeds which is used in the manufacturing of numerous products such as lubricants, paints, polymers, hydraulic brake fluids, perfumery products and soaps. Besides them, many bye-products of castor oil are also used by manufacturing industries (Anjani, 2012). About 193 arthropod species and 150 pathogens have been reported to be associated with the castor crop. Castor semilooper, *Achaea janata* L. (Lepidoptera: Noctuidae) is a major defoliator of the economically important castor crop. A very wide range of natural enemies are reported to attack various life stages of castor semilooper (CABI, 2020). The most commonly reported natural enemies of this insect pest are *Bacillus thuringiensis*, *B. cereus*, *B. popilliae*, *Trichogramma achaeae*, *T. chilonis*, *T. minutum*, *T. australicum*, *T. dendrolimi*, *T. pretiosum*, *T. evanescens*, *Microplitis rufiventris*, *M. maculipennis*, *M. ophiusae*, *Telenomus remus*, *T. proditor*, *Stethorus siphonulus* and *S. histrio* (López-Guillén *et al.*, 2020). In nature, semilooper population is regulated by its larval endoparasiotid, *Microplitis* (=*Snellenius*) *maculipennis* (Hymenoptera: Braconidae) (Prabhakar and Prasad, 2005).

Host range of castor semilooper, *Achaea janata*- Semilooper, *Achaea janata* L. (Lepidoptera: Noctuidae) is a polyphagous pest feeding on several ornamental and fruit crops, but castor is the major or preferred host (Gaikwad and Bilapate, 1992). It is a major pest of castor and other hosts including rose, ber, mango, *Tridax procumbens*, *Cardiospermum helicacabum*, *Ficus*, *Bauhinia* (ICAR-NBAIR Database, 2020), citrus (Sharma, 2011), pomegranate (Byale and Bilapate, 1990), *Excoecaria agallocha* (Ismail and Salim, 1982), *Bauhinia purpurea*, *Phaseolus mungo* (Jayaramaiah *et al.*, 1975), *Psidium guajava*, *Dodonaea viscosa*, *Quisqualis indica* (Kavadia and Verma, 1973), tamarind (Ahmed, 1990), *Euphorbia*, *Zizyphus*, Mustard (Wise, 1956), *Euphorbia hirta* and *E. hypersifolia* (David and Ramamurthy, 2015).

Distribution of castor semilooper, *Achaea janata*- Castor semilooper is widely distributed in Asia (India, China, Indonesia, Cambodia, Laos, Malaysia, Myanmar, Philippines, Thailand and Vietnam), North America (USA) and Ocean countries (Australia and Papua New Guinea). In India, castor semilooper has been reported from Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Manipur, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh and Andaman & Nicobar Islands (Distribution Maps of Plant Pests, 2022).

Damage to castor crop by castor semilooper, *A. janata*- The insect pests accounts for 17.2-63.3 per cent yield losses (Lakshminarayana and Duraimurugan, 2014). Castor is a highly tolerant crop to defoliation and can tolerate leaf damage up to 25 per cent without exhibiting any substantial reduction in seed yield (Sujatha *et al.,* 2011). Castor semilooper is one of the most important defoliators of castor crop (Umbarkar and Patel, 2016). Semilooper causes extensive defoliation in castor during its peak vegetative growth phase and also feeds on tender capsules in developing spikes causing 30-50% yield loss (Parthasarathy and Rao, 1989; Rao *et al.*, 2012).

Biocontrol using parasitoids. The parasitoids attacking the *A. janata* at various life stages are tabulated as Table 1. Many natural enemies are reported to attack the insect-pests of castor such as insect parasitoids (18 egg parasitoids, 34 larval, 1 larval-pupal and 2 pupal parasitoids), insect diseases (3 bacterial, 2 fungal, baculovirus and rickettsia) and four nematode species. Some of the noted examples are *Trichogramma chilonis* (egg-parasitoid), *Microplitis maculipennis*, predatory insects, insectivorous birds, other general predators and some microbial pathogens (Basappa, 2003). Among the parasitoids, the braconid, *Microplitis maculipennis* is the most potential and unique parasitoid being the key mortality factor of castor semilooper larval population (Gaikwad and Bilpate, 1989). It is an internal and solitary larval parasitoid affecting mostly the third instar larvae. For castor semilooper, it was recommended that insecticides should not be sprayed if the defoliation is less than 25% and 1–2 *Microplitis* per plant are observed (Basappa and Duraimurugan 2018).

