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Population dynamics of *P. xylostella* associated with its parasitoids on cabbage cultivar in Mansehra and Taxila areas

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Abstract
The main objective of this study was to determine the potential parasitoids of *Plutella xylostella* and assess their parasitism level in relation to cabbage cultivar. Studies concerning population dynamics of primary parasitoids, percent parasitism of parasitoids and interaction of *P. xylostella* in relation with cabbage cultivar carried out in two areas namely Mansehra and Taxila during 2011-12. During autumn 2011, the maximum population of *P. xylostella* (54 individuals/plant) was recorded at an average minimum (10.9°C) and maximum (25.8°C) temperatures, with 75% relative humidity at Taxila site. Among them larval parasitoid species i.e. *Diadegma insulare* (Ichneumonidae) was solitary parasitoid. *O. sokolowskii* (Eulophidae) was a gregarious parasitoid which attack both in larval and pupal stages whereas *Diadromus collaris* (Ichneumonidae) was found to be pupal parasitoid. The maximum parasitism (40%) was recorded in case of *D. insulare* in the spring season, followed by 19.2% parasitism in case of *O. sokolowskii* in autumn season and maximum parasitism recorded in case of *D. Collaris* was 8.0% in the spring season at Taxila site.

Keywords: cabbage, cultivar, *Plutella xylostella*, population dynamics

1. Introduction
Cruciferae family occurs in tropical and temperate climates. It is a diverse and crucial group of plants which includes cauliflower, brussels, broccoli, sprouts, rapeseed, cabbage, mustard, collards and chimes cabbage cultivars. Crucifers are most important crops which are grown all around the year and vital vegetable component of the diet of Asians as well as around the world. Cabbage (*Brassica oleracea* L. var. *capitata*) is the most popular winter vegetable grown in various areas of Pakistan. The area under cabbage cultivation is around 0.369 million hectare with 7.949 million tones production and average yield of 21.5 million tones/ha during 2010-11 [1]. It is rich in minerals and vitamins A, B_1, B_2 and C.
Diamondback moth (DBM), is the most destructive insect pest of cruciferous plants worldwide. In the Indo-Pakistan sub-continent it was first recorded in 1914 and outbreaks of *P. xylostella* (Plutellidae: Lepidoptera) caused crop losses of more than 90% [2, 3]. It is a very destructive pest in southern Sindh of Pakistan. Due to the severe infestations of *P. xylostella*, growers are sometimes compelled to plough down their standing crops in spite of multiple insecticide applications [4]. The larvae feed on leaves, flowers, buds, seed pods and green outer layer of the stem of plants [5] In case of high infestation the larvae can cause large defoliation of leaves and crop failure [6].
This crucifer specialist may have its origin in Europe [7], but seeing its bio-control agents and host plants, [8] pointed that it originated in South Africa. Observing same conditions, [9] have the opinion that *P. xylostella* originated in China. *P. xylostella* is now present wherever its host plants are present and is the most widely distributed of all lepidopterans [10].
Instead of just using chemical control methods, the concept of integrated IPM has been introduced [11]. Certain lacewings, ants, spider flies, hemipterans, beetles and birds also control its larvae [12 and 13]. In field conditions different life forms/stages of *P. xylostella* are affected by a number of diseases, parasitoids and predators. Among these, parasitoids are very important biological control agents of Brassica pests [14]. These play pivotal role in managing *P. xylostella* [15]. The most common hymenopterans parasitoids include from genus *Oomyzus*, *Cotesia*, *Diadromus* and *Diadegma*.

These wasps is also reported from different countries of Africa. Success of biological control of *P. xylostella* by these parasitoids is also reported by [11]. A complex of 135 species of parasitoids are reported, which attack on different life stages of *P. xylostella*. *Oomyzus sokolowskii* (Kurdjumov) (Hymenoptera: Eulophidae) is one of the major gregarious larval-pupal parasitoids of *P. xylostella* [16]. In the Eastern Cape (South Africa) there were four species viz. *C. plutellae*, *D. mollipla* (Holmgren), *O. sokolowskii* and *D. collaris*, which were the major parasitoids and parasitism levels differentiated throughout the year which ranged from 10-80% [17].

