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Influence of Abiotic Factors on Population Dynamics of Major Insect Pests of Mulberry

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ABSTRACT
During the sampling survey 11 species of sapsuckers, 15 species of leaf defoliators and 2 species each of borers, mites and termites belonging to different families were collected and incidence in different season was recorded. The peak incidence of sapsuckers was reported during the summer (February-May) and winter season (November-February) and some of the sapsuckers were present throughout the year. However, majority of the defoliators were active and causing severe damage during the rainy season (June-October). Highest pest incidence was caused by defoliating pest, *Diaphania pulverulentalis* (39.43%) during September followed by sap sucking pests such as *Maconellicoccus hirsutes* (32.12%) and *Pseudodendrothrips mori* (23.23%) during May. The correlation results revealed that the incidence of defoliating pests were significantly and negatively correlated with maximum temperature and positively correlated with maximum relative humidity. However, the incidence of important sapsuckers were significantly and positively correlated with maximum temperature and negatively correlated with maximum relative humidity.

Key words: Seasonal incidence, mulberry pests, correlation analysis

INTRODUCTION

Sericulture is the science that deals with the production of silk by rearing of silkworm. Silk is called the queen of textiles due to its glittering luster, softness, elegance, durability and tensile properties. Silk originating in the spittle of an insect is a natural fibrous substance and is obtained from pupal nests or cocoons spun by larvae known as silkworms. Mulberry leaf is the sole food for silkworm (*Bombyx mori* L.) and is a major economic component in sericulture, the quality and quantity of the leaf produced per unit area has a direct relation to cocoon production. Mulberry the food plant of silkworm (*Bombyx mori* L.) is prone to attack by about 300 species of arthropod pests worldwide. The productivity of mulberry both qualitatively and quantitatively has a direct relationship with productivity in sericulture, which can be achieved by following improved cultivation technology and also with the management of pest and diseases. Pest populations have a tendency to fluctuate as a result of the influence of the environmental factors. The degree of influence of various environmental factors determined the magnitude of increase or decrease in the number of a pest population. However, a functionally viable model for pest forecast is the need of the hour for effective integrated pest management strategy. In other crops weather based pest and disease-forewarning models have been developed to a certain extent (Singh *et al*., 1990; Jayanthi *et al*., 1993; Prasad *et al*., 2008). Several environmental factors are known to incidence the inherited characters specially those involving physiological characteristics of crop plants and the associated insect pest populations (Cammel and Knight, 1992). Therefore, pest populations have a tendency to fluctuate as a result of the influence of the environmental factors. The degree of influence of various environmental factors determined the magnitude of increase or decrease in the number of a pest population. The rate of change in pest population is determined by the fecundity, speed of development and survival among its numbers. The same factor may be favorable in case of one type of population but may become unfavorable for another. It is therefore necessary to consider the influence

of various environmental factors with respect to a particular pest population (Atwal, 1999). Information on pest complex in particular agro climatic condition is a prerequisite, which helps in designing a successful pest management strategy. In view of the existing situation in mulberry pest management and the importance of sericulture in India, it is a necessary prerequisite for developing effective pest management programmes to know the proper and appropriate ecological requirements. Weather factors like temperature, relative humidity and rainfall, which play a vital role in multiplication and distribution of insect pests and these factors have given a great momentum to a research approach in pest management. To develop any pest management programme f or a specific agro-ecosystem, information on abundance and distribution of pest in relation to weather parameters is a basic requirement (Patel and Shekh, 2006). However, no systematic efforts have been made to observe the diversity of insect pests and their seasonal occurrence with relation to crop phenological stages in mulberry ecosystem. Seasonal incidence of some of the pests of mulberry were exclusively studied by various workers such as about thrips (Pillai and Krishnaswami, 1980; Sahakundu, 1994; Manjunath *et al*., 2001), leaf roller (Gowda *et al*., 2000; Velavan *et al*., 2001; Samuthiravelu *et al*., 2004; Rahmathulla *et al*., 2012), mealy bug (Sudhakara *et al*., 2006; Manjunath *et al*., 2003; Rao *et al*., 1993; Balachandran *et al*., 2009), white fly (Bandyopadhyay *et al*., 2002: Mukhopadhyay, 2006; Narayanaswamy and Ramegowda, 1999), grasshopper (Manjunatha and Shree, 2000), termite (Bania and Khan, 2006) and mites (Rajadurai and Shekar, 2003; Pillai and Jolly, 1986). A combined and concentrated efforts about the seasonal occurrence of various pests and information about the relationship with environmental factors in mulberry ecosystem is scanty. Therefore, the present work is envisaged to study the diversity of pests of mulberry agro ecosystem in relation to environmental factors.

