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Studies on assessment of dominant natural enemies of diamondback mothon cauliflower in Dindigul and Theni Districts of Tamil Nadu, India

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Abstract
The seasonal incidence of diamondback moth and its parasitoids was recorded since September, 2015 to December, 2017 in Theni and Dindigul districts of Tamil Nadu, India. During the periods of investigation, the larval parasitoid, *Cotesia plutellae* Kurdjumov (Braconidae: Hymenoptera) was recorded as dominant causing 32.85 per cent and 15.23 per cent parasitisation in unsprayed and sprayed field during 2015-2016 in Theni district whereas the parasitisation recorded in unsprayed and sprayed field of Dindigul district during 2016-17 were 34.48 per cent and 14.78 per cent respectively. This was followed by *Oomyzus sokolowskii* (Eulophidae: Hymenoptera) a larval-pupal parasitoid causing 27.08, 13.33 per cent and 28.07, 13.42 per cent parasitisation in unsprayed and sprayed field of Theni and Dindigul districts in the 2015-16 and 2016-17 respectively. *Diadegma semiclausum* (Ichneumonidae: Hymenoptera) a larval parasitoid activity was recorded in both districts and the intensity were low and ranged between 12.15, 5.39 per cent and 12.36, 5.41 per cent in unsprayed and sprayed field of above mentioned districts and season. Both the diamondback moth larva and Parasitisation was recorded maximum in unsprayed as compared to sprayed fields. The larval survivability and success of pupa was more on compact curd as compared to loose curd. The gravid female *Cotesia plutellae* were more active during dusk hour for seeking their host for oviposition and oviposits near the head region of II, III and IV instars larvae of diamondback moth. The plant age, larval population and natural enemies occurrence showed a positive significant correlation.

Keywords: cauliflower, *Plutella xylostella*, *Cotesia plutellae*, *Oomyzus sokolowskii*, *Diadegma semiclausum*, parasitoids, unsprayed and sprayed

Introduction
Diamondback moth, *Plutella xylostella* (Linn.) (Plutellidae: Lepidoptera) is most important insects pests that causes severe damage to cauliflower crop in Tamil Nadu (India) and Worldwide [18, 8, 44 and 11]. Diamondback moth, has developed resistance to several groups of insecticides including *Bacillus thuringiensis* [43, 28, and 21]. The immature stage of this pest is attacked by a diverse guild of indigenous parasitoids [22]. However, the biggest challenge in integrated pest management of Diamondback moth is unsuitability of combining biological control with Chemical control [35]. It is learnt that parasitoids such as endo-parasites were more vulnerable to chemical toxicology. The toxicity of various insecticides such as organophosphates, carbamates and synthetic pyrethroids to braconid parasitoids has been reported by several authors [26, 32, 46, 23, 25, 6] and [39, 45]observed that insecticides use on cabbage farms reduce the efficiency of *C. plutellae and Diadegma insulare* (Cresson) in Malaysia. However, many pesticides are also known to be more toxic to natural enemies and consumers than pests [34].

Cotesia plutellae Kurdjumov a Braconid native to Europe, was introduced in Southern United Statesfrom Hawaii against diamondback moth larvae [5]. *Cotesia plutellae* is koinobiont endo-larval [42] and *Oomyzus sokolowskii* a pupal parasitoids of *Plutella xylostella*. The extent of larval and pupal parasitisation was 10.80 and 26.83 per cent respectively, in 2002-2003 while it was 11.33 and 28.38 per cent in 2003-04 [37, 24] reported that *Cotesia plutellae, Oomyzus sokolowski and Diadromus collaris* as major larval, larval-pupal and pupal parsitoids of *Plutella xylostella* and during peak the rates of parasitisation were in the range of 10-60 per cent and reached over 80 per cent in few occasions [19]. Reported 40-83 per cent parasitisation by *Cotesia plutellae* in Shinsei Cabbage.

