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Incidence and diversity of lepidopterous insect pests and their parasitoids (natural enemies) on cole crops at danderkhah location in Srinagar District (J&K, India)

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Abstract
The Cole crops like cabbage, cauliflower, knolkhol, kale and turnip are widely cultivated and consumed as vegetables in J&K state and Danderkhah location in this region is well known for the cultivation of these crops. The present investigation was undertaken in order to study the incidence and diversity of major lepidopterous insect pests and their potential parasitoids (natural enemies) on Cole crops at Danderkhah Study site. Two plots (50X 50 m) of Cole crop at this site were selected and fortnightly field survey was conducted in the year 2016-17. As many as 16 lepidopterous insect pest species, belonging to 5 insect families and 12 Insect genera, were recorded on Cole crops during present study, among which, *Thysanoplusia orichalcea, Pieris brassicae, Pieris rapae, Plutella xylostella, Agrotis ipsilon* and *Helicoverpa armigera* were the abundant ones. The other detailed studies with special reference to seasonal incidence and diversity, pertaining to these lepidopterous pests were conducted. Moreover, during this study, as many as 16 parasitoid species were found parasitizing the lepidopterous pests on Cole cops. The data collected during this investigation can be helpful in future studies for devising the pest management strategies, especially against afore-mentioned pests in this region.

Keywords: cole crops, diversity, lepidoptera, parasitoids, pest, Srinagar

1. Introduction
The leafy vegetables, especially Cole crops, make up a major portion of the diet of humans and are sources of phytonutriceuticals: vitamins (C, A, B1, B6, B9, and E), minerals, dietary fiber and phytochemicals (Dias, 2012) [10]. The moist climatic and soil conditions, especially in Kashmir region, are highly favorable for cultivation of broad-leaved vegetables like cabbage, cauliflower, knollhol, kale (Rishi, 1967) [11]. Among the various temperate vegetables produced in Jammu and Kashmir, the Cole vegetable crops are the important ones that add higher revenue to the state (Shanker *et al*., 2006) [18]. Insect pests are the major biotic constraints to vegetables production given that, they not only inflict direct damage to host crops, but also many of them act as vectors for several viral diseases and in J&K at least 50-80% losses in the marketable yield have been reported under severe infestation (Shanker *et al*., 2006) [18]. Some of the insect associated with vegetable crops have become major pests for the host crop, while as others are gradually attaining the major pest status in different regions of India, due to changes in the ecosystems and habitats (Rai *et al.,* 2014) [15].

Among the lepidopterous insect pests of Cole crops, Diamondback moth (DBM), *Plutella xylostella* is the important one, particularly damaging cabbage and cauliflower (Devi & Raj, 1995) [9]. The cabbage butterflies, *Pieris brassicae, P. canidia* and *P. rapae* have also been found to be major pests of cabbage and cauliflower in India (Bhatia & verma, 1993; Bhutani & Jotwani, 1984; Firake *et al*., 2012 and Lal, 1975) [6, 7, 12, 13]. In one of the studies, it has been documented that *P. xylostella* inflicts 17-99% damage, while as *P. brassicae* and Cabbage leaf webber, *Crocidolomia binotalis* causes 69% & 28-51% damages respectively to the Cole crops in India (Rai *et al.,* 2014)[15]. Likewise, some important studies have been previously conducted, wherein of few insect pests of Cole crop have been recorded in Kashmir (Simmonds & Rao, 1960; Rishi, 1967; Bhat, 2008 and Bhat *et al.,* 2011) [19, 11, 2, 4]. However, no major comprehensive and detailed work for investigating the incidence, diversity and natural enemies of lepidopterous insect pests in Cole crop ecosystems, especially in Srinagar District, has previously been conducted. Moreover, the biodiversity studies of insect pests and their natural enemies offer great potential for managing pest problems, especially through biological control methods. Keeping in view these aspects, the present study was undertaken to study these aspects, in order to generate some base line data of lepidopterous insect pests and their parasitoids (natural enemies) in Cole crop ecosystem in Srinagar district (J&K). The data collected during this investigation will serve as ready reference and can be helpful in future studies of insect pests, especially of lepidopterans, and for devising their pest management strategies, particularly in this region.

