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Assessing the Impact of Weather Parameters on the Population Dynamics of Insect Pests in Cucurbit Vegetables under Mid-Hill Conditions of Himachal Pradesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MS and PR designed the study and Author PR performed the experiment and statistical analysis, wrote the first draft of the manuscript. Authors PR and BD managed the analyses of the study. Authors HG and PK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A study focusing on population dynamics of sucking and leaf-eating some insect pests along with their correlation with weather parameters in cucurbits was conducted at research field, Department of Entomology, Dr. YSPUHF, Solan, H.P., India from June-October, 2019 and 2020. The results

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revealed that *Amrasca biguttula biguttula* (I), *Trialeurodes vaporariorum* (W), *Aulacophora foveicollis* (L), *Henosepilachna vigintioctopunctata* (F), *Liriomyza trifolii* (B), *Aulacophora* sp., were recorded as the major insect pests. In bitter gourd, maximum population of jassids recorded was (2.33/leaf) in first week of August while, maximum whitefly population in bottle gourd (2.96/leaf) during last week of August and in ridge gourd during last week of July (3.76/leaf). The maximum red pumpkin beetle population on bitter gourd (2.4 beetles/plant) and bottle gourd (2.6 beetles/plant) was observed during last week of August while, hadda beetle attained peak population during first and third week of August in ridge gourd (1.0/plant) and bitter gourd (1.1 adults/plant), respectively. Maximum leaf miner infestation (2.7 mines/leaf) in bottle gourd and ridge gourd was observed during first and third week of August. All pest attained maximum population between 30 to 32 SMW when weather parameters values were T_{max}: 27.50 to 28.90; T_{min}: 20.60 to 20.80 ^{o}C; RH: 79 to 80 %; Rainfall: 25.80 to 30.20 mm. Relative humidity and rainfall played major role with non-significant positive influence on the population build-up of these pests in cucurbit crops along with temperature. The present findings on weather-driven pest dynamics can inform strategies to boost crop yields and reduce farmers' economic losses in similar environments.

Keywords: Cucurbits; seasonal incidence; insect pests; weather factor correlation.

1. INTRODUCTION

Cucurbits belongs to the family of Cucurbitaceae are considered as an important and largest group of vegetables which consists of about 118 genera and 825 species distributed in tropical and subtropical regions of the world [1]. India is blessed with a rich diversity of cucurbits and considered as the primary and secondary centers of origin for several species in Cucurbitaceae family [2]. Cucurbits are mostly annuals, directly sown and propagated through seed. However, some cucurbits such as pointed gourd, ivy gourd and chow-chow are difficult to propagate from seeds are propagated vegetatively. Cucurbits are frost-sensitive and predominantly tendril-bearing vines [3]. Some of the cucurbits like cucumber are grown in green houses in temperate regions.

Cucurbits are nutrient-dense, offering vitamins (A, C, K), minerals (potassium, magnesium), and antioxidants, promoting heart health, immunity, and digestion. They also possess medicinal properties like anti-inflammatory, anti-diabetic, and antimicrobial benefits [4,5]. Majority of cucurbits possess the bitter principle called cucurbitacin at one stage of development or the other. Bitterness is more prominent in crops like cucumber, bottle gourd and long melon. Around the globe, India is the second-largest producer of vegetables next to China with total of 2000445 (000MT) production from 10859 thousand hectares of cultivated area [6]. About fifty per cent of the production is contributed by summer vegetables. In India, cucurbits are cultivated in 9083 thousand hectares of area with the production of 587 thousand MT [7], whereas in Himachal Pradesh area under cucurbits is 89.317 thousand hectares with a production of 1811.77 thousand MT [8].

Cucurbits are attacked by several insect and nematode pests at different growth stages that cause defoliation of leaves, damage to roots, flowers or fruits, contribute to poor crop stand, transmission of bacterial and viral diseases, and generate wounds that help the invasion of fungal pathogens. Major insect and nematode pests include spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber and red pumpkin beetle, *Aulacophora foveicollis* Lucas (Coleoptera: Chrysomelidae); fruit flies, *Bactrocera cucurbitae* Coquillet*, B. tau* Walker*, B. scutellaris* Bezzi (Diptera: Tephritidae); hadda beetles, *Epilachna vigintioctopunctata* Fabricius (Coleoptera: Coccinellidae); squash bugs, *Anasa tristis* De Geer (Hemiptera: Coreidae); aphids *Myzus persicae* Sulzer, *Aphis gossypii* Glover (Hemiptera: Aphididae); whiteflies, *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae); two-spotted spider mites, *Tetranychus urticae* (Arachnida: Tetranychidae) and root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood (Tylenchida: Heteroderidae) [9-14]. The management of these pests for sustained yield is very important. Keeping in view the importance of cucurbits and damage caused by sucking and leaf-eating insect pests, the present investigations were carried out to study the impact of weather parameters on pest population build-up that can help in the development of effective pest management strategies, ultimately contributing to improved crop yields and reduced economic losses for farmers in bitter gourd, bottle gourd

and ridge gourd under mid-hills of Himachal Pradesh, India.