MATERIALS AND METHODS

Study area: The study area P3 Basic Seed Farm is located in Mysore, Karnataka state of India and it has situated at 12° 18’ N’ 76°39’ E and has an average altitude of 770 m (2,526 ft). It is in the southern region of the state of Karnataka and spreads across an area of 128.42 km^2. The summer season is from March to the middle of June, followed by the Monsoon season from the middle of June to October and the Winter season from November to mid February. The highest temperature recorded in Mysore was 38.5°C (101°F) and in Winter, temperatures were recorded as low as 9.6°C (49°F) (Fig. 1). The average annual rainfall received was 798.2 mm. The silkworm rearing of parental races at basic seed farm has to be organized in a scientific manner and also to ensure that silkworm rearing is free from disease menace. Besides, this various cocoon characters and fecundity, etc., have to be achieved according to the norms fixed for each race.

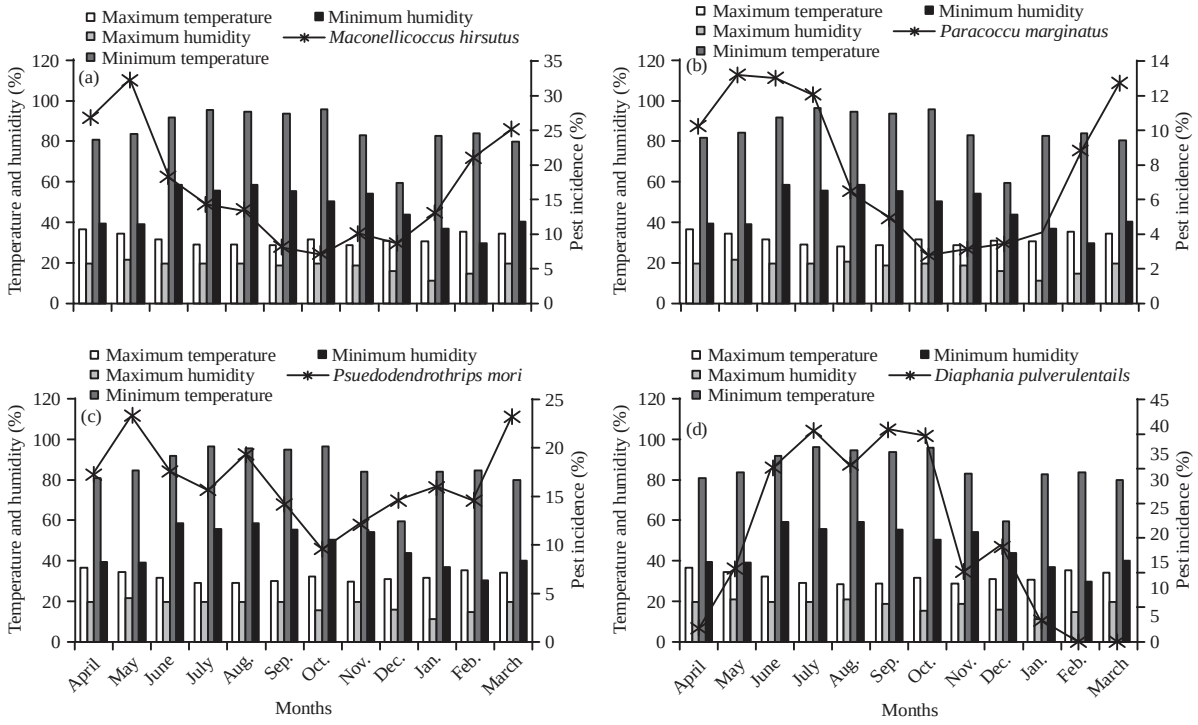

Fig. 1(a-d): Association of weather factors with pest incidence, (a) *Maconellicoccus hirsutus*, (b) *Paracoccus marginatus*, (c) *Pseudodendrothrips mori* and (d) *Diaphania pulverulentalis*

Host plant: Mulberry (*Morus* sp.) is the exclusive food for economically important silkworm (*Bombyx mori* L.), which is cultivated in tropical and temperate countries of the world. In India, it is cultivated mostly in the tropical region, evergreen throughout the year. The mulberry garden has to be managed with due care and right inputs to be added to produce healthy and succulent leaf, which is very much essential for quality silk production. Due to continuous crop improvement in the field of mulberry breeding and genetics, many new mulberry varieties have been evolved, much better than the local varieties in respect of quality and quantity of leaf produced. At the same time, these improvements paved ways for their susceptibility to attack by various pests and diseases.