Table 1: Parasitoids reported to attack castor semilooper, *Achaea janata.*

Natural enemy	Stage attacked	Reference(s)
Microplitis (= *Snellenius*) *maculipennis*	Larval	Cherian and Basheer (1946); Khan (1946); Rai and Jaya Ramaiah, (1978); Gaikwad and Bilpate (1989); Somasekhar *et al.* (1993); DOR (2003); Naik *et al.* (2010); Laxman and Maheswari (2017) Manjunatha *et al.* (2019)
Telenomus proditor	Egg	Thobbi *et al.* (1976); DOR APR (1988); Parasharya *et al.* (1988); Lakshminarayana and Ramesh Babu (1992); Lakshminarayana (1992)
T. remus	Egg	Kulshreshtha *et al*. (1967); DOR APR (1988)
Trichogramma chilonis	Egg	DOR APR (1988); Parasharya *et al.* (1988); Lakshminarayana and Ramesh Babu (1992); Lakshminarayana (1992); Naik *et al.* (2010)
T. japonicum	Egg	DOR APR (1988)
T. pretiosum	Egg	DOR APR (1988)
T. breziliensis	Egg	DOR APR (1988)
T. australicum	Egg	Patel and Yadav (1979)
T. achaeae	Egg	Patel and Yadav (1979)
Trissolcus sp.	Egg	Patel and Yadav (1979)
Trichogramma evanescens mintum	Egg	Khan and Rao (1948); Krishnamurthy and Usman (1954)
Bracon sp.	Larval	DOR (2003)
Apanteles spp.	Larval	DOR (2003)
Euplectrus leucostomus	Larval	Manjunatha *et al.* (2019)
Brachymeria spp.	Larval	Manjunatha *et al.* (2019)

The natural enemies caused 40 per cent parasitisation of eggs and 70-90 per cent mortality of larvae under field conditions. The damage on flowers and capsules along with foliage due to larval feeding was also reported. *Microplitis maculipennis* Szepl. was the major larval parasitoid and caused 70-75 per cent parasitisation of *A. janata* populations in the field. Some bird species were also found to be very effective predators of semilooper larvae especially in their III and IV larval instars (Rai and Jaya Ramaiah, 1978).

Microplitis sp. caused 68-70.0 per cent parasitism in castor semilooper larvae in field conditions (Somasekhar *et al.*, 1993). The braconid larval parasitoids, *Microplitis maculipennis*, *Bracon* sp., *Apanteles* spp. and tachinid parasitoids were reported to be a common occurrence on semilooper larvae (DOR, 2003). Manjunatha *et al.* (2019) reported three larval parasitoids *Microplitis maculipennis*, *Euplectrus leucostomus* and *Brachymeria* spp. from castor semilooper. *M. maculipennis* was the dominant species with per cent parasitisation up to 32.3% which was much higher than *E. leucostomus* with 4.3 per cent parasitisation. The parasitisation due to *Brachymeria* spp. was found to be negligible.

The egg parasitoid, *Trichogramma evanescens mintum* was reported to parasitize the eggs of castor semilooper (Khan and Rao, 1948; Krishnamurthy and Usman, 1954). Parasharya *et al.* (1988) reported that the egg parasitism by *Trichogramma chilonis* Ishii and *Telenomous* sp. ranged from 50.0 to 92.2 per cent. Patel and Yadav (1979) conducted laboratory studies on emergence of parasites from eggs of *Achaea janata* (L.). It was observed that four species of parasitoids emerged from *A. janata* eggs- *Trichogramma australicum* Gir., *T. achaeae* Nagaraja & Nagarkatti, *Telenomus* sp. and *Trissolcus* sp. The natural parasitism ranged from 25 to 100 per cent and it was observed that up to 9 adults of *Trichogramma* spp. but only one scelionid adult emerged from a single *A. janata* egg. However, from no egg both parasites emerged simultaneously. It was observed that the indigenous parasitoid, *Trichogramma chilonis* was more competitive than the exotic parasitoid, *Telenomus* sp. as far as egg parasitisation caused by them on semilooper eggs is concerned (Lakshminarayana, 1992; Lakshminarayana and Ramesh Babu, 1992). Egg parastization by *T. proditor* and *T. chilonis* when released alone was 91.3 and 87.87%, respectively.