It was reported that the percent parasitism sometimes increased from 50% in 3rd larval instar and above 80% in 4th larval instar by *D. insulare* [18]. Comparatively it proved to be the best host searcher [19 and 20]. It can also easily distinguish between parasitized and non-parasitized hosts (i.e. it avoids superparasitism and multiparasitism) [21]. When, *P. xylostella* come in contact with the parasitoid, it moves quickly, fell down suspending with the help of a silken thread, but the parasitoid lay its eggs quickly in the larvae as soon as it comes up. *D. semiclausum* have also the same behavior [20].

The main objective of this study was to determine the potential parasitoids of *P. xylostella* and assess their parasitism level in relation to cabbage cultivar. It also included the interactions among *P. xylostella* and its parasitoids in relation to cabbage crop to develop strategies for effective pest management. The resultant strategy will help in enhancing parasitism and determining the most effective parasitoid species and indirectly will impact in reducing pesticide use for *P. xylostella* management.

2. Materials and Methods

Experimental fields were divided into 4 plots and it includes ten (10) rows of each plot. One plant per row of each plot was sampled randomly on a weekly basis in each season both at Mansehra and Taxila sites during 2011-12. Thus, a total of 40 plants per plot were monitored to check the population fluctuation of *P. xylostella* and its parasitoids. Sampled plants were examined for different life stages of insect pest i.e. eggs, various larval stages and pupae on weekly basis and records were maintained in both crop seasons at each site.

All *P. xylostella* specimens (eggs, larvae and pupae) and cocoons of parasitoids were brought to Bio-systematic Laboratory in Department of Entomology. All the collected specimens (larvae and pupae) were kept individually in petri dishes and shifted in growth chamber operating at 23±1°C, 70±10 RH, 16: 8 (L: D) photoperiod. Larval stages were reared individually in to petri dishes by providing with fresh and clean cabbage leaves collected from experimental fields at Taxila site. Leaves were washed in order to eliminate potential pathogens and unwanted *P. xylostella* eggs and larvae. Leaves were changed at two days interval until adult *P. xylostella* and/ or parasitoids emergence.

These cocoons and parasitized *P. xylostella* pupae (recognizable by the color or later by longer developmental duration) were kept individually in glass vials. The mean number of individuals emerging from a single attacked host in gregarious parasitoid species was recorded. The number of adult *P. xylostella* moth/ or parasitoids emerged were recorded every day from the date of collection until no further emergence occurred. Eggs collected as a result of sampling were kept in rearing chamber to check their parasitism by egg parasitoids.

Population of *P. xylostella* larvae and pupae per plant and percent parasitism for each sampling period (autumn and spring) was monitored for both of the locations i.e. Mansehra and Taxila site. To determine parasitism by the gregarious parasitoid species (*O. sokolowskii*), 10 to 15 individuals were regarded as emerging from one larva or pupa.

Meteorological data (amount of rainfall, relative humidity, minimum and maximum temperature) were obtained from Meteorology Division of the respective areas i.e. Mansehra and Taxila.

2.1 Statistical Analysis

Mean insect number per plant was calculated for each stage of the insect per sampling period to examine the population fluctuation for the different seasons and locations. Potential parasitism, i.e. parasitism level of each parasitoid species in the absence of others, was recorded. analysis was carried out by using Microsoft Excel software.

3. Results and Discussion

3.1 Seasonal Population Dynamics of *P. xylostella* in Cabbage Crop at Mansehra Site

Population dynamics of *P. xylostella* was observed periodically in cabbage crop on a weekly basis randomly in a field during autumn and spring season at Mansehra in 2011-12 (Figures 1 and 2). The mean number of *P. xylostella* population 13±5.39/plant was recorded in the first week of October in the autumn season, when the average minimum and maximum temperature was 15.3°C and 32.1°C, respectively. In the last week of October, highest population (46±10.30/plant) was observed when the average minimum (8.6°C) and maximum (24.7°C) temperatures were recorded, with 75% relative humidity. After that population progressively declined and reached to 13.4±4.67/plant till 26th November. During this period, 40% relative humidity was recorded although no major change was observed in meteorological variables but the decline in population might be due to some other reasons. After that the crop got matured and harvested.