2. MATERIALS AND METHODS

The present investigations on seasonal incidence of major insect pests of three cucurbit crops *viz.*, bitter gourd, bottle gourd and ridge gourd were carried out from June-October, 2019 and 2020, at the experimental farm, Department of Entomology, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, located at an elevation of 1262 meters above mean sea level, lying between $30^0$51.607' N latitude and $077^0$10.951' E longitude. Agro-climatically, the location falls under zone-II (Sub-temperate sub humid mid-hills) of Himachal Pradesh. Solan Hara (bitter gourd), Punjab Round (bottle gourd) and Henry (ridge gourd) varieties were grown under natural conditions without pesticide at a spacing (row to row and plant to plant) of 1.5m and 0.6 m (bitter gourd), 1.5m and 0.6m (bottle gourd) and 1.5m and 0.5 m (ridge gourd) in 2×1m plot following Randomized Block Design. The appropriate sampling techniques were adopted for estimating the population of different insect pests attacking cucurbits and observations were recorded on 10 plants per crop. The whitefly (*T. vaporariorum* (Westwood) population were recorded by adopting the method suggested by Haldhar [15]. The defoliating insects such as red pumpkin beetle (*Aulacophora foveicollis* (Lucas), hadda beetle (*Epilachna vigintioctopunctata* (Fabricius), spotted cucumber beetles (*Diabrotica undecimpunctata howardi* (Barber) and lepidopteran pests were recorded on ten randomly selected plants. For recording the infestation of serpentine leaf miner, *L. trifolii* (Burgess), infested leaves were collected randomly from the upper, middle and lower canopy of each plant and examined under a microscope for the presence of live mines. The weekly data on maximum and minimum temperature, RH and rainfall during the study period were collected from the Department of Environmental Science, College of Forestry, Dr Y S Parmar University of Horticulture and Forestry, to find out the impact of weather parameters on the incidence/population of different insect pests.

3. RESULTS AND DISCUSSION

3.1 Seasonal Incidence of Insect Pests in Bitter Gourd

The major insect pests recorded on bitter gourd during summer, 2019 were jassid, *Amrasca biguttula biguttula* Ishida (Hemiptera: Cicadellidae), red pumpkin beetle, *Aulacophora foveicollis* Lucas (Coleoptera: Chrysomelidae), hadda beetle, *Henosepilachna vigintioctopunctata* Fabricius (Coleoptera: Coccinellidae) and fruit fly, *Bacterocera tau* Walker (Tephritidae: Diptera).

Jassids infestation was first recorded on bitter gourd during last week of June (26th SMW), with an average number of 0.16 jassids per leaf (Table 1, Fig. 1) and started increasing gradually attaining peak (2.33 jassids per leaf) during first week of August, 2019 (31st SMW). Thereafter, population declined and reached to its minimum during last week of September (39th SMW) with mean population density of 0.3 jassids per leaf. Jassid population showed a negative and non-significant correlation with maximum temperature (r = -0.252) and rainfall (r = 0.194) while correlation positive and significant with minimum temperature (r = 0.508) and relative humidity (r = 0.553) (Table 2) was recorded. Similar observation on jassids incidence from August to October has been reported by Patial and Mehta [16] at Palampur, Himachal Pradesh [17]. Sunil et al*.* [18] reported maximum population of jassids (2.60 per leaf) during 37th standard week on bitter gourd at horticulture division, G.K.V.K.U.A.S., Bengaluru. The negative correlation with maximum temperature and positive correlation with minimum temperature also reported by Sunil et al*.* [18,19].

