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Role of natural enemies parasitoids and predators in management of insect pest of Cauliflower: A review

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Abstract
Cauliflower is grown all year in the state of Punjab, in one part or other part of region. Insect pests are one of the most serious restrictions for production failure in this crop. Insect pests are critical because they cause significant economic losses in the cauliflower crop. Insect pest destruction affects both the quality and quantity of cauliflower crops, resulting in poor returns to farmers. Farmers are primarily reliant on the application of various insecticides and pesticides to protect their crops from losses caused by insect pests. Cost-effective crucifer production has been almost impossible in some parts of the world due to insecticidal control failures. As a result, efforts to create integrated pest management (IPM) programmes, which are primarily based on manipulating natural enemies, have increased across the world. Natural enemies play an important role in the control of cauliflower insect pests. The natural enemies such as the mantis, seven-spotted lady beetle (*Coccinella septempunctata*), spiders, and ants, which are general aphid predators, may provide sufficient control. Among hymenopteran parasitoids, *Diadegma fenestralis* (Holm.), *Diadromus collaris* (Gravenhorst) and *Cotesia* spp. The dominant species of diamondback moth where about 90% of the parasitism detected was caused by *Diadegma* spp. and *Cotesia plutellae* (Kurdj.) in Ethiopia. This paper investigates the effectiveness of a variety of parasitoids and predators against cauliflower insect pests, as well as their interactions and possible integration into existing IPM systems.

Keywords: Cauliflower, natural enemies, predators and parasitoid

Introduction

Cauliflower (*Brassica oleracea* L var *botrytis*) is a common cruciferous vegetable crop in India and around the world. It is commonly grown in the sub-tropical regions of north India. Cauliflower comes from the Latin words 'Caulis' and 'Floris,' which mean stem and flower, respectively (Shelton 2004). Cauliflower is the third most common crop in India. Cauliflower is grown on 453 thousand hectares in India, with an annual production of 8668 metric tonnes (NHB 2019). In more than 100 countries around the world, the diamondback moth is a major pest insect that attacks cruciferous plants, especially *Brassica oleracea* crops like cabbage, cauliflower, broccoli, Brussels sprouts, and turnips. It's a major pest all over the world, causing large crucifer yield losses. The estimated annual crop losses in India due to this pest are 16 million dollars (Mojan and Guhar 2003) [48]. The diamondback moth (Lepidoptera: Plutellidae) is one of the most widespread cosmopolitan insect pests of cruciferous crops in the world (Cobblah and colleagues, 2012). *P. xylostella* is one of the world's most destructive insect pests of *Brassica* vegetable and oilseed crops (Furlong *et al*., 2013; Zalucki *et al*., 2012) [19]. From seedling to harvest, *P. xylostella* larvae feed on the leaves of their host plants, drastically reducing yield and efficiency (Furlong *et al*. 2013) [19]. Global DBM management expenses and lost production are expected to be in the range of US$ 4–5 billion per year (Zalucki *et al*., 2012). *P. xylostella* was first found on cruciferous crops in India, and the pest is now widespread throughout the world. In India, the diamondback moth is a national pest of cabbage, causing a 50-80% average reduction in marketable yield (Devjani and Singh 1999, Ayalew 2006, Krishnamoorthy 2004) [35]. Cabbage aphid triggers 35-75 percent yield declines, according to Khan *et al*. (2015). Cabbage aphids are also vectors for the viruses that cause blackening spot in cauliflower, cauliflower mosaic, and cabbage viruses A and B. *P. brassicae* larvae skeletonize leaves and bore faecal excreta into the heads of cauliflower. The recently hatched larvae feed on the leaves' outer epidermis, giving them a cellophane-like appearance (Kaul, 1998). According to Sood (1992), a single caterpillar of *P. brassicae* lowers the yield at curd formation to a limit of 1.79 percent.