In spring season during the last week of March, the mean number of *P. xylostella* population (18.8±2.59/plant) was recorded, when the average minimum temperature (11.1°C) and maximum temperature (24.9°C) was observed.

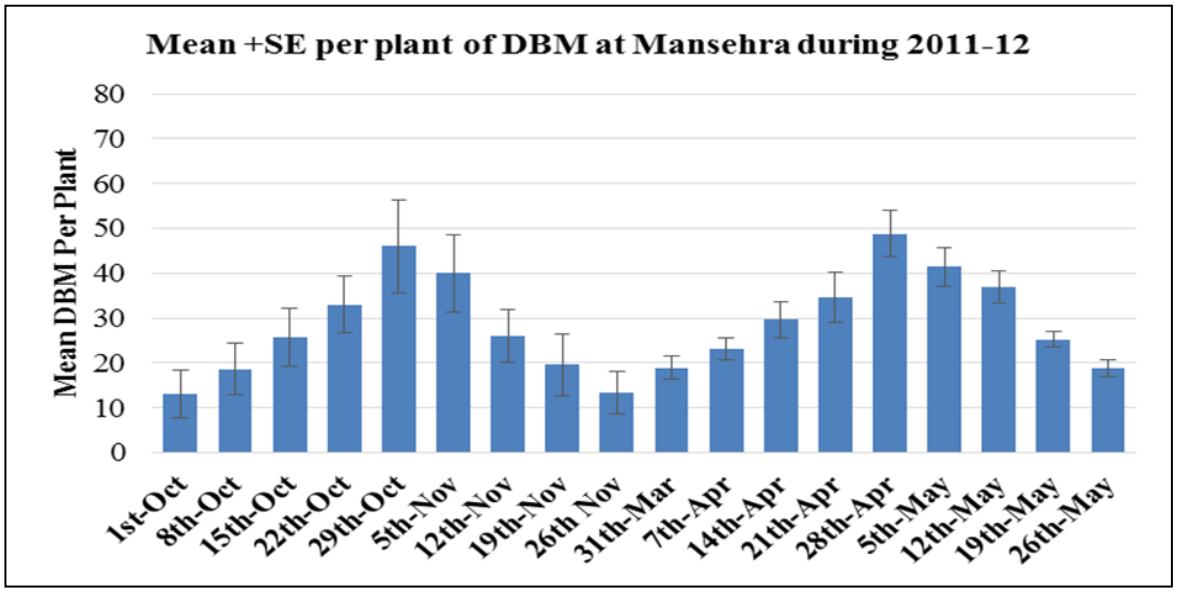

Fig 1: Mean seasonal population dynamic of P. xylostella per cabbage plant on weekly at Mansehra site in autumn and spring during 2011-12.