Incidence of red pumpkin beetle *A. foveicollis* in bitter gourd field was first noticed during last week of June (26th SMW), 2019 with an average of 0.2 beetles per plant (Table 1, Fig. 1). The beetle population started increasing gradually with maximum number (average of 2.4 beetles per plant) during last week of August (35th SMW). The corresponding weather parameters during the week were maximum temperature of 30.0°C, minimum temperature of 20.6°C, relative humidity of 73% and rainfall of 1.4 mm. After that the beetle population started decreasing with minimum average number of beetles (0.4 per plant) in the third week of September (38th SMW). The red pumpkin beetle population showed negative correlation with maximum temperature (r = - 0.009) (Table 2). The correlation was positive and significant with minimum temperature (r = 0.607) and relative humidity (r = 0.541). The correlation between beetle population and rainfall was non-significant (r = 0.085). Khan et al [20] recorded incidence of red pumpkin beetle in bitter gourd from first week of May to last week of June at Peshawer valley. Sunil et al*.* [18] observed 0.30 average number

of red pumpkin beetle population in bitter gourd during 39th standard week. Shinde et al. [21] reported 3.64 per cent infestation of red pumpkin beetle as maximum during 32nd SMW. Earlier, negative correlation of beetle population with maximum temperature and the positive correlation with minimum temperature (Sunil et al. [18] and Saha et al. [22] and relative humidity Sunil et al. [18] has been reported.

The infestation of Hadda beetle**,** *H. vigintioctopunctata* was initiated during first week of July, 2019 (28th SMW) with 0.3 average number of beetles per plant (Table 1, Fig. 1). The beetle population increased gradually to reach the maximum (1.1 adults per plant) during second week of August, 2019 (33rd SMW). After that beetle population started decreasing with minimum (0.3 adult per plant) recorded in the last week of September (39th SMW). The hadda beetle population showed non-significant correlation with maximum temperature (r = -0.161) (Table 2). Whereas positive and significant correlation was found with minimum temperature (r = 0.571) and relative humidity (r = 0.647), correlation was non-significant with rainfall (r = 0.383). Rathod and Borad [23] on the other hand recorded incidence of epilachna beetle in bitter gourd from July-October in Mohanpur (West Bengal). Similar observations were made by Painkra et al. [24], Kalkal et al. [25] and Kumar and Saini [26] who recorded peak population of hadda beetle during August-September on bitter gourd. Jamwal [27] recorded 0.23 and 5.48 mean number of beetles per plant as minimum and maximum population, respectively in brinjal crop at Jammu during 2015-16. Similarly, Ghule et al. [28] and Saha et al. [22] reported positive correlation of *H. septima* (Epilachna beetle) adult population with minimum temperature and Jamwal [27] reported negative correlation of maximum temperature and positive correlation of minimum temperature & relative humidity. with adult population of hadda beetle.

3.2 Seasonal Incidence of Insect Pests in Bottle Gourd

The major insect pests recorded on bottle gourd from second fortnight of May to first week of November, 2019 were, leaf miner, *Liriomyza trifolii* Burgess (Agromyzidae: Diptera); red pumpkin beetle *A. foveicollis*; leaf eating beetle *Aulacophora* sp. (Coleoptera: Chrysomelidae); whitefly, *Trialeurodes vaporariorum* Westwood (Aleyrodidae: Hemiptera); fruit fly, *B. tau* and root-knot nematode, *M. incognita.*

The leaf miner infestation was observed from first week of July to second week of September (27th SMW to 36th SMW) (Table 1, Fig. 2). The maximum average number of mines (2.7 mines per leaf) was noticed during second week of August (32nd SMW). As crop growth progressed, infestation declined to minimum number of mines (0.66 mean mines per leaf) during first week of September (36th SMW). The leaf miner incidence showed negative and non-significant correlation (r = -0.164) with maximum temperature, whereas positive and significant correlation with minimum temperature (r = 0.555) and relative humidity (r = 0.584) was recorded. The correlation of leaf miner population with rainfall was positive and significant (Table 3). Similar results were observed by Saha et al. [22] who recorded on an average maximum of 3.30 mines per leaf as the maximum leaf damage caused by *L. trifolii* on cucumber. However, higher incidence of leaf miner has been observed by other workers. Civelek et al. [29] reported 15.5 and 16.2 average number of mines per leaf during spring and autumn seasons, respectively, on cucumber in Western Turkey during 2000. Chaudhuri and Senapati [30] explained that population densities slowly increased during early crop growing stages, but gained momentum from flowering stage onwards to reproductive stage. Chakraborty [31] reported 28.3 and 26.2 percent of damage due to leaf miner during July and August in tomato in Jalpaiguri area of West Bengal. The variations in damage by leaf miner may be due to the different locations and weather conditions.

Reddy and Kumar [32], Durairaj [33] and Shilpakala and Krishna [34] also reported positive correlation of leaf miner population with minimum temperature in other crops. As observed in present investigations, Chaudhuri and Senapati [30] also reported positive correlation of incidence of leafminer with average relative humidity. Contrary to the results obtained during present investigations, Chakraborty [31] found a significant negative correlation with maximum temperature. However, a positive correlation with minimum temperature and average relative humidity was in correspondence with the present investigations.