Basappa and Lingappa (2002) reported the egg parasitisation by *Trichogramma chilonis* Ishii and *Telenomus* sp. to be 92.22 per cent in castor semilooper eggs. Among the various parasitoids attacking the castor semilooper life stages *T. chilonis* was the predominant species with parasitism reaching as high as 92%, while the solitary larval endoparasitoid, *S. maculipennis* was able to parasitize up to 96% of larvae under favourable conditions (Basappa, 2003; Prabhakar and Prasad, 2005).

An exotic strain of scelionid parasitoid, *Telenomus remus* from New Guinea was imported into India and mass multiplication technique on the eggs of semilooper was developed. The parasitoid was earlier reported to keep the semilooper larval population under control in New Guinea. The parasitoid, *T. remus* completed its life cycle in 9-16 days on castor semilooper eggs. The extent of egg parasitisation in laboratory conditions ranged from 10.6 to 93.4 per cent. The releases made in field on preliminary basis and subsequent recoveries provided more affirmation to potential of *T. remus* as a biological control agent of *A. janata* (Thobbi and Srihari, 1968). *Telenomus proditor* Nixon cultured in lab and released in field caused parasitisation to the tune of 61.47-78.88% over a study period of three years (Thobbi *et al.,* 1976). The maximum egg and larval parasitisation in field populations of castor semilooper caused by *Trichogramma* spp. and *Microplitis* sp. was found to be 30.58% and 94.43%, respectively. Egg parasitisation by different parasitoids was also recorded in laboratory experiments. A very high per cent egg parasitisation was recorded in case of all the parasitoids under consideration *viz*., *T. chilonis* (Indian strain) (96.5%), *T. chilonis* (exotic strain) (91.0%), *T. japonicum* (86.0%), *T. pretiosum* (84.0%), *T. breziliensis* (84.0%), *Telenomus proditor* (98.0%) and *T. Remus* (54.5%) (DOR APR, 1988).

Laxman and Maheswari (2017) reported differential parasitism percentage on different cultivars sown on different dates. On early sowings the parasitism ranged from 21.43-58.06 per cent whereas on late sowings the parasitism was recorded to be in the tune of 12.50-52.94 per cent. The differences in parasitism were due to differences in larval incidence on different cultivars.

Microbial biological control- Various microbial agents targeting the *A. janata* at various life stages, most commonly the caterpillars are tabulated as Table 2.

Table 2: Pathogens and nematodes utilised against castor semilooper, *Achaea janata.*

Nematodes	*Neoplectena carpocapsae*	Larval	DOR APR (1987)
	Mermis sp.	Larval	Chatterjee *et al.* (1968)
Fungi	*Nomuraea rileyi*	Larval	Kamat *et al.* (1978)
Virus	AjGV (*Achaea janata* Granulosis Virus)	Larval	Kumar *et al.* (2013)
	Mixed infection of NPV and GV	Larval	Vimala Devi (1992)
	Mixed infection of GV and RLO (Rickettsia-like organism)	Larval	Vyas *et al.* (1989)
Bacteria	*Bacillus thuringiensis var. kurstaki*	Larval	Pal (1977); Deshpande and Ramakrishnan, (1982); Vimala Devi *et al.* (1996)
	Bacillus cereus	III-V larval instars	Kattegoudar *et al.* (1994)

Biocontrol using fungi- *Nomuraea rileyi* in dust formulation caused 100 per cent mortality in castor semilooper larvae as compared to 30-40 per cent in spray formulation and the fungus was found safe to *Telenomus proditor* both within the egg as well as in adult stages after emerging from the egg (Phadke and Rao, 1978). Kamat *et al.* (1978) conducted lab studies to study the effect of spore suspension and dust formulation of *Nomuraea rileyi* on castor semilooper larvae. *N. rileyi* larvae treated with spore suspension became sluggish within one week of treatment and 80-90% larvae were killed after 2 weeks of application. Dust formulation was found more effective than spore suspension and caused 100% larval mortality. The fungus was found safe to *Telenomus proditor* Nixon (egg-parasitoid of semilooper).