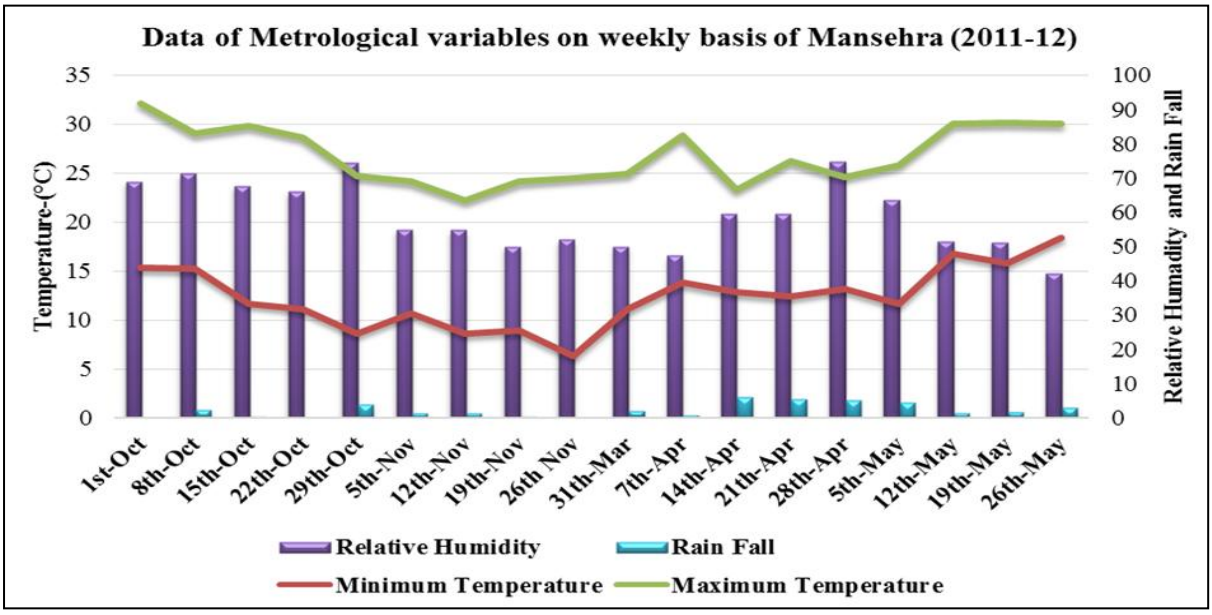

Fig 2: Average minimum and maximum temperature (°C) on weekly basis at Mansehra site (autumn and spring) during 2011-12

During last week of April highest population (48.8±5.12/plant) was observed when (13.2°C and 24.6°C) minimum and maximum temperature, respectively with relative humidity 75% was recorded. It is due to favorable environmental conditions for the highest growth of *P. xylostella* population. During 26th May at Mansehra site minimum population (18.8±1.92/plant) was documented when metrological variables were minimum (18.4°C) and maximum temperature (30.0°C) while relative humidity declined to 42%. Population of *P. xylostella* fluctuated between 0-15.7 and 0-1.7 insects per plant in December (Figure 1) and the April-planted field [22].

3.2 Percent Parasitisation of *P. xylostella* Stages by Parasitoids at Mansehra Site

3.2.1 Percent parasitism by *D. insulare*

In Mansehra area (Figure 3), during autumn season the parasitism level of *D. insulare* declined (21.54% to 17.20%) from 1st to 2nd week of October. A short decline (17.83%) in parasitism level was observed at the end of October. During the last week (November) in the autumn season, the highest parasitism level (22.39%) was recorded.

In spring season, the parasitism level initiated (17.02%) from the last week of March. Parasitism level progressively increased to 21.74% during 12th May. Parasitism level reached to peak (22.22%) during 19th May then declined to 18% at the end of spring season.