Cotesia vestalis is a major parasitoid of *Plutella xylostella* and parasitism accounts more than 80 per cent [6] and [1] also revealed that *Cotesia plutellae* as major parasitoids of diamondback moth followed by *Oomyzus sokoloskii* [7] revealed that *Diadegma semiclausum* and *Cotesia plutellae* as major parasitoids of DBM the former occurred during September and the later occurred during the hot season and revealed that host density have influence over later [12]. Reported that during April-May, *Diadegma fenestralis* parasitisation ranged between 73.33 to 86.67 per cent in Himachal Pradesh [4] also revealed that *Diadegma fenestralis* and *Cotesia plutellae* as major parasitoids of DBM in Kashmir causing 57.3 per cent and 29.4 per cent respectively. [3] revealed that *Diadegma insulare* (Cresson) (Hymenoptera: Ichneumonidae) was the predominant endemic parasitoid, in the Lower Rio Grande Valley of Texas on pesticide-free cabbage accounting for >98 per cent of the parasitoids reared from field-collected host larvae. The larvae of *Plutella xylostella* wriggle violently when disturbed [47] and the gravid female parasitoids has to gain control of each host larvae to insert ovipositor and to complete oviposition [30].

Keeping this in view, the assessment studies of major parasitoids of *Plutella xylostella* in cauliflower crop and their phenology was carried in unsprayed and sprayed field of Theni and Dindigul districts.

Materials and Methods

The studies were carried out to assess the natural enemies associated with diamondback moth, *Plutella xylostella* (Linn.) in spray and unsprayed fields. Eight quadrats each of minimum 5 × 5 m was layout to monitor parasitoids and the four plots were kept free from the plant protection operation, [37] whereas remaining four plots were sprayed with insecticides. The spacing of cauliflower was 60 × 45 cm. The plant numbers observed were based on pest density and as much as hundred plants were selected randomly to collect fifty larvae on each surveyed date. The larvae was closely monitored on loose curds, compact curds, early transplanted crop, vegetative growth stage, curds initiation stages, and maturity stages. The larvae of Diamondback moth were collected in dusk hours. The larvae of II, III and IV instars as well as pupa of *Plutella xylostella* was collected separately from unsprayed and sprayed field and reared separately in insectary and the larvae were kept in bials at room temperature for parasitoids emergence. The per cent assessment of parasitisation was calculated using the following formula.

$$\text{Per cent parasitism} = \frac{\text{Total parasitoids emerged from collected larvae}}{\text{Total no. of larva collected from field}} \times 100$$

The per cent parasitisation increased in unsprayed crop over sprayed cauliflower is calculated by using the following formula.

$$\text{\% Parasitisation increased} = \frac{\text{(Mean \% parasitisation in unsprayed - Mean \% parasitisation in sprayed)}}{\text{Mean per cent parasitisation in unsprayed}} \times 100$$

The plant age, pest occurrence and activity of parasitoids were correlated by using correlation formula.

Results and Discussion

The study on assessment of dominant parasitoid of diamondback moth were carried out for two consecutive year *viz*., 2015-16 to 2016-17 in Theni and Dindigul districts of Tamil Nadu during Rabi season. The detailed field observations, pertaining to various parasitoids of diamondback moth, *Plutella xylostella* is given below:

The two years studies on the assessment of major parasitoids of *Plutella xylostella* in unsprayed and sprayed cauliflower crop at Theni and Dindigul Districts of Tamil Nadu revealed that *Cotesia plutellae* Kurdjumov a larval koinobiont endoparasites as major parasitoids of diamondback moth causing parasitisation upto 32.85 per cent in unsprayed field whereas 15.23 per cent parasitisation was recorded in sprayed field in Theni district during 2015-16 (Table 1 and Fig. 1). During 2016-17 the parasitisation recorded were 34.48 per cent in unsprayed field and 14.78 per cent in sprayed field in Dindigul district in Rabi season (Table No. 2 and fig. No. 1). The findings are in conformity with the findings of [37, 24 and 19]. The low level of parasitisation in sprayed cauliflower is similar with the findings of [15]. However, the present findings is dissimilar with [45] who found mean level of parasitism of 48.6 per cent in sprayed field while [24] recorded high rates of parasitism even under heavy insecticides pressure [10] also found higher parasitism of 81.3 per cent in synthethic pyrethoroids (Karate) sprayed cruciferous field and their findings is not in accordance with the present finding. The variations in findings may be due to abiotic conditions as well as the behavioral adaptation of *Plutella xylostella* and *Cotesia plutellae*. During the studies defence mechanism of *Plutella xylostella* against parasitoids were monitored and found that the larvae drops with a help of silken thread from host plant to escape from *Cotesia plutellae*. The larval density study revealed that larvae was higher on loose curd than compact whereas the survivability of larva and pupa of *Plutella xylostella* was more on compact curds and this may also influence parasitisation activity.

This was followed by *Oomyzus sokolowskii* a larval-pupal parasitoids causing parasitisation upto 27.08 per cent in unsprayed field whereas it was recorded 13.33 per cent in sprayed field in Theni district during 2015-16 (Table 1 and Fig. No.1). The parasitisation was comparatively higher in Dindigul district during the year 2016-17 reaching upto 28.08 per cent in unsprayed and 13.42 per cent in sprayed field. The findings are in conformity with the findings of [9, 24, 36 and 4] (Table No. 2 and fig. No.1).

The next dominant parasitoids of *Plutella xylotella* in Theni and Dindigul districts is *Diadegma semiclausum* a larval parasitoid of diamondback moth. *Diadegma semiclausum* causing parasitisation of 12.15 per cent in unsprayed and 5.39 per cent on sprayed field of Theni district in 2015-16 (Table No. 1 and fig. No.1). During the year 2016-17 the parasitisation recorded were 12.36 per cent in unsprayed and 5.41 per cent in sprayed field in Dindigul district (Table No. 2 and fig. No.1). The findings are in conformity with the finding of [35]. However, the present findings are dissimilar with the findings several others authors such as higher

parasitisation of 25-80 per cent was recorded by [14] whereas [12] reported 73.33 to 86.67 per cent parasitisation [16] reported that *Diadegma semiclausum* was dominant parasitoid of *Plutella xylostella* in Queensland (Australia) and [20] also reported *Diadegma semiclausum* as dominant parasitoid in Japan. *D. semiclausum* became the dominant parasitoid of diamondback moth in the Cameron Highlands (about 1800 m above sea level) of Malaysia [33].

The per cent parasitisation of *Plutella xylostella* larvae in unsprayed was comparatively higher than sprayed field by *Cotesia plutellae* where 53.63 and 57.13 per cent increased was recorded in the year 2015-16 and 2016-17 respectively. The per cent parasitisation increased also noted in unsprayed over sprayed field by *Oomyzus sokolowkii* such as 50.77 and 52.19 per cent in 2015-16 and 2016-17 respectively. The per cent parasitisation also recorded higher in unsprayed field as compare with sprayed field by *Diadegma semiclausum viz*., 55.72 and 56.22 per cent in 2015-16 and 2016-17 respectively (Table No. 1, 2 and fig. No.1).

Cauliflower plant age, larval population and natural enemies phenology

The studies were carried out in a farmer field in Theni and Dindigul districts of Tamil Nadu during rabi 2015 to 2017 (Table No. 3 and Fig. No.2). The detailed field observations, pertaining to crop pest and parasitoids phenology of cauliflower is given below:

The cauliflower plant age parameters were *viz*., 15, 30, 45, 60, 75, 90 and 105 days respectively. The *Plutella xylostella* larval density and natural enemy's occurrence were monitored on the above mentioned age and recorded to correlate to their phenology with plant age, larval population and natural enemies occurrence in Theni and Dindigul districts for three consecutive years. The studies revealed that both plant age and larval population have positive significant relation with natural enemies in cauliflower ecosystems. During early days of plant growth the *Plutella xylostella* load in cauliflower was recorded low and the mean average were 0.80/ plants. The diamondback moth larvae and natural enemies remain low upto 30 days after transplanting. However, the larvae density increased in count and recorded maximum in 75 and 90 days after transplanting and declines just prior to harvest *i.e* 105 days after transplanting. The low density of larvae population in initial stages and subsequent increased in number were in conformity with the findings of [13] and [35]. Low level of parasitisation of *Plutella xylostella* larvae in early stages is influenced by low pest density. The findings are in conformity with the findings of [6]. The correlation studies on plant age, larval population and natural enemies occurrence showed positive significant correlation at the 0.05 level. The positive correlation between larval population and parasitoids is conformity with the findings of [17, 40] and [27] whereas [2] found that parasitism was negatively and significantly correlated with plant age.

Table 1: Per cent parasitization of parasitoids emerged on different stages of *Plutella xylostella* in cauliflower during Rabi 2015-16 in Theni District

Parasitoids	**Per cent Parasitoids emerged from different stages of *Plutella xylostella* in unsprayed field**				**Pooled mean***	**Per cent Parasitoids emerged from different stages of *Plutella xylostella* in sprayed field**				**Pooled mean**	**Per cent increased over sprayed field**
	II instars*	**III instars***	**IV instars***	**Pupa**		**II instars***	**III instars***	**IV instars***	**Pupa**		
Cotesia plutellae	7.97	36.29	54.30	0.00	32.85	3.23	18.28	24.18	0.00	15.23	53.63
Oomyzus sokoloswki	0.0	0.0	21.73	32.43	27.08	0.0	0.0	9.69	16.98	13.33	50.77
Diadegma semiclausum	4.03	10.26	15.13	0.00	12.15	3.01	4.47	8.69	0.00	5.39	55.72

*pooled mean are mean of II, III and IV instars for larval parasitoids whereas for larval-pupal parasitoids it is mean of IV instars and pupa of *Plutella xylostella*

Table 2: Per cent parasitization of parasitoids emerged on different stages of *Plutella xylostella* in cauliflower during Rabi 2016-17 in Dindigul District

Parasitoids	Per cent Parasitoids emerged from different stages of *Plutella xylostella* in unsprayed field				Pooled mean*	Per cent Parasitoids emerged from different stages of *Plutella xylostella* in sprayed field				Pooled mean	Per cent increased over sprayed field
	II instars*	III instars*	IV instars*	Pupa		II instars*	III instars*	IV instars*	Pupa		
Cotesia plutellae	8.00	38.49	56.96	0.00	34.48	3.24	18.20	22.90	0.00	14.78	57.13
Oomyzus sokoloswki	0.0	0.0	21.95	34.19	28.07	0.0	0.0	10.51	16.33	13.42	52.19
Diadegma semiclausum	0.0	8.45	15.13	0.00	12.36	0.0	8.45	15.13	0.00	5.41	56.22

*pooled mean are mean of II, III and IV instars for larval parasitoids whereas for larval-pupal parasitoids it is mean of IV instars and pupa of *Plutella xylostella*

Table 3: Cauliflower, *Plutella xylostella* and their natural enemies phenology during Rabi 2015 to 2017 in Dindigul Districts

Plant age in days	*Plutella xylostella*/plants			Pooled mean	*Cotesia plutellae*/plants			Pooled mean	*Oomyzus sokolowskii*/plants			Pooled mean	*Diadegma semiclausum*/plants			Pooled mean
	2015	2016	2017		2015	2016	2017		2015	2016	2017		2015	2016	2017	
15	0.8	0.9	0.70	0.80	0	0	0	0	0	0	0	0	0	0	0	**0**
30	1.2	1.4	1.6	1.40	0.20	0.20	0.30	0.23	0.10	0.20	0.20	0.17	0.10	0.20	0.10	**0.13**
45	2.6	2.4	2.5	2.50	0.60	0.50	0.40	0.50	0.50	0.40	0.40	0.43	0.20	0.30	0.30	**0.27**
60	4.3	4.2	4.5	4.33	0.80	0.90	1.0	0.90	1.0	1.10	1.20	1.10	0.90	0.90	1.0	**0.93**
75	7.9	9.9	10.4	9.40	2.90	3.10	3.40	3.13	2.30	2.60	2.80	2.57	2.0	1.90	2.20	**2.03**
90	7.1	10.8	11.7	9.87	2.40	2.90	3.50	2.93	2.10	2.50	3.0	2.53	1.70	2.20	2.30	**2.07**
105	6.8	6	6.7	6.50	1.90	1.70	2.0	1.87	1.40	1.30	1.30	1.33	1.20	1.20	1.30	**1.23**