2. Materials and Methods
2.1 Study Area
The present study was conducted at Danderkhah study site in District Srinagar (J&K) (22° 57' 0" N, 79° 31' 0" E.). Danderkhah location is the hot bed of Cole crop cultivation in Kashmir Valley. Two experimental plots of Cole crops (50 X 50 m plot each) at this location were selected for the present survey and study

2.2 Sampling Method

The main Cole crops investigated for sampling were cabbage, cauliflower, kale, knolkhol and turnip. For monitoring the population trends of the lepidopterous pests and their parasitoids (natural enemies), 500 plants of cole crop from each plot were selected and examined at random, by taking 100 plants each from the four corners and 100 plants from the middle of the plot. Sampling of lepidopterous larvae/ caterpillars was done at fortnightly intervals. Monthly population fluctuation of the lepidoptrous larvae/ caterpillars of major pests were recorded. The immature stages (larvae/ caterpillars/ pupae) were taken to laboratory for rearing. The adult pests or the parasitoids of these pests recovered during the rearing process were identified. Filed observations of lepidtoptrous larval infestations were recorded and the data obtained, in respect of monthly mean number of larvae/ pupae observed, was recorded.

2.3 Species diversity estimates

The following formula was used to find out the individual species per cent/ relative density

$$\text{Individuals Species Per cent/ Relative density} = \frac{\text{Number of individuals of the species}}{\text{Number of individual of all the species}} \text{ X } 100$$

The evaluation of the diversity indices of lepidopterous pest species sampled, with special reference to Shannon index, Simpson's diversity index, Megalef richness index and other related indices, were assessed by using online diversity index software (https://www.alyoung.com)

2.4 Parasitism estimates

The Percentage of Parasitsm (PP) of different lepidopterous larvae by various parasitoid species was calculated by the following formula

$$PP = \frac{\text{Number of parasitized larvae}}{\text{Total number of parasitized and non-parasitized larvae}} \text{ X } 100$$

3. Results

3.1 Studies on lepidopterous insect pests of cole crops at location (Srinagar. J&K)

In the present investigation, as many as 16 lepidopterous insect pests, belonging to 5 insect families and 12 Insect genera, were recorded on Cole crops. In this regard, the detailed list of these pests and the observations, pertaining to their seasonal incidence, species composition and abundance, has been provided in table I and figures I, II and III. As depicted in the table I and figures I, II and III, *Thysanoplusia orichalcea, Pieris brassicae, P. rapae, Plutella xylostella, Agrotis ipsilon* and *Helicoverpa armigera* were highly abundant and dominant pest species in Cole crop ecosystems recorded during this study. The results of diversity indices of lepidopterous pest species sampled, with special reference to Shannon index, Simpson's diversity index, Megalef richness index etc., (assessed by using online diversity index software, https://www.alyoung.com), are presented in table 2 supported by figures IV and V. The nature of damage inflicted by various lepidopterous pest larvae on the Cole crops, recorded during the present study, is depicted through photo graphic plates (Figures 1-4).

Fig 1: Caterpillar (*Agrotis ipsilon*) infestation on cabbage

Fig 2: Caterpillar (*Pontia daplidice*) infestation on kale

Fig 3: *Pieris rapae* larvae devouring turnip foliage

Fig 4: *Thysanaplusia orichalcea* larva feeding on knolkho

Fig 5: *Brachymeria femorata* (Parasitoid) recovered from *P. rapae* pupa

Table 1: Seasonal Incidence, species composition and monthly mean of lepidopterous insect pests (larvae) collected in two 50X 50 m Cole Crop plots at Danderkhah station (Srinagar) during 2016-17