3.2.2 Percent parasitism by *O. sokolowskii*

In Mansehra area (Figure 3), during autumn season the parasitism level

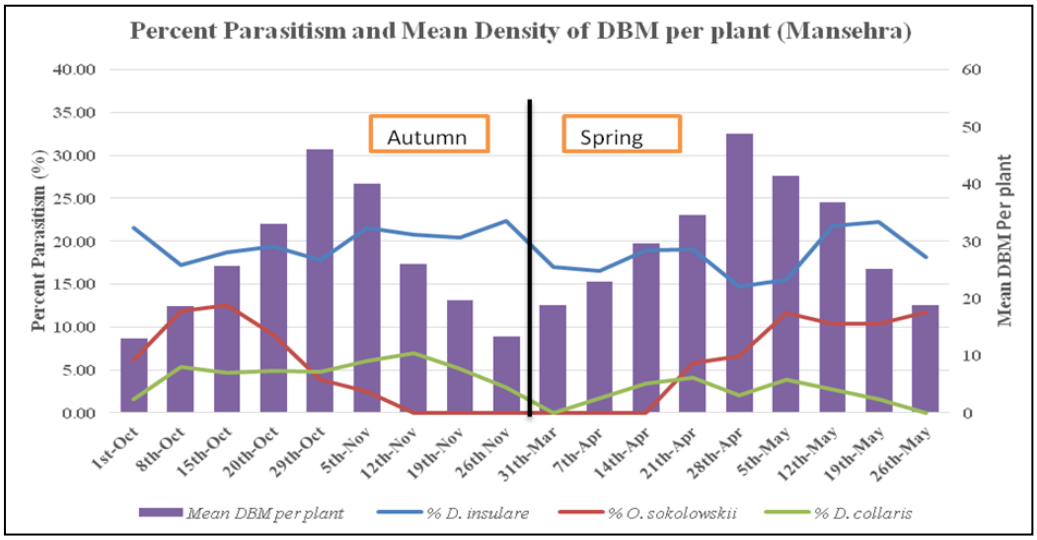

Fig 3: Percent parasitism of *P. xylostella* by *Diadegma insulare*, *Oomyzus sokolowskii* and *Diadromus collaris* on weekly basis in autumn and spring seasons at Mansehra site during 2011-12.

was initiated with 6.15% in the 1st week (October) then it reached to peak value (12.50%) during 3rd week (October). After that parasitism level was gradually declined and reached to 0% during the end of the season.

In spring season, the percent parasitism level 5.78% was recorded during 28th April. After that progressively parasitism level reached to peak (11.70%) by *O. sokolowskii* during the last week in May (2012).

3.2.3 Percent parasitism by *D. collaris*

Parasitism level initiated with 1.54% during the autumn season during 1st of October. Whereas, percent parasitism level (6%, 6.92%) by *D. collaris* gradually increased as per data recorded on 5th and 12th November, respectively (Figure 3).

In spring season, parasitism level with 1.74%, and reached to peak 3.86% by *D. collaris* during 1st week (April) and percent parasitism increased 3.86% during 1st week of May, respectively. While, the lowest parasitism level was recorded due to interaction between parasitoids and environmental condition.

3.3 Seasonal Population Dynamics of *P. xylostella* in Cabbage Crop at Taxila Site

Population dynamics of *P. xylostella* was observed periodically in cabbage crop on a weekly basis in autumn and spring season at Taxila during 2011-12 (Figure 4 and 5). The mean number of *P. xylostella* population 9.60±2.42/plant was recorded in the 2nd week of October, when the average minimum and maximum temperature was 19°C and 32.30°C, respectively. Afterward, in 2nd week of November highest population (54.6±7.96/plant) was observed. At (10.9°C and 25.8°C) minimum and maximum temperature, respectively with relative humidity 70.43% was recorded. Whereas, *P. xylostella* population progressively declined (41.40±7.90/plant and 13.6±3.20/plant) from 20th November to 4th December, during this period the gradual decrease in minimum temperature was 9.4°C to 6.10°C and maximum temperature was 27.6°C to 24.9°C, respectively. Although no major change was observed in other meteorological variables but the decline in population was might be due to some other reasons. After that the crop got matured and harvested.

In spring season, during 11th March, the population (9.8±5.27/plant) and was recorded. During the last week in March the highest population 22.60±4.84/plant was observed. At (13.1°C and 26.1°C) minimum and maximum temperature, respectively with relative humidity 47% was recorded. It's due to favorable environmental condition for the highest growth of *P. xylostella* population. Further, mean number decreased 12.80±1.94/plant) during 8th April at Taxila site. In case of metrological variables, increasing minimum (18.5°C) and maximum temperature (33.2°C) while relative humidity declined gradually from (43.2%), respectively. Then, mean *P. xylostella* population increased to 21±3.58/plant during the 3rd week in April when average minimum and maximum temperature as 19.10°C and 29.10°C was recorded, respectively.

Accordingly, mean number decreased to 9.20±4.62/plant during 6th May at Taxila site. In case of, minimum (18.5°C) and maximum temperature (32.93°C) was recorded.