The yield loss in cauliflower due to *P. xylostella* was stated to be 34.4 percent. Kaul *et al*., (1998) reported synthetic insecticides are often used to combat pest management in many countries, resulting in the eradication of natural enemies. As a result, continued heavy use of insecticides could lead to insecticide resistance and control failure. DBM was the first crop insect to demonstrate resistance to DDT in 1953 in Java, Indonesia (Ankersmit 1953), and it now has strong resistance to almost any insecticide used in the field, including modern chemistries including spinosyns, avermectins, neonicotinoids, pyrazoles, and oxadiazines in many crucifer-producing regions (Sarfraz & Keddie 2005 and Sarfraz *et al*. 2005) [63].

This has resulted in intensified attempts around the world to implement integrated pest management (IPM) systems, which are mostly focused on manipulating natural enemies. Natural enemies play a critical role in the control of cauliflower insect pests (Manyangarirwa, 2009). The natural enemies, including general aphid predators such as the mantis, seven-spotted lady beetle (*Coccinella septempunctata*), spiders and ants may provide adequate control under certain circumstances. In most production areas, several worm pests such as loopers (*Trichoplusia ni*), imported cabbage worm (*Pieris brassicae*), tobacco caterpillar (*Spodoptera litura*), diamondback moth (*Plutella xylostella*) and others are potential problems, depending on the time of year and weather conditions (Atwal and Dhaliwal 2009).

Natural Enemies associated with Insect Pest of Cauliflower 2017-18

Table 1: Shows in Scientific Name, Family and Prey/ Host

Common Name of Predator	Scientific Name	Family	Prey/ Host
Ladybird beetle	*Coccinella septempunctata* Linnaeus *Oenopiasauzetii (*Mulsant*)* *Oenopiakirbyii (*Mulsant*)*	Coccinelliade	Aphid
Variegated ladybird	*Hippodamia variegata (*Goeze)	Coccinelliade	Aphid
Green lace wing	*Chrysoperla zastrowi sillemi* (*Esben-Peterson*) *Chrysoperla carnea*	Chrysopidae	Aphid DBM, Head Borer, C. Butterfly, Tobbaco Caterpillar and Cabbage Aphids.
Hoverfly	*Eupeodesfrequens (*Matsumura*)* *Metasyrphusconfrator (*Wiedemann*)*	Syrphidae	Aphid
Mantid	*Mantis religiosa* (Linnaeus)	Mantidae	Lepidoptern Insect
Lynx spider	*Oxyopes* sp.	Oxyopidae	Aphids
Sac spider	*Clubonina* sp.	Clubionidae	Aphids

Table 1: Shows in Scientific Name, Order Family and Prey/ Host

Common Name of Parasitoids	Scientific Name	Order Family	Prey/ Host
Braconid wasp	*Cotesia glomerata* (L.) *Cotesia Plutellae* (L)	Hymenoptera:Braconidae	Cabbage butterfly Diamondback moth
Ichneumon wasp	*Diadegma semiclausam* (Hellen)	Hymenoptera: Ichneumonidae	Diamondback moth
Ichneumon wasp	*Diadromus collaris* (Gravenhorst)	Hymenoptera: Ichneumonidae	Diamondback moth
Braconid wasp	*Diaeretiella rapae* (McIntosh)	Hymenoptera:Braconidae	Cabbage aphid
Brachymeria sp.	*Brachymeria excaritana*	Hymenoptera: chalcididae	Diamondback moth

Source: Shikha Sharma *et al*., (2020) [69] and Singh *et al*., (2016)**.**

Review on natural enemies associated with insect pest of cauliflower

Predators

Camponotus sp.

Arthropods of the symbiotic community *Camponotus sp*. were involved in the 50th SW during year 2010 and 2011, with a population of 0.33/10 plants at temperatures ranging from 11.0 -25.9 ^{0}C and RH 64.4 percent in 2009-10 and 7.3 -24.00 ^{0}C and RH 68.9 percent in 2010-11. During both years, it was active until the end of the harvest. The statistics also show that population fluctuated between 0.33-0.58/10 plants during the year 2010 and 0.33-0.66/10 plants during the year 2011. Other workers had previously confirmed the presence of *Camponotus* sp. in this region, but on different crops (Singh *et al* 2016) [54]. Hemchandra and Singh (2006) had recorded 2 species of ants on cauliflower crop.

Coccinellid beetle, *Coccinella septempunctata* L.