Sampling of pest population and Statistical analysis: For the study purpose the mulberry garden of the basic seed farm was divided into six sub plots and pruning schedule of mulberry plant was adjusted to conduct six silkworm crops annually. Luxuriant growth and availability of different quality leaves such as tender, medium and coarse are assured throughout the year. For observations and data collection, ten plants from each sub plots were selected at random. Thus, 60 plants were observed every 10 days during a month for a period of three years (2008-09, 2009-10 and 2010-11). The incidences of different pests were observed and the number of adult insects and nymphs or larvae on each selected plant was counted and calculated total pest infestation. The data was tabulated in different months and experiment was continued for a three-year period and the average infestation for each month was tabulated. The weather factors like maximum temperature, minimum temperature, maximum humidity, minimum humidity and rainfall were recorded from the study location every day and month wise data were pooled and tabulated. The influence of weather factors on population density of various pests was analyzed by a simple correlation study and coefficients were worked out.

RESULTS AND DISCUSSION

Observation on entomo fauna from the study location: A total of 15 defoliating insect species were collected from the study location and out of this 10 lepidopteran species belonging to 10 different families were identified (Table 1). Two-weevils belonging to order Coleoptera and family Curculionidae, one beetle (May-June beetle) belonging to order Coleoptera and family Melonthidae and two leaf feeding grasshoppers belonging to order Orthoptera and family Acrididae were also recorded from the study.

Eleven species belonging to sap sucking groups and order Hemiptera, Homoptera, Heteroptera and Thysanoptera were recorded. The family wise distribution showed that 2 species belong to family Pseudococcidae and one species each belonging to different families such as Aleyrodidae, Cicadellidae, Coccidae, Pentatomidae, Cercopidae, Membracidae, Aleydidae and Thripidae were recorded from the study location (Table 2).

Two stem borers belonging to order Coloeoptera and family Ceramycidae were recorded. The distribution of two species of mites belonging to family Tetranychidae was observed, beside this termite species belonging to order Isoptera and family termitoidae were recorded. Two species of snail were recorded which cause extensive damage to mulberry plant during rainy season and voraciously feed on mulberry leaf except midrib.

Incidence of sap sucking pests: As, mulberry is perennial plant producing luxuriant foliage, it attracts various insects and non-insect pests. Although, the frequent leaf plucking and pruning of the shoot restrict the attack of pests, many of them are still finding enough time and place on mulberry for feeding and breeding. The incidence of sap sucking species during different months were recorded and presented in Table 3. Among these species most prominent and causing severe

Table 1: Sap sucking and borer pests recorded from the study location

Sap sucking pest species	Pest status	Family	Order
Maconellicoccus hirsutus green	Major	Pseudococcidae	Hemiptera
Paracoccus marginatus Williams and Granara de Willink	Major	Pseudococcidae	Hemiptera
Aleurodicus dispersus Russel	Minor	Aleyrodidae	Hemiptera
Pseudodendrothrips mori (Niwa)	Minor	Thripidae	Thysanoptera
Empoasca flavescens Fabricius	Minor	Cicadellidae	Hemiptera
Pulvinaria maxima. Green	Minor	Coccidae	Homoptera
Nizara virudula Linnaeus	Occasional	Pentatomidae	Heteroptera
Clovia puncta Walker	Minor	Cercopidae	Homoptera
Oxyrachis tarandus Fabricius	Minor	Membracidae	Homoptera
Riptortus fuscus Fabricius	Occasional	Aleydidae	Heteroptera
Chrysocoris purpurea (Linnaeus)	Occasional	Scuttelleridae	Heteroptera
Borers			
Sthenias grisator Fabricius	Minor	Ceramycidae	Coleoptera
Apriona germari Hope	Minor	Ceramycidae	Coleoptera
Mites			
Tetranychus ludeni Zacher	Minor	Tetranychidae	Acarina
Tetranychus equitorius	Minor	Tetranychidae	Acarina
Termites			
Odontotermes sp., *obesus* (Rambur)	Minor	Termitidae	Isoptera
Odontotermes sp., *indicus* Thakur	Minor	Termitidae	Isoptera