Table 1. Population fluctuations of major insect pests infesting cucurbits at Nauni, Solan, Himachal Pradesh, 2019

SMW	Bitter gourd				Bottle gourd			Ridge gourd				Weather parameters			
	Jassids	Red pumpkin beetle	Hadda beetle	Whitefly	Red pumpkin beetle	Leaf eating beetle	Leaf miner	Whitefly	Hadda beetle	Red pumpkin beetle	Leaf miner	$T_{Max.}$	$T_{Min.}$	RH (%)	Rainfall (mm)
21	0	0	0	0	0	0	0	0	0	0	0	30.20	15.00	47	9.80
22	0	0	0	0	0	0	0	0	0	0	0	35.30	17.20	44	1.00
23	0	0	0	0	0	0	0	0.23	0	0	0	34.90	17.60	39	3.80
24	0	0	0	0	0	0	0	0.55	0	0	0	36.30	18.50	38	4.00
25	0	0	0	0	0	0	0	1.06	0	0.20	0	31.10	16.50	58	44.80
26	0.16	0.20	0	0	0	0	0	1.33	0	0.40	0	31.40	18.90	61	44.90
27	0.26	0.30	0	0	0.20	0.30	0.33	1.96	0	0.50	0.26	29.10	20.00	75	66.80
28	0.83	0.50	0.30	0	0.50	0.50	0.90	2.10	0.20	0.40	0.76	27.80	20.00	81	82.80
29	1.23	0.70	0.20	0.21	1.20	0.70	1.36	2.73	0.30	0.90	1.06	27.10	18.90	80	15.40
30	1.70	0.90	0.40	0.53	1.80	1.10	1.63	3.76	0.80	1.30	1.43	27.50	20.60	79	25.80
31	2.33	1.10	0.90	0.93	0.60	0.90	2.06	2.40	1.00	0.90	1.96	26.60	20.20	82	27.30
32	1.46	1.30	0.70	1.30	1.20	0.70	2.70	2.00	0.70	1.30	2.53	28.90	20.80	80	30.20
33	0.63	1.60	1.10	1.63	1.70	0.40	2.66	1.80	0.80	1.80	2.70	27.70	20.20	83	190.80
34	0.36	2.10	0.80	2.23	2.20	0.20	1.83	1.86	0.50	2.20	1.76	29.50	18.80	77	3.40
35	0.26	2.40	0.50	2.96	2.60	0	0.93	1.87	0.40	2.40	0.83	30.00	20.60	73	1.40
36	0.16	1.70	0.70	2.20	1.90	0	0.66	1.50	0.60	1.80	0.53	30.10	20.30	77	0
37	0.13	1.20	0.40	1.60	1.10	0	0	1.33	0.30	1.30	0	29.80	19.90	74	0
38	0.60	0.40	0.50	1.16	0.60	0	0	1.16	0.50	0.50	0	28.30	16.00	72	16.40
39	0.30	0	0.30	0.63	0	0	0	0.63	0.40	0	0	24.80	17.80	86	135.00
40	0	0	0	0	0	0	0	0	0	0	0	25.90	14.40	74	5.60
41	0	0	0	0	0	0	0	0	0	0	0	26.10	11.90	69	0

(SMW- Standard Weeks; Jassids, Whitefly - No./leaf; Red pumpkin beetle, Hadda beetle- No./plant; Leaf eating beetle – Adult/plant; Leaf miner- mines/leaf)

Table 2. Correlation coefficient (r) of population of insect pests infesting bitter gourd with weather parameters

Insect pests of bitter gourd	Temperature		Relative humidity (%)	Rainfall (mm)
	Maximum temperature (°C)	Minimum temperature (oC)		
Red pumpkin beetle	-0.009	0.607	0.541	0.085
Hadda beetle	-0.161	0.571	0.647	0.383
Jassids	-0.252	0.508*	0.553	0.194

**Significant at 5%*

Table 3. Correlation coefficient (r) of population of insect pests infesting bottle gourd with weather parameters

Insect pests of bottle gourd	Temperature		Relative humidity (%)	Rainfall (mm)*
	Maximum Temperature (°C)	Minimum Temperature (°C)		
Leaf miner	-0.164	0.555	0.584	0.367
Red pumpkin beetle	0.031	0.583	0.535	0.062
Leaf eating beetle	-0.237	0.487*	0.523	0.222
Whitefly	-0.003	0.499*	0.476*	0.055

**Significant at 5%*

Table 4. Correlation coefficient (r) of population of insect pests infesting ridge gourd with weather parameters