3.3.1 Percent Parasitisation of *P. xylostella* Stages by Parasitoids at Taxila Site

3.3.2 Percent parasitism by *D. insulare*

In Taxila area, during autumn season the parasitism level of *D. insulare* was initiated (23.08%) during 9th October. After that no simple trend was observed in the parasitism level by *D. insulare*, rather fluctuation in percent parasitism was observed throughout the autumn season. Furthermore, the maximum parasitism level (30.91%) was observed at 27th November while minimum parasitism level (21.33%) was recorded at 16th October (Figure 6).

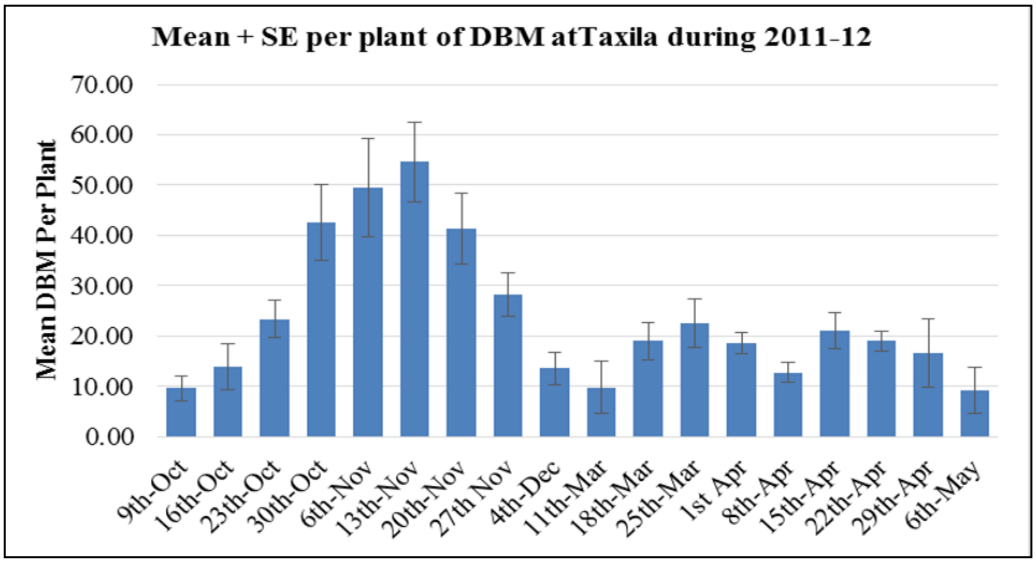

Fig 4: Mean (S.E) seasonal population dynamics of *P. xylostella* per cabbage plant on weekly basis at Taxila site during 2011-12.