Table 2: Defoliating pests recorded from the study location

Defoliating pest species	Pest status	Family	Order
Diaphania pulverulentalis Hampson	Major	Pyralidae	Lepidoptera
Spilarctia obliqua (Walker)	Sporadic	Arctidae	Lepidoptera
Spodoptera litura (Fabricius)	Minor	Noctuidae	Lepidoptera
Eupterote mollifera. Walker	Minor	Eupterotidae	Lepidoptera
Euproctis fraterna (Moore)	Minor	Lymantridae	Lepidoptera
Amata passalis Fabricius	Minor	Amatidae	Lepidoptera
Archips micaceana Walker	Minor	Totricidae	Lepidoptera
Paradoxecia pieli Lieu	Minor	Aegeridae	Lepidoptera
Phthonandria sp.	Minor	Geometridae	Lepidoptera
Amsacta moorei Butler	Minor	Arctidae	Lepidoptera
Myllocerus subfaciatus Guerin-Meneville	Minor	Curculionidae	Coleoptera
Myllocerus viridanus Fabricius	Minor	Curculionidae	Coleoptera
Holotrichia serrata Fabricius	Minor	Melolonthidae	Coleoptera
Neorthacris acuticeps nilgiriencis Uvarov	Minor	Acrididae	Orthoptera
Cyrtacanthacris ranacea Stoll	Minor	Acrididae	Orthoptera

Table 3: Seasonal occurrence of sap sucking pest population in mulberry ecosystem during the period 2008-11(%)

Sap sucking pest species	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan	Feb.	March	Average	Range
Maconellicoccus hirsutus	26.68	32.12	18.12	14.23	13.34	08.11	07.07	10.01	8.62	12.89	20.97	25.11	16.44	7.07-32.12
Paracoccus marginatus	10.12	13.05	12.84	11.88	06.31	04.82	02.63	3.11	3.30	03.99	08.69	12.57	07.78	3.11-13.05
Aleurodicus dispersus	06.00	06.88	04.11	04.78	0.00	0.00	00.00	0.00	0.00	0.00	01.23	06.02	02.42	1.23-06.88
Pseudodendrothrips mori	17.06	23.23	17.45	15.49	19.30	14.22	09.45	11.98	14.45	15.78	14.34	23.12	16.32	9.45-23.33
Empoasca flavescens	05.08	05.34	05.19	04.00	01.40	0.00	0.00	0.00	0.00	0.00	05.80	06.67	02.79	1.40-06.67
Pulvinaria maxima	01.60	01.24	00.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	00.00	00.00	00.28	0.52-01.60
Nizara virudula	0.00	0.00	01.19	01.85	02.44	05.27	02.78	1.43	0.00	0.00	00.00	00.00	01.25	1.19-05.27
Clovia puncta	0.00	0	00.0	01.24	03.34	02.45	02.56	2.45	3.45	02.34	00.89	00.00	02.29	0.89-03.34
Oxyrachis tarandus	0.53	0.597	0.81	0.77	0.77	00.66	00.46	0.67	0.44	00.58	00.30	0.33	00.57	0.30-0.77
Riptortus fuscus	0.50	0.653	0.32	0.33	0.33	00.54	0	0	0	0	0	0	00.22	0.32-0.65
Chrysocoris purpurea	0	0	0	0.31	0.81	01.11	01.22	0.8	0.77	0.68	00.68	0.073	00.54	0.31-01.11