Insect pests of ridge gourd	Temperature		Relative humidity (%)	Rainfall (mm)
	Maximum Temperature (°C)	Minimum Temperature (°C)		
Leaf miner	-0.159	0.537**	0.567**	0.396
Red pumpkin beetle	0.001	0.628**	0.547**	0.114
Hadda Beetle	-0.231	0.586**	0.675**	0.325
Whitefly	-0.084	0.751**	0.630**	0.261

*** Significant at 1%*

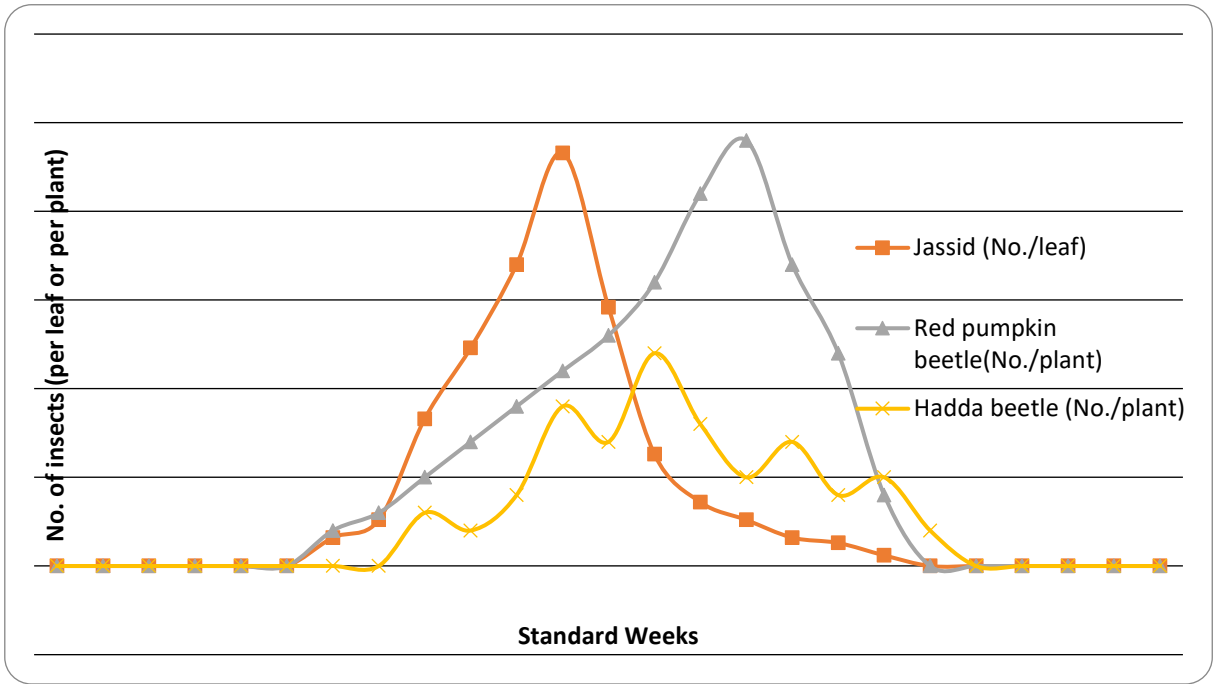

Fig. 1. Population fluctuations of insect pests in bitter gourd crop ecosystem in mid hills of Himachal Pradesh during 2019