The seven-spot ladybird, *Coccinella septempunctata*, is a widespread species native to Europe, Asia, and Northern Africa. It has the ability to be used as a biological control agent for crop insect pests. According to Ali and Rizvi (2009) [4], the Coccinellid beetle, *Coccinella septempunctata* L. (Coccinellidae: Coleoptera), is a multicultural with substantial dispersal capacity and the potential to predate aphids and other soft-bodied insects of valuable vegetables similarly Singh and Singh (2013) [70] found that the voracity of *C. septempunctata* increased with age and predated all phases. According to Singh *et al.,* (2006) *C. septempunctata* was found in the 9th week after the crop was sown. According to Soni *et al*. (2004) [73] *C.septempunctata* ate more aphids than *Brumoides suturalis*, *Cheilomenes sexmaculata*, and *Menochilus sexmaculatus*. *C. septumpuntata* was the most abundant predator, According to Sherma *et al*., (2020) [69], with a proportional proportion of 74.55 and 52.98 percent in 2017 and 2018, respectively similarly Akram *et al*., (1996) and Suhail *et al*., (1999) both young (grubs) and adults of *C. septempunctata* eat 40-173 aphids per day. According to Arshad *et al*., (2017) [49] beetle stages (adults, third and fourth instars) ate more aphids than early stages (1st and 2nd instar). In the free option feeding assay, pea aphid intake (77.647) was statistically higher than spinach (66.276), coriander (66.14), and cabbage (61.48) aphid consumption. During 2009 and 2010 years of research, Singh *et al* (2016) [54] confirmed that grubs and adults of the Lady bird beetle, *C. septumpunctata*, appeared on the crop for the first time in the 51st SW. During this week in the corresponding years, the colonies were 0.50 and 0.41/ 10 trees. In both year 2009 and

2010 the lady bird beetle was present from the 51st to the 5th SW, and its population ranged from 0.50-2.080.66/10 plants in 2009-10 and 0.41- 2.750.85/10 plants in 2010-11. According to Bilashini and Singh (2010 and 2011), as the density of *erysimi* increased, so did the density of *C. septempunctata* on *Brassica juncea* var. *rugosa*. They discovered a strong connection between predator and prey populations. Temperature, relative humidity, and rainfall all had negative correlations with predator and prey populations, while sunlight and wind speed had positive correlations. According to Sharma and Verma (1993) [64] *C. septempunctata* was found to be the most abundant species, accounting for 47.3% of the adult count, followed by *A. variegata* (26.2 percent). Lady bird beetles (*Coccinella septempunctata* L., *Cheilomenes sexmaculata* F., and *Hippodamia variegata* Goeze) were prevalent in Himachal Pradesh, according to Sharma *et al.,* (2015).

Predatory spiders

Singh *et al*., (2016) [54] found parasitic spiders, *Oxyops sp*. and *Clubonina sp*., associated with insect-pests of mid-early season cauliflower crop twice during 2009-10, first from 45th SW (2009) and then from 2nd-3rd (2010). During these weeks, the population was 0.33/10 plants. Over 2010-11, it happened only from the 45th to the 46th (2010), with a median population of 0.50/10 plants in the 46th SW (2010) at a temperature range of 16.4-29.20C and a relative humidity of 78.3 percent.

Mantis

Singh *et al.,* (2016) [54] recorded that *M. religiosa* was associated with cauliflower insects in two stages, the first from the 46th - 47th SW and the second from the 50th - 51st SW during the 2009 year and the 47th - 48th SW and the 50th SW during the 2010 year. During 2009-10, the highest population of 0.66 adult/10 plants was estimated in the 50th SW at temperatures ranging from 11.0 to 25.90 degrees Celsius and RH of 64.4 percent, while an equivalent population of 0.33/10 plants was recorded in all three weeks.

Others

Reddy *et al*., (2004) [57] recorded that *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) are attracted to DBM pheromone blend, larval frass, and green leaf volatiles of crucifers.

DBM larvae are also eaten by ants, bees, lacewings, hemipterans, beetles, spiders, and birds (Reddy *et al*., 2004; Endersby & Cameron 2004) [57, 16].