damage was *Maconellicoccus hirsutus* (pink mealy bug), which causes tukra disease symptom in mulberry (Manjunath *et al*., 1996). The Infestation was reported throughout the year and severe damage to mulberry plants was reported during dry and hot climate conditions (February- April). The attack of pink mealy bug is known to cause malformation of the apical stem, wrinkling of leaves, flattening of stem giving bunchy appearance, which affect the apical growth of the main stem and branches (Ghose, 1972). The highest infestation was recorded in the month of May (32.12%). The average incidence of pink mealy bug (*Tukra*) in the southern sericulture states is estimated to be 34.24%. Another species of mealy bug popularly known as Papaya mealy bug (*Paracoccus marginatus*) was an occasional minor pest of mulberry, due to some unknown reason the pest becomes a serious problem not only to mulberry but also to other agricultural crops in South India. The infestation of the pest was observed throughout the year and severe infestation was occurred during May-June period (13.05 and 12.84%). Interestingly, thrips, jassids and white fly species that suck the sap from underneath the foliage exhibited strikingly similar trend of infestation. It was evident from the observation that the peak infestation of sapsuckers was in summer, which may be attributed to the congenial environment prevailing in the season for proper framing of their secretion into the protective layer surrounding the insect. The *Aleurodicus dispersus* (white fly) is an occasional pest of mulberry and sometimes due to fluctuation in environmental conditions it become a serious threat to mulberry and the pest was reported during the dry season after January and was persisted up to 3-4 months. Highest Infestation was recorded during the month of May (6.88%). Scientists (Bandyopadhyay *et al*., 2002) determined the economic thresh hold level of white fly in mulberry. Another sap sucking insect namely *Pseudodendrothrips mori* (Thrips) is also known as a minor pest to mulberry and was reported throughout the year and sometimes the pest become serious nature and causing severe qualitative and quantitative damage particularly in dry and hot climatic conditions and the incidence was continued up to the rainy season. Thrips feed by opening wounds on the plant surface and sucking out the contents of the plant cells, the feeding results in small whitish streaks on the leaves. The highest incidence of the pest was recorded in the month March and May (23.12 and 23.72%, respectively). Workers (Sahakundu, 1994) studied the population dynamics of mulberry thrips in West Bengal, India conditions. Some of the researchers (Manjunath *et al*., 2001) also studied the species composition and seasonal incidence of thrips in mulberry. Mulberry crop improvement in many studies has also paved the way for their susceptibility to attack by pests and diseases. Prominent workers (Hesami *et al*., 2007) studied the spatial distribution of thrips on mulberry and concluded that nymphal stages concentrated on lower canopy and adult preferred upper canopy of the of the plant. It was reported that thrips and whitefly have emerged as major pests in Eastern India account for about 11-24% crop loss (Mukhopadhyay, 2006). Scientists (Sathyaprasad *et al*., 2000)

screened the germplasm to identify varieties resistant to pest attack and utilize the same in the breeding program to evolve pest tolerant variety. Several minor and occasional pests were reported from mulberry garden (Table 1), among them *Empoasca flavescens* (plant hopper) and *Pulvinaria maxima* were cause infestation during dry months and it was continued up to rainy season. However, *Nizara virudula* and *Clovia puncta* was recorded through out the year except few months during dry season. The species *Oxyrachis tarandus* reported from mulberry throughout the year and maximum infestation was occurred during June and July months (0.81 and 0.77%, respectively). Species like *Chrysocoris purpurea* and *Riptortus fuscus* are occasional pests in mulberry and the maximum infestation was reported during October (1.22%) and May (0.7%). In overall pest management practices were tested to suit the sericulture ecosystem for avoidance of major pests such as tukra causing mealy bug (*Maconellicoccus hirsutus*) and leaf webber (*Diaphania pulverulentalis*) on mulberry. Researchers (Muthulakshmi *et al*., 2003) developed sustainable pest management strategies for important mulberry pests. It was observed that different tactics of integrated methods for control of major pests of mulberry for their management of certain ruling mulberry varieties, viz., S36, S34, S13, K2 and V1 for their tolerance to tukra through induction method (Samuthiravelu *et al*., 2003).

Incidence of leaf defoliating pests: Defoliating pests are common in all agricultural ecosystem, feeding on all plants and they detrimental to the healthy and productivity of the plants. Several leaf-defoliating pests were reported from mulberry and some of them are known as serious pests and others are known as occasional or minor pest associated with mulberry ecosystem (Table 2). The species like *D. pulverulentalis* and *S. obliqua* are serious pests and among these *D. pulverulentalis* species commonly known as leaf roller or webber and causing severe damage to apical portion of mulberry plant and causes considerable loss in leaf yield particularly to chawki leaves (Siddegowda *et al*., 1995). The incidence of pest was reported throughout the year from the study location except a few months in the Summer season (February and March). Peak infestation was recorded during the rainy season and the incidence was correlated with the onset of monsoon and availability extra moisture in mulberry leaf and atmosphere humidity builds up. The highest incidence of the infestation was recorded during September (39.40%) and July (39.10%). Several workers studied the seasonal incidence of the pest and higher infestation was reported during October to February under South Indian climatic condition (Qadri *et al*., 2003; Samuthiravelu *et al*., 2004). The association temperature factors and parasitoid with pest incidence and out break of the leaf roller was reported from Karnataka (Bai *et al*., 1997; Bai and Marimadaiah, 2002).