Family	Lepidopterous pest species	Monthly mean no. of larvae collected						Total (n) / Abundance	%age
		May	June	July	August	September	October		
Lym	*Euproctis* sp.	-	5	-	-	2	1	8	0.25
Noc.	*Agrotis ipsilon*	12	53	47	39	11	4	166	0.39
	Thysanoplusia orichalcea	24	289	241	146	7	-	707	22.71
	Helicoverpa armigera	9	48	32	23	-	-	112	3.60
	Spodoptera litura	-	40	13	11	-	-	64	2.06
	Spodoptera exigua	-	13	9	2	-	-	24	0.77
	Mamestra brassicae	-	27	11	11	-	-	49	1.57
	Trichoplusia ni	-	35	19	13	-	-	67	2.15
Pie.	*Pieris brassicae*	45	250	24	8	89	158	574	18.39
	P. canidia	-	9	7	5	11	15	47	1.51
	P. rapae	-	25	45	33	22	12	137	4.40
	Pontia daplidice	-	13	24	12	3	5	57	1.83
	Pontia glouconome	-	4	5	6	1	2	18	0.58
Plu.	*Plutella xylostella*	67	310	307	207	32	3	926	29.75
Pyr.	*Evergestis forficalis*	-	12	10	17	20	30	89	2.86
	Hellula undalis	-	16	9	11	15	17	68	2.18
		157	1149	803	544	213	247	3113	
		Total (N)						3113	

Table 2: Diversity indices of lepidopterous pest species of Cole crops at Danderkhah location (Srinagar) by following online diversity index software (https://www.alyoung.com)

S. No	Observation	Result
1	Total Number of Lepidopterous larvae sampled during this investigation	3113
2	Total Number of Species	16
3	Average population size	194.6
4	Decimal Accuracy	4
5	Simpson Index $\frac{\sum_i n_i(n_i-1)}{N(N-1)}$	0.183
6	Simpson Index Approximation $\frac{\sum_i n_i^2}{N^2}$	0.1832
7	Dominance Index $1-\left(\frac{\sum_i n_i(n_i-1)}{N(N-1)}\right)$	0.817
8	Dominance Index Approximation $1-\left(\frac{\sum_i n_i^2}{N^2}\right)$	0.8168
9	Reciprocal Simpson Index $\frac{1}{\left(\frac{\sum_i n_i^2}{N^2}\right)}$	5.466
10	Alternate Reciprocal Simpson Index $\frac{1}{\left(\frac{\sum_i n_i(n_i-1)}{N(N-1)}\right)}$	5.458

11	Shannon Index $-\sum_i \left(\frac{n_i}{N} \cdot \log_2 \left(\frac{n_i}{N}\right)\right)$	2.964
12	Berger-Parker Dominance Index $\frac{n_{max}}{N}$	0.2975
13	Shannon Index $-\sum_i \left(\frac{n_i}{N} \cdot \ln \left(\frac{n_i}{N}\right)\right)$	2.055
14	Inverted Berger-Parker Dominance Index $\frac{N}{n_{max}}$	3.362
15	Shannon Index $\sum_i \left(\frac{n_i}{N} \cdot \log_{10} \left(\frac{n_i}{N}\right)\right)$	-0.8923
16	Margalef Richness Index $\frac{S-1}{\ln N}$	1.865
17	Menhinick Index $\frac{S}{\sqrt{\sum_i n_i}}$	0.2868
18	Rényi Entropy/Hill Numbers(r=0, 1, 2, ∞) $\frac{1}{1-r} \cdot \ln \left(\sum_i p_i^r\right)$	16, 7.833, 5.458, ≈∞
19	Buzas and Gibson's Index $\frac{e^{-\sum_i \left(\frac{n_i}{N} \cdot \ln\left(\frac{n_i}{N}\right)\right)}}{S}$	0.4877
20	Gini Coefficient $\frac{2\sum_i i n_i}{n\sum_i n_i} - \frac{N+1}{N}$	0.6187
21	Equitability Index $-\frac{\sum_i \left(\frac{n_i}{N} \cdot \ln \left(\frac{n_i}{N}\right)\right)}{\ln N}$	0.741
22	ln() of Hill Numbers (0,1,2,∞)	2.773, 2.058, 1.697, ≈∞