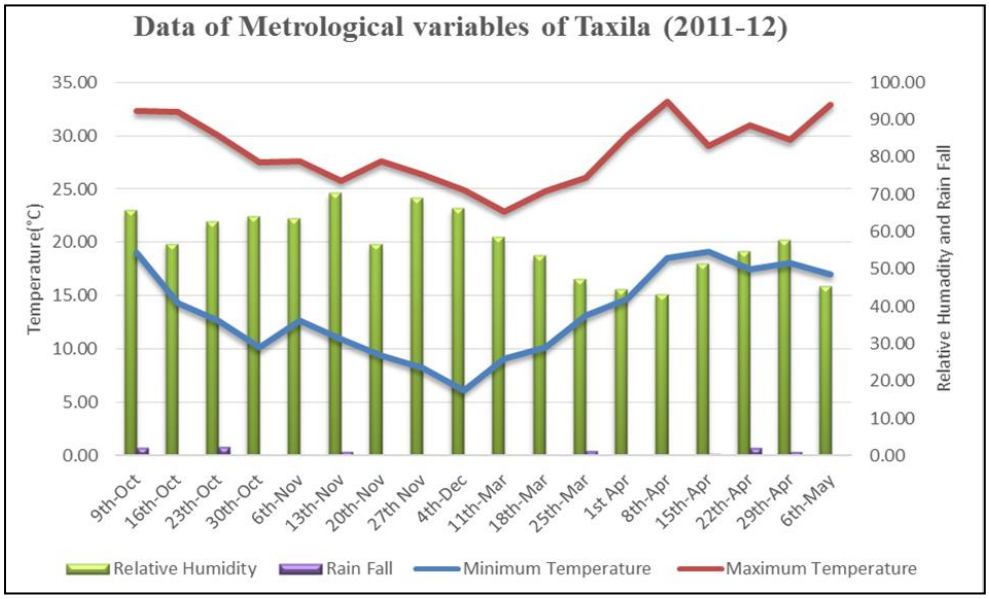

Fig 5: Average minimum and maximum temperature (°C) on weekly basis in each season at Taxilla site during 2011-12.

In spring season, the parasitism level started (14.29%) in 2nd week of March. Then, parasitism level progressively increased (17.89% and 25.66%) from 18th and 25th in March, respectively and reached to the peak value (39.78%) during 1st week in April. Parasitism level again gradually decreased 29.69% - 23.58% during 8th and 15th April in spring season respectively. Again parasitism level increased (27.37% - 27.71%) from 22nd to 29th in April, respectively then it was declined to 21.74% on 6th of May.

3.3.3 Percent parasitism by *O. sokolowskii*

At Taxila site, during autumn season the parasitism level gradually increased from 11.51% to 18.09%) by *O. sokolowskii* from 9th to 23rd October, respectively. Afterwards, it shot declined (17.33%) during the last week in October. However, the highest parasitism level (19.19%) was observed on 6th November. After that fluctuation in the parasitism level was recorded with no simple trend till the end of the autumn season, 2011 (Figure 6).

In the spring season (2012), the percent parasitism level (3.54%) was initiated in 25th March. During 8th April, the peak parasitism level (15.63%) was recorded. Then, percent parasitism level decline (4.35%) during 6th May, respectively.

Whereas, by *O. sokolowskii* the parasitism level (2.77% and 4.0%) was observed during (winter) January and February. At the same time, [23] reported the percent parasitism (0.92% and 1.33%) respectively in Sindh province of Pakistan.

At all sampling times, the highest and lowest percent parasitism(7.93% and 1.28%) was recorded by *O. sokolowskii* on cultivated (Buris and SG) cultivars during 21st October, but the highest parasitism (10%) was observed on Buris cultivar and the lowest one was observed on Galiblanka (1.66%). [24].

3.3.4 Percent parasitism by *D. collaris*

In the autumn season during 2011 (Figure 6), initially parasitism was not observed during 9th October, while 4.00% parasitism was recorded on 16th October Parasitism level decreased as 2.13% and 2.00% during 21st and 30th October, respectively. After that, a slow and gradual increase in parasitism (4.07%, 4.33% and 5.59%) was observed on 6th, 13th and 20th November, respectively. During 27th November and 4th December percent parasitism level again gradually decreased (4.55% - 2.94%), respectively.

Parasitism level (2.11%) was started from 18th March during spring season. Then, parasitism level reached to highest (7.81%) in 25th March (2012). At the end of season decline

(2.41%) during 29th April.

[22] Reported the parasitism ranged from 0 to 81% by *O. sokolowskii*, *Apanteles* sp. and *Diadegma* sp. varied the percent parasitism from 0 to 62.7%, 0 and 20%, and 0 and 3.3% was recorded, respectively.