However, the Bihar hairy caterpillar (*Spilarctia obliqua*) is a sporadic pest and sometimes it causes severe defoliation in mulberry garden and resulted in economic loss. The early instar larvae of *S. obliqua* fed gregariously on the under surface of the leaves, later stages defoliated the mulberry leaves (Jayaswal, 1987). The severe infestation was reported during rainy season (5.37% during August) and there was no incidence reported during the summer months (February-May). Although, the number of pests attacking on mulberry is higher, only a limited portion of it is considered to be important and the leaf yield loss caused by the important pest of mulberry estimated in South India is about 10-20% (Rajadurai, 2005).

Several other lepidopteran pests are reported from mulberry and most of them not causing severe damage and the species reported during the study were *Spodoptera litura*, *Eupterote mellifera*, *Euproctis fraterna*, *Amata passalis*, *Archips micaceana*, *Paradoxecia pieli* and *Phthonandria* sp (Table 4). All of these defoliating pests were active particularly during rainy season. Among them *S. litura* is a worldwide distributed polyphagous pest and sometimes it causes severe damage to mulberry and the infestation was reported maximum during September and October months (3.79 and 3, 73%, respectively). Similarly, the species *E. mellifera* is an occasional pest and causing minor injury to mulberry leaf and maximum infestation was reported during the month of August (2.56%). The species, *A. passalis*

Table 4: Seasonal occurrence of defoliating pest population in mulberry ecosystem during the period 2008-11 (%)

Defoliating pest species	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Average	Range
Diaphania pulverulentalis	02.49	13.68	32.20	39.10	32.90	39.40	38.40	13.10	17.83	03.93	0	0	19.42	2.49-39.40
Spilarctia obliqua	0	0	02.23	02.96	05.37	03.73	02.23	1.57	00.82	00.81	0	0	01.64	0.81-05.37
Spodoptera litura	0	0	0	00.26	01.60	03.79	03.73	1.54	02.03	00.81	0	0	01.15	0.26-03.73
Eupterote mollifera	0	0	0	0	00.82	02.56	01.41	0.79	01.81	0	0	0	00.62	0.62-02.56
Euproctis fraterna	01.60	01.09	00.55	00.33	0	0	0	0	0	0	01.47	01.33	00.53	0.33-1.47
Amata passalis	1.96	02.28	02.31	01.07	00.08	0	0	0	0	0	01.08	01.29	00.84	0.84-2.31
Archips micaceana	0	0.72	00.31	00.73	00.56	00.88	00.98	0.41	00.64	0	00.21	0	00.45	0.21-0.98
Paradoxecia pieli	0	0	0	00.43	01.23	00.92	01.42	0.6	00.45	00.13	0	0	00.43	0.6-1.23
Phthonandria sp.	0	0	00.54	00.87	00.99	00.83	00.34	0.54	00.82	0	0	0	00.41	0.34-0.99
Amsacta moorei	0	0	00.87	00.67	01.83	01.90	01.78	0.75	00.83	00.68	0	0	00.78	0.68-1.9
Myllocerus subfaciatus	0.78	0.54	00.89	01.23	01.34	01.56	00.68	1.43	00.32	00.43	00.32	00.41	00.83	0.32-1.56
Myllocerus viridanus	0.72	0.32	01.72	00.98	01.56	01.53	00.32	1.72	01.22	00.73	00.18	00.15	00.93	0.15-1.56
Holotrichia serrata	0.73	0.82	00.97	00.53	00.54	0	0	0	0	0	0	0	00.29	0.53-0.97
Neorthacris acuticeps nilgriencis	2.45	4.46	06.67	04.25	02.23	03.74	03.82	2.89	02.34	02.23	1.87	00.89	03.15	0.89-4.45
Cyrtacanthacris ranacea	0.76	1.43	02.56	02.67	03.87	01.08	01.79	1.45	00.98	00.86	0.74	00.81	01.58	0.74-3.87