Parasitoids

I) Larvel Parasitoid

Kirk *et al*., (2004) [33] found 27 principal parasitoid species on 115 DBM populations collected in 32 countries, mostly from the genera *Diadegma, Cotesia*, and *Oomyzus*. *Diadegma* spp. and *Cotesia plutellae* (Kurdj.) were responsible for more than 90% of parasitism found in Ethiopia (Ayalew *et al*. 2004). According to Chauhan *et al*. (1997) [9] and Devi *et al*. (2004) [13], the dominant species of diamondback moth among hymenopteran parasitoids is *Diadegma fenestralis* (Holm.), *Diadromus collaris* (Gravenhorst), and *Cotesia spp*.

A) *Cotesia sp*.

***Cotesia plutellae* (Kurdjumov) (= *Cotesia vestalis* (Haliday) (Hymenoptera: Braconidae)**

Cotesia vestalis is a parasitoid wasp that appears to be capable of detecting volatile organic compounds released by the plant *Brassica oleracea* in response to herbivore disruption, such as that caused by heavy infestation with the wasp's host caterpillar *Plutella xylostella*. (Robbie *et al* 2011) [58]. *C. plutellae* is the most common larval endoparasitoid attacking the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) (Soyelu 2010) [77]. When separate larval instars of *P. xylostella* were provided to the parasitoid at the same time, Saini *et al* (2019) [1] found major variations in *C. vestalis* parasitization rates (p 0.01). While the parasitoid could parasitize all host instars, it favoured the second instar (84 percent), followed by the third instar (52 percent). The parasitoid favoured the first and fourth instar larvae less, with parasitism rates of 8 and 20%, respectively. Similarly *C. vestalis*, a synovigenic arrhenotokous braconid, is one of the prevalent larval parasitoids, inducing 16 to 70% larval parasitism of *P. xylostella* in various areas of the world, according to Seenivasagan *et al*., (2010) as well as Smith and Villet (2003) [72] estimated that more than 80% of overall parasitism on *P. xylostella,* a devastating parasite of cruciferous crops in many parts of the world, was on *P. xylostella*. *Cotesia plutellae* is synovigenic in nature, according to Shi *et al*., (2002), and it still egresses from a stillliving L4 (the final instar) of *P. xylostella* to pupate externally, regardless of the host instar at oviposition and on the other hand, found that the parasitoid preferred both the third and second instar host larvae. According to Kawaguchi and Tanaka (1999), *C. vestalis* can parasitize all *P. Xylostella* larval instars. According to the findings of Alizadeh *et al*. (2011) [5], *C. vestalis* prefers to parasitize the second instar larvae of *P. xylostella*. The parasitism percentages of the second, third, and fourth instars were 78.58, 69.94, and 4.36 percent, respectively. *C. vestalis* is endemic to the colder regions of the Palearctic, but it has been introduced to other parts of the world for the suppression of *P. xylostella*, according to Furlong *et al*., (2013) [19]. According to Wang and Keller (2002) [82] *C. plutellae* unlike specialist parasitoids, displayed a fixed host seeking nature, chased the host(s) down the silk thread, and spent a considerably greater proportion of time on the ground (17.79/3.6 percent) than *D. semiclausum* (4.79/1.1 percent). *C. plutellae* could parasitize DBM larvae in the first three instars but not the fourth, according to Velasco (1982). *C. plutellae* could parasitize all four instars, according to Talekar and Yang (1991), but chose to parasitize L2, followed by L3.

B) *Cotesia glomerata* (Hymenoptera: Braconidae)

Cotesia glomerata, also known as the white butterfly parasite, is a small parasitic wasp genus in the Braconidae family. Carl Linnaeus described it for the first time in the 10th edition of Systema Naturae, published in 1758. *Cotesia glomerata* parasitizes up to 65 percent of *Pieris brassicae* eggs, according to Singh (1993) and Jalali *et al*., (2001). *C. glomerata* was also described by Sood *et al*., (2011) [75] as an effective parasitoid of P. brassicae in Palampur. Sherma *et al*., (2020) [69] discovered parasitoids *C. glomerata* parasitizing *Pieris brassicae* and *Pieris rapae* larvae, with *C. glomerata* being the most common parasitoid with relative proportions of 42.43 and 57.58 percent in 2017 and 2018, respectively. According to Dempster (1967), *C. glomerata* is similar to *C. rubecula* in that both parasitize the host in the first or second instar. The biggest distinction is that *C. glomerata* often kills the host in the fifth instar, while *C. glomerata* will raise several larvae within a single host. Sood and Bhalla (1996) [74] identified *C. glomerata* and *Hyposoter ebeninius*

(Gravenhorst) as major parasitoids responsible for cabbage butterfly mortality.