Table 4: Correlation between Plant age, Diamondback moth larvae and its parasitoids in cauliflower in Dindigul district during 2015 to 2017, Rabi season

Intercepts	Plant age
Plutella xylostella	0.851* (0.015)
Cotesia plutellae	0.818* (0.025)
Oomyzus sokolowskii	0.789* (0.035)
Diadegma semiclausum	0.0828* (0.021)

*Correlation is significant at the level 0.05 level (2-tailed) and Parentheses indicates probability values

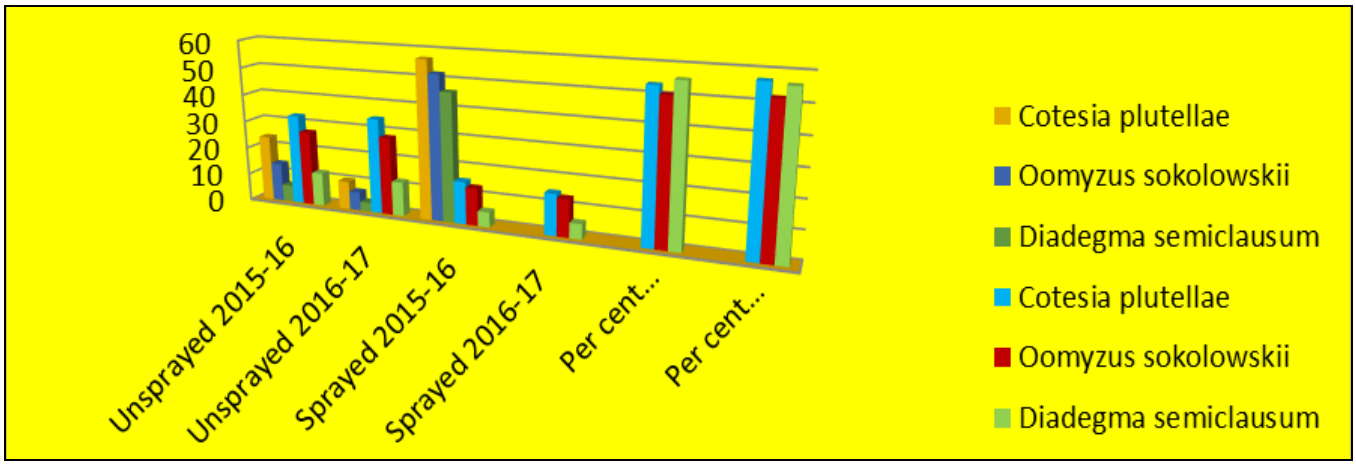


Fig 1: Per cent parasitisation of parasitoids and increased parasitisation of unsprayed field over sprayed field in Theni and Dindigul Districts during Rabi, 2015-16 and 2016-17