popularly known as wasp moth and its was appeared during June to July and the hairy caterpillar causing minor defoliation to mulberry and maximum infestation was reported during August (1.83%) and September (1.9%). The presence of looping caterpillar *Phthonandria* sp. was also noticed in mulberry garden during June-December months and causing minor damage to leaf and maximum infestation was reported during August (0.99%). Besides, this several leaf defoliating grasshoppers, weevils, beetles were reported from the mulberry garden and *Myllocerus* sp. (ash weevil) showed its presence throughout the year and maximum infestation was recorded during the month of August-September for *M. subfasciatus* and November and August for *M. viridinus.* The beetle *Holotrichia serrata* (May-June beetle) infestation was reported during April-July. The two species of grasshoppers *Neorthacris acuticeps nilgiriencis* and *Cyrtacanthacris ranacea* were recorded throughout the year from the study location and the first species popularly known as wingless grasshopper and maximum infestation recorded during the month of June (6.67%) and sometimes the species cause severe problems, nymphs and adults feed on spongy buds and leaves. Singh *et al*. (2000) listed out important pests of mulberry plants and their control measures.

Incidence of borers and termites: The pest species observed from these groups were presented in Table 5. Two species of cerambycid borers were reported from mulberry (*Sthenias grisator* and *Apriona* sp.) among this *Sthenias grisator* popularly known as stem girdler beetle occasionally causing damage to mulberry plant and the incidence was reported during the months June-October. The adult beetle is stout built with long antennae and well-developed mouthparts and the symptom of incidence can be identified by observing a peculiar habit of the beetle, ringing stem and bark and forms a healthy cut around the main stem or branch leaving a clean girdle. The portion above the girdle slowly wilts and dries the plant. Another species, *Apriona* was recorded during April to August months and this species laid eggs on the trunk branches usually creamy layer of the bark and hatch in about 7-8 days and the grub burrowing under the bark sap wood. Two species of mite such as *Tetranychus ludeni* and *Tetranychus equitorius* recorded its infestation throughout the year and maximum incidence was recorded during February and March. Mites are found on the leaves, bud, scales, nodes and apical shoots. Both nymphs and adult insect insert their stylets into leaf tissues and suck the sap. Pillai and Jolly (1986) and Rajalakshmi *et al*. (2009) recorded the breeding behavior and seasonal variation of mulberry infesting mite and stated that increased temperature has enhanced the egg laying capacity in the mites. Two species of termites belonging to genus *Odontotermes* reported from the study and they mainly attack on the rain-fed garden and sometimes severe infestation in the irrigated mulberry garden was also noticed. The termites form an earthen sheath on the stem and feed on the bark and they also make sub terrains galleries and feed on the roots and resulting mortality (Rajadurai and Shekar, 2003). Bania and Khan (2006) also studied the termite problem of the subtropical climatic zone of Jammu region.

Association pest incidence and environmental factors

Sap sucking pests: The correlation analysis data showed that there was a significant positive correlation recorded between pest incidences of some of the pests with maximum temperature recorded from the study location (Table 6). However, some other pests, which were active during rainy as well as summer season, had a negative correlation with maximum temperature. The species like *M. hirsutus* (r = 0.769), *P. marginatus* (r = 0.484) and *A. disperses* (r = 0.596) had a highly significant positive correlation with maximum temperature. The species like *C. puncta* (r = -0.703), *N. virudula* (r = -0.637), *O. tarandus* and (r = 0.639), *C. purpurea* (r = -0.557) had a highly significant negative correlation with maximum temperature. Similarly, most of the species recorded from the study had a significant

Table 5: Seasonal occurrence of borer/termite pest population in mulberry ecosystem during the period 2008-11 (%)

Borer/termite pests	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	Average	Range
Sthenias grisator	0	0	0.23	2.26	2.34	1.35	0.67	0	0	0	0	0	0.570	0.23-2.34
Apriona	0.23	0.56	0.67	0.48	0.23	0	0	0.68	0.45	0	0	0	0.275	0.23-0.68
Tetranychus ludeni	2.25	2.45	1.56	0.45	0.56	1.23	0.56	1.67	3.78	4.89	6.78	7.98	2.846	0.45-7.98
Tetranychus equitorius	2.23	2.13	0.23	0.67	0.78	0.33	0.67	0.88	1.34	2.56	3.78	4.67	1.689	0.23-4.87
Odontotermes sp., *Obesus*	0.45	1.78	2.78	1.89	1.45	0.56	0.89	0.78	1.34	1.56	0.78	0.32	1.215	0.32-2.78
Odontotermes sp.	0.32	0.68	1.54	1.43	0.32	0.45	0.67	0.89	1.67	1.98	0.88	0.56	0.941	0.32-1.98