Biocontrol using viruses. From field collected larvae of castor semilooper, a nuclear polyhedrosis virus (NPV) and a granulosis virus (GV) both were isolated. The infection caused by them led to retarded growth in larvae 3-4 days after infection and later disrupted moulting in the later stages of the disease. The infection also resulted in decrease in food intake of the larvae (Battu, 1986). Along with the NPV and GV infections, some *A. janata* larvae also showed infection symptoms of unknown pathogen later found to be a rickettsia-like organism (RLO). Some larvae exhibited mixed infections of both RLO and GV (Vyas *et al.,* 1989). Granuloviruses belonging to family Baculoviridae are highly insect-specific viruses. They are found exclusively associated with the Lepidopterans especially in their larval instars. They are highly host-specific as well as safe to mammals, that is why they are considered to be an eco-friendly alternative in pest management strategies than their chemical counterparts (Lacey *et al.,* 2008). Vimala Devi (1992) first isolated and reported infections of naturally occurring baculovirus of *A. janata* from lab cultures and it was later characterized and designated as a granulovirus (Singaravelu and Ramakrishnan, 1998). Prasad *et al.* (2001) later studied the effect of granulovirus on castor semilooper. Prabhakar and Prasad (2005) found that the application of GV in field was safe due to high host specificity and its endoparasitoid completing its development within the host before it was killed by the virus. The first lab assay report of *A. Janata* susceptibility to its granulovirus was prepared and mortality was noticed after 12-14 days of infection in all the treatments (Kumar *et al.,* 2013).

Biocontrol using bacteria- The pathogenicity of the bacterium, *Bacillus thuringiensis* (Thobbi and Srihari, 1968) and its strain *Bt* var. *kurstaki* (Deshpande and Ramakrishnan, 1982; Vimala Devi *et al*., 1996) was reported in castor semilooper larvae. Another species from the same genus, *Bacillus cereus* was found pathogenic to the *A. janata* larvae in lab studies. *B. cereus* cell culture formulation (10.5×10^8 viable cells ml^{-1}) caused at least 50% mortality of the pest in III, IV and V larval instars (Kattegoudar *et al*., 1994). A cost-effective standardized method of production of *Bt* on wheat bran was developed by Vimala Devi *et al.* (2005). The *Bt* thus obtained caused 100 per cent mortality in lab conditions and reduced the field populations of castor semilooper to a great extent when used at 0.1% concentration. The cost of production of 1 kg of *Bt* was approximately US $ 0.70.

Field application of DOR Bt-127 SC formulation caused reduction in *A. janata* larval population by 74-82 per cent over control within 3 days after spray (DAS) (Vineela *et al.,* 2020).

Biocontrol using nematodes- *Mermis* sp. was reported to cause parasitisation in semilooper caterpillars (Chatterjee *et al.,* 1968). *Neoplectena carpocapsae* (nematode) and its symbiont *Achromobactor nematophilus*(bacteria) caused a disease complex in castor semilooper larvae. Their commercial formulation DD136 caused 0.00, 13.33, 40.00, 86.67 and 20.00 per cent mortality in lab experiment after 48 hours of application in I, II, III, IV and V larval instars of castor semilooper, respectively (DOR APR, 1988).

Biocontrol using birds. Various bird species reported to feed on *A. janata* are tabulated as Table 3. Parasharya *et al.* (1988) reported 18 bird species to feed on semilooper larvae and rosy pastor, *Sturnus roseus* (Linnaeas) was found to be the most abundant. Bird populations in field disappeared with the reduction in larval populations. Laxmi Narayana *et al.* (2011) reported a total of 29 avian species to be present in the castor agroecosystem mainly active during the flowering and seed formation phases of the crop. The birds were found actively feeding on larval stages of castor semilooper and other lepidopterans.