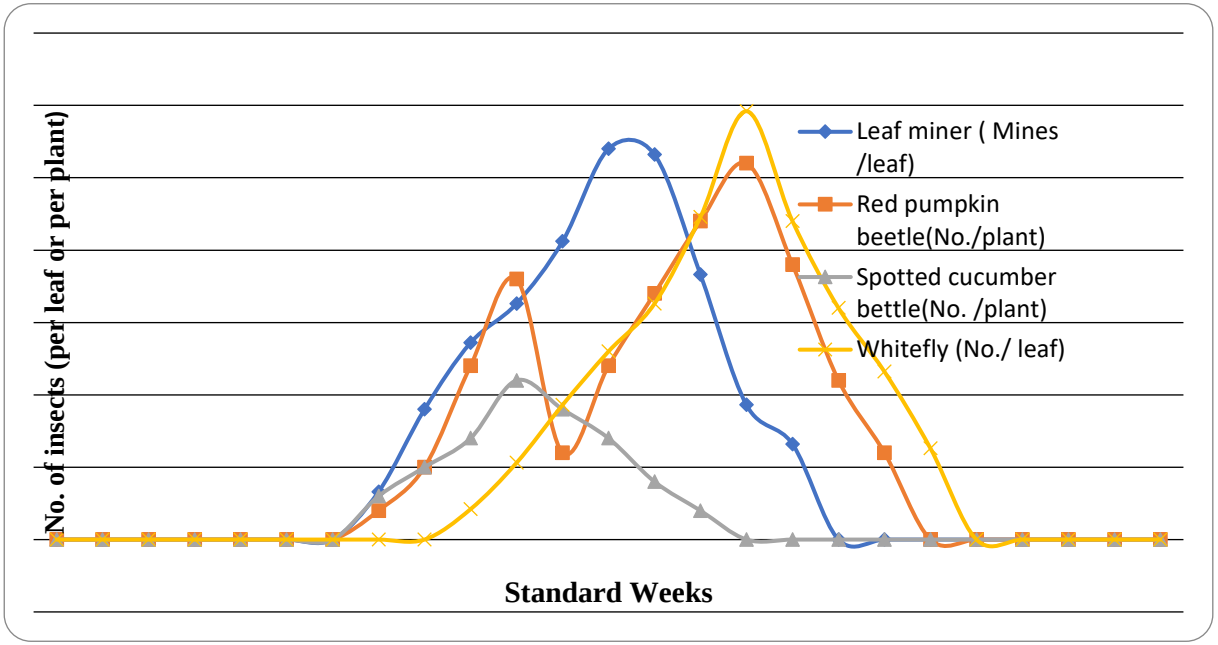

Fig. 2. Population fluctuations of insect pests in bottle gourd crop ecosystem in mid hills of Himachal Pradesh during 2019

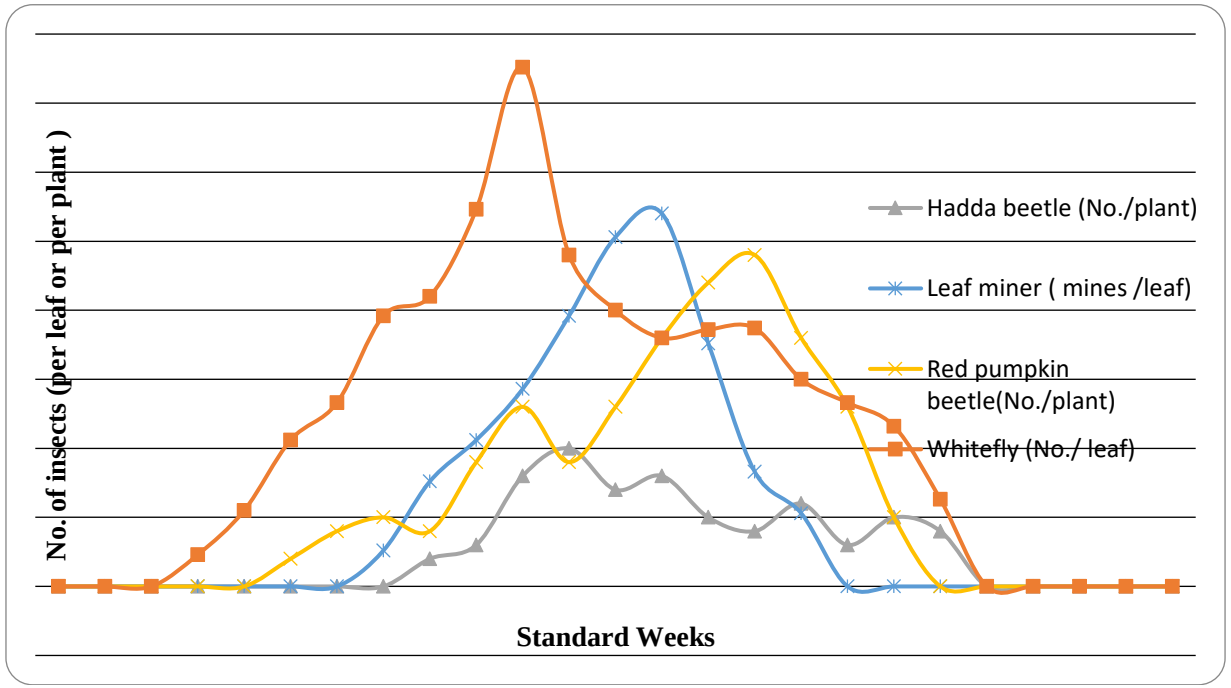

Fig. 3. Population fluctuations of insect pests in ridge gourd crop ecosystem in mid hills of Himachal Pradesh during 2019

The pest activity was observed from first week of July to third week of September (27th SMW to 38th SMW). The population reached maximum (2.6 beetles/plant) during last week of August (35th SMW) (Table 1, Fig. 2). Thereafter, decline in beetle population was observed with average minimum count of 0.6 adults/plant during third week of September (38th SMW). The red pumpkin beetle population was not affected by maximum temperature (r = 0.031). Whereas, correlation was found significant and positive with minimum temperature (r = 0.583) and relative humidity (r = 0.535). The correlation was non-significant with rainfall (Table 3).