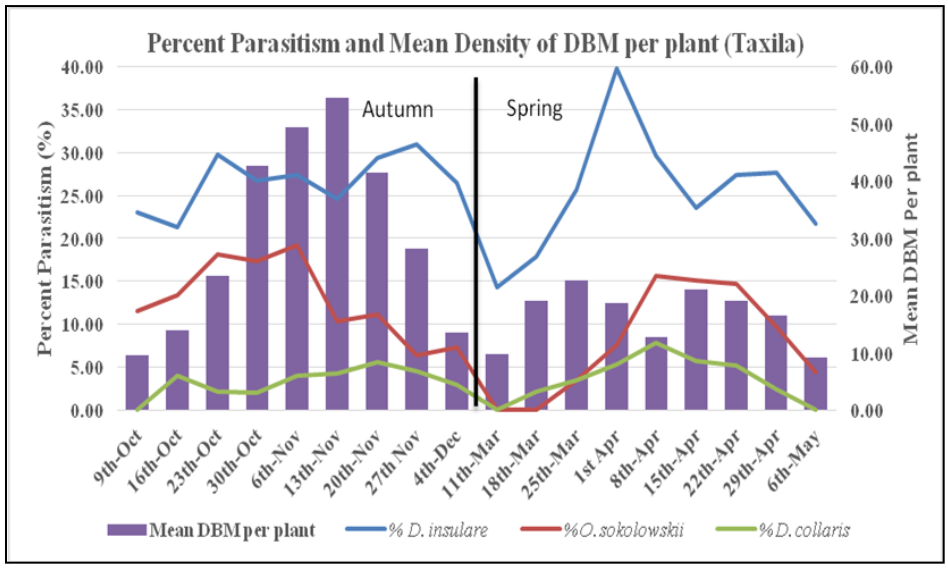

Fig 6: Percent parasitism of *P. xylostella* by *Diadegma insulare*, *Oomyzus sokolowskii* and *Diadromus collaris* on weekly basis in autumn and spring seasons at Taxila site during 2011-12

Potential parasitism i.e. parasitism of *P. xylostella* contributed by each parasitoid species in the absence of other natural enemies was observed. Overall average parasitism was observed by larval and pupal parasitoids species from October to December in autumn and in spring season from March to May during each year.

In Melkassa site, the results shown as the same population was observed during each season, because the maximum temperature and rainfall had not affected the population density but the fluctuation in maximum temperature was less high and rainfall lowered in the experiment site during April. *P. xylostella* density at Melkassa fluctuated between 0 and 3.2% insects in the December 2001 planted field and between 0 and 8.5% insects per plant in the April 2002-planted field [22].

Accordingly, higher parasitism level by *D. insulare* in the second season as compared to the first season. At Holeta site, negative effect on host density was observed when population *D. insulare* increased. [25] Reported that when the parasitism was increased by *D. semiclausum* and *Apanteles* sp. the population density was decreased.

[26] Studied the field infestation of *P. xylostella* on crucifers and found an average density range (0.90 to 2.38) and (0.27 to 5.84) larvae and pupae per plant, respectively. Quite lower parasitization was observed, while temperature and relative humidity fluctuation (24.15°C to 32.91°C) and (68.60% to 91.30%) were recorded, respectively.

In the present study, maximum percent parasitism by *D. insulare* (39.78%) was observed during 1st week in April at Taxilla site, when minimum and maximum temperatures (14.8°C and 27°C) were recorded, respectively. [27 and 28] Found the *D. insulare* as major parasitoid of *P. xylostella* with (0% - 58.5%) and (24.3% - 45.2%) pupal parasitism, respectively. Their results resemble with the outcomes of the present study.

In the present study, very little percent parasitism was recorded by *D. collaris* (2011-12) at both sites i.e. Mansehra and Taxilla site. This is due to the high male ratio in the collected population. Furthermore, competition between the parasitoid species had also suppressed the percent parasitism by *D. collaris* in opposition to *P. xylostella*. Similar studies were performed by [23] and explored the little pupal percent parasitism (1.33%) by *D. collaris* against *P. xylostella*.

[29] Discussed that prevalence of few parasitoid species and less percent parasitisation might be because of heavy application of broad spectrum compounds and their persistency. Furthermore, competition between the parasitoids species is another factor to make them less or more prevalent in the field against *P. xylostella*.

Studies on *P. xylostella* parasitisation were performed by [26]. Their results revealed that parasitisation rate was correlated erratically with temperature, humidity and rainfall. Whereas, [21] reported a minor difference between potential parasitism and apparent parasitism. In these results, regression model showed a significant interaction between different parasitoids while, statistical analysis showed limited competition between parasitoids.

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