Table 3: Bird species reported to feed on caterpillars of castor semilooper, *Achaea janata.*

Scientific name	Stage attacked	Reference
Rosy Pastor, *Sturnus roseus*	Larval	Parasharya *et al.* (1988)
Indian Myna, *Acridotheres tristis*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Bank Myna, *Acridotheres ginginianus*	Larval	Parasharya *et al.* (1988);
Brahminy Myna, *Sturnus pagodarum*	Larval	Parasharya *et al.* (1988)
Hoopoe, *Upupa epops*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Kashmir Roller *Coracias garrulus*	Larval	Parasharya *et al.* (1988)
Northern Roller, *Coracias benghalensis*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Black Drongo, *Dicrurus adsimilis*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Pipits, *Anthus spp.*	Larval	Parasharya*et al.* (1988); Laxmi Narayana *et al.* (2013)
Redvented Bulbul, *Pycnonolus cafer*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Cattle Egret, *Bubulcus ibis*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
House Crow, *Corvus splendens*	Larval	Parasharya *et al.* (1988); Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Western Swallow, *Hirundo rustica*	Larval	Parasharya *et al.* (1988)
Collard Bush Chat, *Saxicola torquate*	Larval	Parasharya *et al.* (1988)
Pied Chat, *Oenanthe picata*	Larval	Parasharya *et al.* (1988)
Pied bush chat, *Saxicola caprata*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Golden Oriol, *Oriolus oriolus*	Larval	Parasharya *et al.* (1988)
Large Cuckoo Shrike, *Coracina novaehollandiae*	Larval	Parasharya *et al.* (1988)
Grey Shrike, *Lanius excubitor*	Larval	Parasharya *et al.* (1988)
Bay-backed shrike, *Lanius vittatus*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Small green bee-eater, *Merops orientalis*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
White-throated king fisher, *Halcyon smyrnensis*	Larval	Narayanamma and Rao (2020)
Greater coucal, *Centropus sinensis*	Larval	Narayanamma and Rao (2020)
Ashy prinia, *Prinia socialis*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Plain prinia, *Prinia inornate*	Larval	Narayanamma and Rao (2020)
Common tailor bird, *Orthotomus sutorius*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Pied wagtail, *Motacilla madarasapatanensis*	Larval	Narayanamma and Rao (2020)
Indian robin, *Saxicoloides fulicatus*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Oriental magpie robin, *Copsychus saularis*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)
Grey babbler, *Turdoides malcolmi*	Larval	Laxmi Narayana *et al.* (2013); Narayanamma and Rao (2020)

A total of 42 species belonging to different orders were noticed in the castor agroecosystems. In the habitat of Castor higher density of Black Drongo (1.86±0.37) was recorded; other dominated species were Large Grey babbler (1.78±0.77), White-throated Munia (1.69±0.47) and Common Babbler (1.31±0.43) (Laxmi Narayana *et al.,* 2013). A total of 20 species of beneficial birds under 15 families and 4 orders were observed with the species diversity (N=36) and bird density per square km was found to be higher than the adjoining areas. These birds not only played a role in devouring the larvae of semilooper, tobacco caterpillar and red hairy caterpillar but also aided in spread of *Sl*-NPV infected larvae from one place to another (Narayanamma and Rao, 2020).

CONCLUSION

Numerous studies have been conducted for biocontrol of *A. janata*es pecially in castor agroecosystems. The eggs of *A. janata* are parasitized naturally to a great extent by a number of egg-parasitoids, *Trichogramma* spp. being the major proportion of them. The larval populations are attacked by number of parasitoids, predators and insectivorous birds. Among the larval parasitoid, *Microplitis maculipennis*is found closely associated with *A. janata* larvae and cause substantial reductions in their population. Insectivorous birds are a major part of natural biocontrol as far as *A. janata* is concerned. Erection of bird perches in castor fields further enhanced their efficacy as predators of larval populations of castor semilooper. Biological control agents can be effective components of the pest management systems focussed on castor semilooper.

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