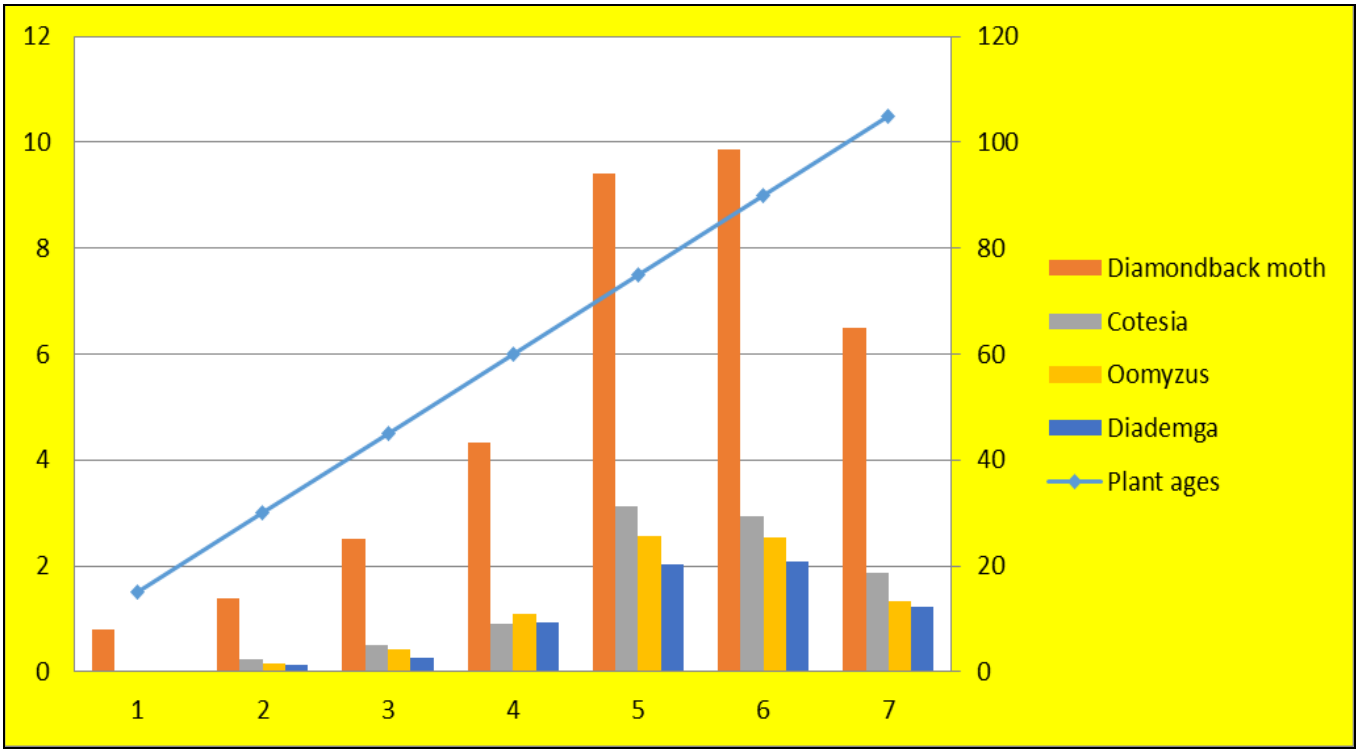
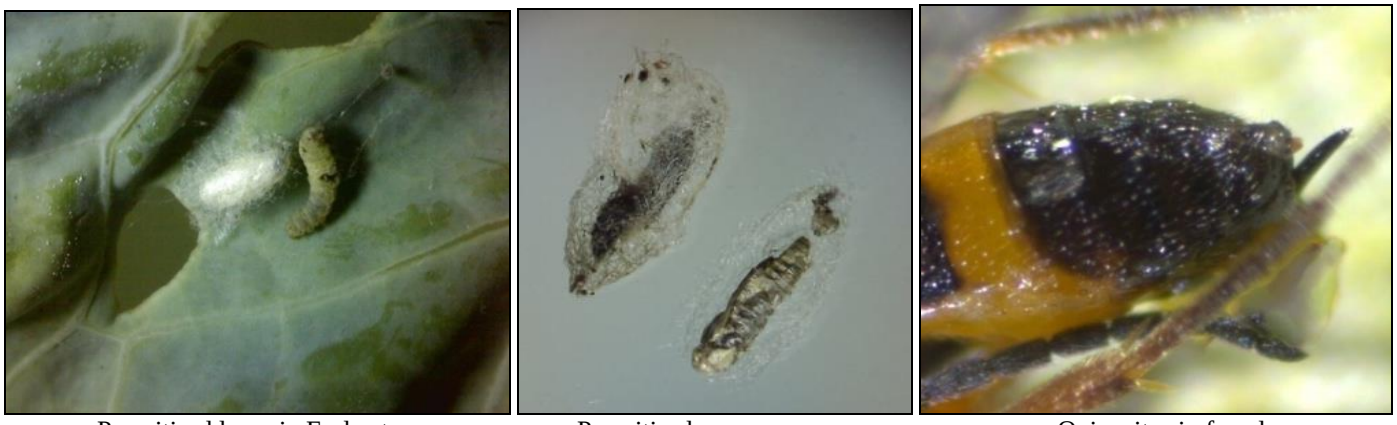