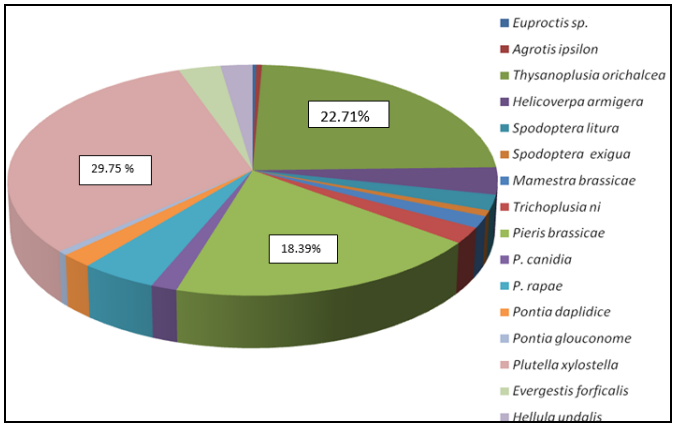

Fig 6: Species Composition of different lepidopterous pests recorded in two 50X 50 m Cole Crop plots at Danderkhah station (Srinagar) during 2016-17 (%ages of dominant species depicted)

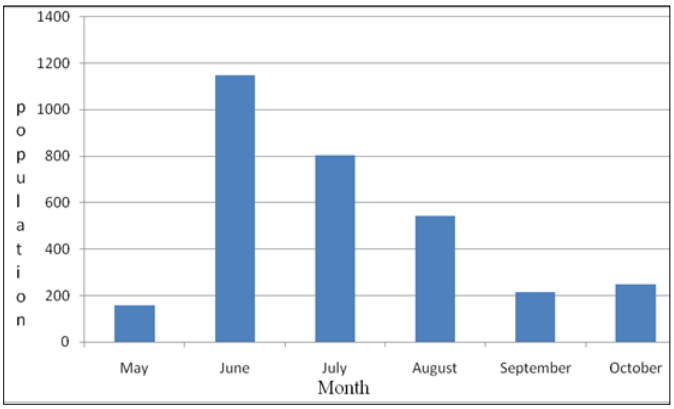

Fig 7: Seasonal incidence and Month-wise Lepidopterous pest populations recorded in two 50X 50 m Cole Crop plots at Danderkhah station (Srinagar) during 2016-17

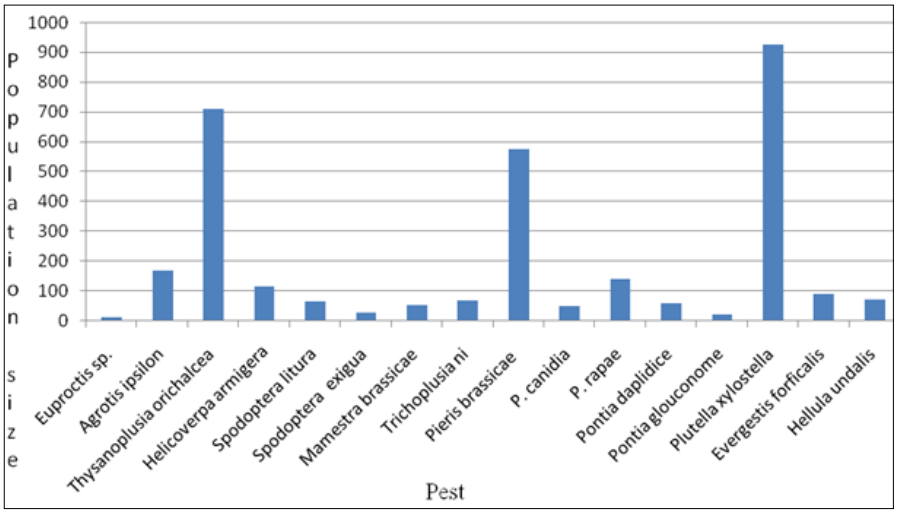

Fig 8: Species-wise populations of lepidopterous pests recorded in two 50X 50 m Cole Crop plots at Danderkhah station (Srinagar) during 2016-17