C. glomerata is unable to distinguish between volatiles of *B. oleracea* caused by first and fifth instar caterpillars, despite the fact that young host larvae are more appropriate for parasitization and less aggressive than older caterpillars (Mattiacci and Dicke 1995). According to Lucas Barbosa (2009), the production of HR (direct defence) appears to be responsible for the structural volatile transition of the plant that attracts *C. glomerata* wasps (indirect defense). In the case of the using population, the hypersensitive solution does not include killing any of the eggs or limiting herbivore feeding; 80-90 percent of the eggs survive. According to research (Eirini Vafia 2010), egg-induced volatiles can be host dependent. The plants' direct and indirect responses were tailored to the Large cabbage White butterfly, which serves as a host for *C. glomerata*. M. brassicae did not cause any chemical modifications in the plant that attract *C. glomerata*, nor did the plant specifically protect its eggs 24 hours after oviposition.

C) *Diadegma Sp.* (Hymenoptera: Ichneumonidae)

The genus *Diadegma* have some species able to parasite *Plutella xylostella* (L.) (DBM). Sherma *et al*., (2020) [69] found that *D. semiclausam* parasitized *P. xyllostella* at a rate of 28.94% and 30.77% in 2017 and 2018, respectively. According to Ooi (1992), the dbm population in Malaysia was decreased by approximately 50% after the release of *D. semiclausam*. In addition Walker *et al*., (2002) and Furlong and Zulucki (2007) found that *D. semiclausam* parasitism was present in up to 70% of cases. *Diadegma insulare* (Cresson) larval parasitoids were reported by Azidah *et al*., in 2000 [6]. (Hymenoptera: Ichneumonidae). *Diadegma* species are the primary regulators of *P. xylostella* globally. According to Braun *et al*., (2004) [8], *D. insulare* was the primary parasitoid of DBM in Alberta in 1992, accounting for approximately 45 percent of total parasitism, whereas *M. plutellae* and *D. subtilicornis* both accounted for approximately 14 percent of total parasitism. A similar condition was found in Saskatchewan, where *D. insulare* parasitized 30% of the population and *M. plutellae* and *D. subtilicornis* parasitized B/8 of the population. Hutchison *et al*. (2004) [25] recorded that in North America, parasitism by *D. insulare* would reach up to 80% for fourth instars and 50% for third instars.

Diadegma sp. was also observed during December and January only, when temperatures were mild, and its parasitism incidence was < 2%, according to Rowell *et al*., (2005) [60]. *Diadegma semiclausum* (Hellen) is a significant European parasite of *P. xylostella* that has been introduced into many tropical and subtropical Asian countries, but it has only been known in cooler areas where temperatures seldom reach 28 °C. Shi *et al*., (2004) discovered that *D. semiclausum* parasitizes hosts that already have larvae of D. semiclausum, but D. semiclausum destroys the *O. sokolowskii* immatures within the host. Temperature has an effect on parasitism rates as well as the sex ratio. According to Wang and Keller (2002) [82], *D. Insulare* behaves very adaptably, lying motionless near the silken thread, waiting for the suspended larva to crawl up and then attacking it again. The wasp also leads the silken thread down and stings the suspended larva (Sarfraz, personal observation). A similar pattern of behaviour has been observed in its congeneric genus, *D. Semiclausum* is an abbreviation for *semiclausum*. Shi *et al*., (2002) [67, 68] found that larvae parasitized by *C. plutellae* ate more food (118.49/2.4 mg) than controls (96.29/4.8 mg) in *D. insulare*. Liu *et al*., (2000) [40, 41] discovered a negative association in parasitism rates of *P. xylostella* larvae by *C. plutellae* and *O. sokolowskii*, implying possible rivalry. According to Liu *et al*., (2000) [40, 41], there are 7.8 3.3 *O. sokolowskii* per *P. xylostella* pupa. Silva-Torres *et al*., (2009) discovered in the laboratory that the amount of ovipositions per host by female *O. sokolowskii* was related to progeny per host. The number of progeny produced per host ranged from 10 per oviposition to more than 20 per host per three ovipositions. *Diadegma insulare* was successfully reared in the greenhouse, with a parasitism score of 95 percent and 45/63 percent females (Xu & Shelton 2001) [83].