Saha et al. [22] also reported averagely 3.40 beetles per plant as maximum population of red pumpkin beetle on cucumber. Shinde et al. [21] reported 2.48 per cent infestation as minimum and 3.64 as maximum during 26th and 32nd SMW, respectively on cucumber. Sunil et al. [18] also observed positive correlation of red pumpkin beetle population with minimum mean temperature and relative humidity in bitter gourd and Saha et al. [22] reported positive correlation of maximum and minimum temperature with population of red pumpkin beetle.

The infestation of *Paridea octomaculata* (Baly) commenced during first week of July (27th SMW) with minimum average 0.3 beetles per plant (Table 1, Fig. 2). Population increased gradually and reached the maximum of average 1.1 adults per leaf during the last week of July (30th SMW), with corresponding maximum temperature of 27.5°C, minimum temperature of 20.6°C, relative humidity of 79% and rainfall of 25.8 mm. Then, population started declining and reached to minimum mean of 0.2 adults per plant during the third week of August (34th SMW).

Paridea octomaculata (Baly) population showed negative and non-significant correlation with maximum temperature. However, whereas correlation was positive and significant with minimum temperature (r = 0.487) and relative humidity (r = 0.523). Rainfall had no impact on the population buildup of the pest (Table 3). The author recorded and reported this insect for the first time in mid hills of Himachal Pradesh.

The population of whitefly, *T. vaporariorum* was recorded on bottle gourd from second fortnight of July to last week of September, 2019 (29th SMW to 39th SMW) (Table 1, Fig. 2). The maximum population (2.96 whiteflies per leaf) was observed in last week of August (35th SMW). No whitefly population was observed in the first week of October (40th SMW). Whitefly population was not affected by maximum temperature and rainfall, whereas it had positive and significant correlation with minimum temperature (r = 0.499) and relative humidity (r = 0.476) (Table 3). Sunil et al. [18] reported incidence of whitefly from 30th to 44th SMW. However, Saha et al. [22] recorded the incidence of whitefly (*B. tabaci*) from last week of April to mid of June, during 2014, 2015 and 2016 on cucumber in Bhagalpur, Bihar, which may be due to climatic variations in the study locations. These results are in correspondence with the revelation of Sunil et al. [18] and Saha et al. [22] also reported negative correlation of whitefly (*B. tabaci*) population with minimum temperature.

3.3 Seasonal Incidence of Insect Pests in Ridge Gourd

The hadda beetle, *H. vigintioctopunctata*; whitefly, *T. vaporariorum*; red pumpkin, *A. foveicollis* and leaf miner, *L. trifolii* were recorded as important pests on ridge gourd.

The infestation of hadda beetle was initiated during first week of July, 2019 (28th SMW) with a minimum average number of 0.2 hadda beetles per plant (Table 1, Fig. 3). The beetle population started increasing gradually and maximum average number of 1.0 beetles per plant was observed during first week of August (31st SMW). After that the beetle population started decreasing and minimum average count of 0.4 adults per plant was recorded in the last week of September (39th SMW). The hadda beetle population was not affected by maximum temperature and rainfall (Table 4). However, the correlation was found positive and significant with minimum temperature (r = 0.586) and relative humidity (r = 0.675). Rathod and Borad [23] also reported incidence of epilachna beetle in bitter gourd from July to October in Mohanpur (West Bengal). Painkra et al. [24]; Kalkal et al. [25]; Kumar and Saini [26] have observed peak population of hadda beetle during August-September on bitter gourd. Jamwal et al., [27] have reported 5.48 average number of beetles per plant as maximum population of hadda beetle in Jammu. These results similar to the observations of Ghule et al. [28] who reported positive correlation of mean maximum as well as minimum temperature with population of epilachna beetle (*H. septima*), but mark with revelation of Jamwal et al., [27] and Saha et al. [22] who reported positive correlation between

minimum mean temperature, relative humidity with adult population of hadda beetle.