3.2 Studies on parasitoids (Natural enemies) of Lepidopterous insect pests associated with Cole crops at Danderkhah Station (Srinagar, J&K)

The rearing of various lepidopterous larvae, collected from the experimental plots during this study, yielded as many as 16 parasitoid species belonging to 2 insect orders (Diptera and Hymenoptera) and 6 insect families (Table II & Photographic figures 9-13)

Fig 9 *Itoplectis* sp. (parasitoid) recovered from *P. xylostella*

Fig 10: *Cotesia glomerata* (Parasitoid) pupae attached to dead *P. rapae* larva

Fig 11: *Hyposoter ebeninus* (parasitoid) emerged from *Pieris Brassicae* larva

Fig 12: Diadegma semiclausum (parasitoid) recovered from P. xylostella

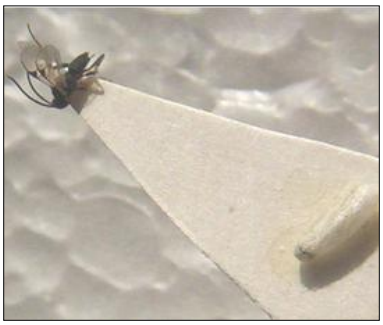

Fig 13: *Cotesia plutellae (parasitoid) recovered from P. xylostella*

Table 3: Parasitoid species recovered after rearing of lepidopterous insect pests collected from two 50X 50 m Cole Crop plots at Danderkhah station during 2016-17

Insect order	Insect family	Parasitoid species	Host-lepidopterous pest	Highest % parasitism (PP) recorded
Diptera	Tachinidae	*Compsilura concinnata*	*Pieris brassicae*	0.12
		Exorista larvarum	*P. brassicae*	2. 90
		Phryxe vulgaris	*P. brassicae*	0. 80
		Unidentified tachinid	*Helicoverpa armigera*	1.20
		Voria ruralis	*Trichoplusia ni*	2.10
Hymenoptera	Braconidae	*Apanteles sp.*	*Plutella xylostella*	5.24
		Cotesia glomerata	*Pieris rapae*	7.20
			Pieris brassica	3.0
		C. plutellae	*Plutella xylostella*	8.4
		Zele chloropthala	*Spodoptera litura*	0.8
	Chalcididae	*Brachymeria femorata*	*Pieris rapae*	4.4
	Eulophidae	*E. euplexae*	*H. armigera*	2.00
	Ichneumonidae	*Campoletis sp.*	*Trichoplusia ni*	7.10
		Diadegma semiclausum	*H. armigera*	11.00
			P. xylostella	26.00
		Hyposoter ebeninus	*P. rapae*	18.00
			Pontia deplidice	6.20

			Pieris brassicae	27.20
		Itoplectis sp.	*Plutella xylostella*	8.00
	Pteromalidae	*Tetrastichus sokolowskii*	*P. xylostella*	12.00
		Pteromalus puparum	*P. brassicae*	3.40