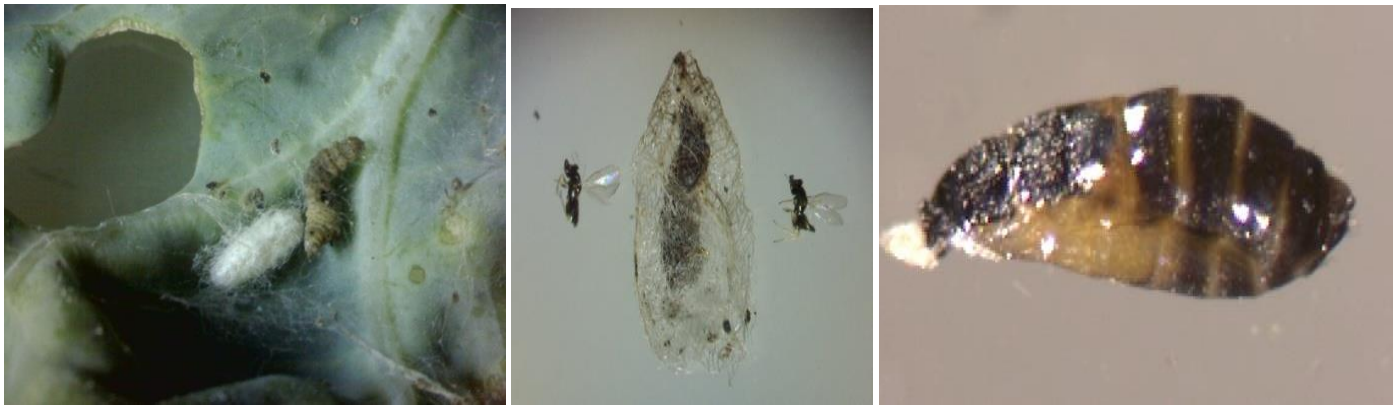
Fig 2: Correlation between Plant age, Diamondback moth, *Cotesia*, *Oomyzus* and *Diadegma*

Cotesia plutellae *Oomyzus sokolowskii* *Diadegma semiclausum*

Plates 1: Dominant parasitoids recorded during 2015-16 to 2016-17 in Theni and Dindigul districts



Parasitised larva in Early stages Parasitised pupa Ovipositor in female



Parasitised larva in later stages Parasitoid emerged from pupa Male abdomen without ovipositor

Plates 2: Nature of parasitisation by dominant parasitoidsand ovipositor

Conclusion

Diamondback moth, *Plutella xylostella* (Linn.) is preferred host for Braconidae, Eulopidae and Ichneumonidae. Augmentation and conservation of natural enemy's *viz*., *Cotesia plutellae*, *Oomyzus sokolowskii* and *Diadegma semiclausum* in cauliflower ecosystem is possible by using selective insecticides and the growers should encouraged to use biological control agents along with selective chemicals to reduce chemical pressure on ecosystems. Considering, the findings proper mass production techniques of the above mentioned parasitoids should encouraged for the management of *Plutella xylostella* in cauliflower.

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