The leafminer infestation was observed from first week of July to second week of September, 2019 (27th SMW to 36th SMW) (Table 1, Fig. 3). The maximum number of mines (2.7 mines per leaf) was noticed during third week of August (33rd SMW). Thereafter, infestation started declining as crop growth progressed to minimum number of mines (0.53 mines per leaf) during first week of September (36th SMW). The leaf miner population was not affected by maximum temperature and level of rainfall. Whereas, correlation was found to be positive and significant with minimum temperature (r = 0.537) and relative humidity (r = 0.567) (Table 4). Earlier, Chaudhuri and Senapati [30] reported that leaf miner incidence slowly increased during early crop growing stages, but gained momentum from flowering stage onwards. Shilpakala and Krishna [34] recorded maximum incidence of leaf miner in castor during 38th, 39th and 40th SMWs. Similar results were obtained by Reddy and Kumar (32); Durairaj [33] and Shilpakala and Krishna [34] who reported positive correlation between leaf miner population and minimum temperature. However, positive correlation between leaf miner population and rainfall, average relative humidity was also reported by Chaudhuri and Senapati [30]. Contrarily, Chakraborty [31] recorded significant negative correlation of the test population with maximum temperature and positive correlation with minimum temperature, average relative humidity and rainfall.

The pest activity of hadda beetle was observed on ridge gourd from third week of June to third week of September *i.e.,* 25th SMW to 38th SMW (Table 1, Fig. 3). The population reached to maximum average of 2.4 beetles/plant in last week of August (35th SMW). Thereafter, population declined to average count of 0.5 beetles per plant during third week of September (38th SMW). The red pumpkin beetle population showed positive and significant correlation with minimum temperature (r = 0.628) and relative humidity (r = 0.547), while correlation was non-significant with maximum temperature and rainfall (Table 4). Sunil et al. [18] observed 0.30 mean number of beetles per plant as maximum population of red pumpkin beetle during 39th in bitter gourd. Shinde et al. [21] also reported maximum infestation i.e. 3.64 per cent of red pumpkin beetle infestation during 26th and 32nd SMW. The positive correlation of beetle population with minimum temperature and relative humidity has also been reported by Sunil et al. [18] in bitter gourd. Contrarily, Jha [35]; Ghule et al. [28] and Yadav et al. [36] revealed positive correlation between maximum mean temperature and red pumpkin population in their studies.

The whitefly population was recorded on ridge gourd from first week of June to last week of September, 2019 i.e. 23rd SMW to 39th SMW (Table 1, Fig. 3). The maximum mean population (3.76 whiteflies per leaf) was observed in last week of July (30th SMW) with corresponding weekly mean maximum temperature of 27.5°C, minimum temperature of 20.6°C, relative humidity of 79 per cent and rainfall of 25.8 mm. The whitefly population remained high up to 38th SMW and then declined to reach zero population in the first week of October (40th SMW). The whitefly population exhibited no correlation with maximum temperature and rainfall, whereas positive and significant correlation was observed with minimum temperature (0.751) and relative humidity (0.630) (Table 4). Sunil et al. [18] recorded incidence of whitefly in bitter gourd from 30th to 44th SMW. Saha et al. [22] reported the incidence of whitefly (*B. tabaci*) from last week of April to mid of June, during 2014, 2015 and 2016 on cucumber in Bhagalpur, Bihar. These differences in pest activity may be attributed to climatic variations or variable cropping periods in their study locations. Sunil et al. [18] reported the positive correlation of whitefly population with rainfall in bitter gourd.

4. CONCLUSION

Among sucking pests, jassids, *Amrasca biguttula biguttula* (Ishida) and whitefly *Trialeurodes vaporariorum* (Westwood); among leaf eating and mining pests, red pumpkin beetle, *Aulacophora foveicollis* (Lucas); hadda beetle, *H. vigintioctopunctata* (Fabricius); leaf miner *Liriomyza trifolii* (Burgess) and spotted cucumber beetle, *Diabrotica* sp.; were observed as major insect pests attacking cucurbit vegetables (bitter gourd, bottle gourd and ridge gourd) at Nauni, Solan, Himachal Pradesh. The peak population of all insect pest were recorded from 30th SMW to 35th SMW in these crops. Peak population of leaf eating beetle in bottle gourd and whitefly in ridge gourd recorded in 30th SMW, and in 31ist SMW jassids in bitter gourd, hadda beetle in ridge gourd attained peak population. In 32nd SMW peak population of leaf miner in bottle gourd was recorded while leaf miner in ridge gourd and hadda beetle in bitter gourd attained maximum

population in 33rd SMW. In 35th SMW peak population of whitefly in bottle gourd and red pumpkin beetle in bitter gourd, bottle gourd and ridge gourd were recorded. So, the study showed that incidence of insect pest attacking cucurbits at mid hill conditions of Himachal Pradesh was high between 30th to 35th SMW. So, the period from mid-August to mid-October is crucial for initiation of pest management practices in cucurbit vegetables under mid-hill conditions of Himachal Pradesh.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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