II) Pupal Parasitoids

Brachymeria is a genus of parasitic wasps in the family Chalcididae. Over 300 species are known worldwide, all of them parasites of insect pupae. *Brachymeria excarinata* was found twice in March by Khaliq *et al*., (2016) [28] from *P. xylostella* pupae.

III) Larvel Pupal Parasitoids

Sarfraz *et al*., (2005) [63] and Furlong *et al*., (2013) [19] announced that the *Oomyzus sokolowskii* Kurdj (Hymenoptera: Eulophidae), a gregarious larval-pupal primary parasitoid, has been found in many countries, including India. According to Silva and Torres *et al*., (2009), *Oomyzus sokolowskii* is a larval-pupal gregarious parasitoid that is naturally found parasitizing *P. xlostella* all over the world.

Shi *et al*., (2004) were also observed by *O. sokolowskii*. The pupal parasitoid *D. collaris* was only found in Southern Sindh, Pakistan, during the month of January when temperatures were colder, and its parasitism was 1.0 percent. Smith and Villet (2004) recorded that four animals, *Diadegma mollipla* (Holmgren), *C. plutellae*, *D. collaris*, and *O. sokolowskii*, were major parasitoids in the Eastern Cape (South Africa), and DBM parasitism rates ranged across the year, varying from 10 to 80 percent. Kirk *et al*.,(2004) [33] reported that a few prepupal and pupal parasitoids of the genus *Diadromus* (Ichneumonidae) also contribute to DBM control.

Others

***Diaeretiella rapae* (M'Intosh) (Hymenoptera: Aphidiidae)**

Diaeretiella rapae (M'Intosh) (Hymenoptera: Aphidiidae) is the most widespread natural enemy of the cabbage aphid (Saleh, 2008; Maghraby, 2012) [62, 43] and can also be used to monitor other aphids such as *Myzus persicae* (Sulzer), *Diuraphis noxia* (Mordvilko), *Aphis craccivora* (Koch). According to Gupta *et al*., (2007) [22], the parasitization rate of aphids by *D. rapae* on cauliflower ranged from 1% to 7.4% from January to April in Solan. According to Kant *et al*., 2008 and Ralec *et al*., (2011) [56], *D. rapae* is a solitary insect, meaning that it lays one or more eggs in a host, but only one evolves into an adult (Godfray, 1994), and females emerge with fully formed eggs. According to the findings of Saleh *et al*., (2014) [2], the parasitoid lasted longer at 10 °C. The lower thermal threshold for *D. rapae* growth was 2.93, 5.14, 6.09, and 3.5°C for the overall time from (egg to adult). On the same aphid genus, the heat units needed during the development process were 241.08, 207.59, 149.07, and 286.53 DD's, respectively.

Conclusion

The most abundant predator was *Coccinella septempunctata*, and the most abundant parasitoid was *D. Rapae*. *Diadegma fenestralis* (Holm.), *Diadromus collaris* (Gravenhorst.), and *Cotesia spp*. were the most common and dominant hymenopteran parasitoids in diamondback moths by parasitizes all instar. *Cotesia* can target and destroy insecticide-resistant and insecticide-susceptible DBM larvae, and it can aid in the prevention of insecticide resistance. Natural enemies are less expensive and less expensive than most means of pest control. Natural enemies defend the crop during the crop cycle. It offered a less polluted, environmentally sustainable climate while the farmers' gross profits.

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