4. Discussion

The present investigation revealed that as many as 16 species of Lepidopterous insect pests attack Cole crops in this region, among which, *T. orichalcea, P. brassicae, P. rapae, P. xylostella, A. ipsilon* and *H. armigera* were highly abundant and dominant pest species of Cole crops at the study site. The results obtained during this study, in respect of these insect pests, are in agreement with studies made by Lal (1975) [13], Devi & Raj (1995) [9], Puri *et al*. (2000) [14], Bhatia & Gupta (2003) [5], Sharma & Rao (2012) [17], Rai *et al.* (2014) [15] and Debbarma *et al*. (2017) [8]. Firake *et al.* (2012) [12] assessed the biodiversity of asrthropod fauna in brassicaceous ecosystems of Meghalaya during 2010-12. He observed that 15 insect pests attacked brassicaceous crop ecosystems, with white cabbage butterfly (*Pieris brassicae*) and *Plutella xylostella*, reported to be major pests in North East region. Thus, his study also falls in line with the results obtained during present investigation. The cabbage butterflies, *Pieris brassicae, P. canidia* and *P. rapae* have also been reported as major pests of cabbage and cauliflower in other Indian states (Bhatia & Verma, 1994; Butani & Jotwani, 1984) [6, 7]. The studies of Devi & Raj (1995) also indicate that diamondback moth (DBM), *P. xylostella* is an important pest of cruciferous crops, particularly cabbage and cauliflower in mid hill region of Himachal Pradesh.

The current study reveals that at least 16 parasitoid species were recovered from different lepidopterous larvae in Cole crop ecosystem (Table 3). Among these parasitoids, *Hyposoter ebeninus, Diadegma semiclausum, Tetrastichus sokolowskii* were found to be *most important parasitoids, reducing their respective pest numbers by* more than 10 % during their peak period of activity. Parasitoids like *Apanteles* sp., *Cotesia glomerata, C. plutellae, Campoletis* sp. and *Itoplectis* sp. caused more than 5% parasitism to their respective host pest, while as other parasitoids recorded during this study (Table 1.) caused less than 5 % parasitism to their respective hosts in field conditions. Razmi *et al*. (2011)[16] have also observed similar results while studying parasitoid complex of *P. brassicae* in Iran. He has recorded ten species of primary parasitoids, including *Cotesia glomerata* (L.), *Brachymeria femorata* Panzer, *Hyposoter clauses* Brischke, *Pteromalus puparum* (L.), *Exorista larvarum* (L.) and *Phryxe vulgaris* Fallén). Firake *et al.* (2012) [12] have also reported similar kind of parasitoid species of *P. brassicae* in North east, which included *Brachymeria femorata, Cotesia glomerata, Exorista larvarum, Hyposoter ebeninus* and *Pteromalus puparum.* Likewise, Murillo *et al.* (2012) [20] have reported *Campoletis sonorensis* as significant parasitoid of *Trichoplusia ni* in Ontario. Bhat & Bhagat (2008) [1] have also previously reported *Apanteles* sp., *C. plutellae, D. semiclausum* and *Itoplectis* sp. as parasitoids of *P. xylostella* in Kashmir region. The bio diversity of natural enemies in some brassica crops has also been studied by of Bhat & Bhagat (2009)[3] and they also have reported three potential hymenopteran parasitoids *viz., H. ebeninus, C. glomerata* and *B. femorata* of cabbage butterflies from Kashmir valley.

5. Conclusion

The Cole crops comprise the important vegetables that add higher revenue to the state of J&K; however, Insect pests are the major biotic constraints for the cultivation and production of these crops. But at the same time a number natural enemies of the insect pests are available, which help in suppressing pest population and hence reduce the extent of pest damages. The present investigation provides vital information pertaining to prevalence of various types of lepidopterous insect pests of Cole crops, their diversity and seasonal occurrence. The study also provides essential information about the prevalence of parasitoids (natural enemies) of said insect pests, present in the field conditions, and also this study encapsulates information regarding the potential of these parasitoids in reducing pest population. The overall database provided in this study will be useful for future studies of Insect pests of not only Cole crop vegetables, but also, of other crops too, given that some of the pests covered in this study, are polyphgous in nature. Since, the complete knowledge of Insect pests is crucial for formulating proper management techniques and the present study in this connection will be helpful in the long run for understanding insect pest problems and devising pest management strategies against them, especially in vegetable ecosystems of this region. The data generated from the study would also be helpful in further understanding of the biodiversity of arthropod fauna associated with vegetable crops in other regions of the country

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