Table 6: Correlation coefficient (r) value between incidences of sap sucking pest and environmental factor

Sap sucking pest species	Maximum temperature	Minimum temperature	Maximum humidity	Minimum humidity	Rain fall
Maconellicoccus hirsutus	0.769**	0.394*	-0.115	0.628**	0.206
Paracoccus marginatus	0.484*	0.556**	0.156	-0.117	0.248
Aleurodicus dispersus	0.596**	0.553**	0.003	-0.228	0.265
Pseudodendrothrips mori	0.341*	0.528**	-0.109	-0.207	0.271
Empoasca flavescens	0.705**	0.400*	0.027	-0.367*	0.077
Pulvinaria maxima	0.631**	0.385*	-0.096	-0.266	0.309*
Nizara virudula	-0.637**	0.229	0.638**	0.710**	0.068
Clovia puncta	-0.703**	-0.308*	-0.159	0.290*	-0.107
Oxyrachis tarandus	-0.639**	0.446*	0.526**	0.806**	0.586**
Riptortus fuscus	0.058	0.648**	0.341*	0.242	0.493*
Chrysocoris purpurea	-0.557**	-0.451*	0.144	0.230	-0.215

*Significant at 5% level, **Significant at 1% level

Table 7: Correlation coefficient (r) value between incidence of defoliating pest and environmental factors

Defoliating pest species	Maximum temperature	Minimum temperature	Maximum humidity	Minimum humidity	Rainfall
Diaphania pulverulentalis	-0.669**	0.277	0.605**	0.849**	0.314*
Spilarctia obliqua	-0.801**	0.303*	0.623**	0.849**	0.405*
Spodoptera litura	-0.531**	-0.185	0.150	0.416*	-0.182
Eupterote mollifera	-0.507**	-0.071	-0.090	0.393*	-0.234
Euproctis fraterna	0.896**	0.224	-0.107	-0.640**	-0.072
Amata passalis	0.666**	0.461*	0.106	-0.214	0.187
Archips micaceana	-0.505**	0.183	0.299*	0.521**	0.302*
Paradoxecia pieli	-0.636**	0.033	0.406*	0.591**	0.237
Phthonandria sp.	-0.838**	0.282*	0.172	0.831**	0.321*
Amsacta moorei	-0.737**	-0.005	0.451*	0.725**	0.080
Myllocerus subfaciatus	-0.703**	0.524**	0.593**	0.817**	0.455*
Myllocerus viridanus	-0.716**	0.276	0.111	0.789**	0.215
Holotrichia serrata	0.205	0.598**	0.350*	0.256	0.596**
Neorthacris acuticeps nilgiriencis	-0.176	0.273	0.434*	0.544**	0.227
Cyrtacanthacris ranacea	-0.559**	0.459*	0.570**	0.754**	0.704**

*Significant at 5% level, **Significant at 1% level

positive correlation with minimum temperature recorded, except the species such as *C. puncta* (r = -0.308) and *C. purpurea* (r = -0.45). Relative humidity was the other most important factor closely related to the activity of the pest. It was observed that some of the species recorded a positive correlation and some other species had a negative correlation with maximum humidity. The species like *N. virudula* (r = 0.638) and *O. tarandus* (r = 0.526) recorded a highly significant positive correlation with maximum humidity. However, species such as *M. hirsutus* (r = -0.115), *P. mori* (r = -0.109) and *C. puncta* (r =-0.109) had a negative correlation.

Similarly, a significant positive correlation was recorded between the pest incidences of most of the species with minimum humidity (Table 4). The species like *M. hirsutus* (r = 0.628) and *N. virudula* (r = 0.760) recorded highly significant positive correlation with the minimum humidity. However, the rest of the species had a positive correlation with minimum humidity. Rainfall is considered as the most important factor regulating the insect population. Rainfall data had a positive correlation with most the species recorded. Some insects are closely tied to a specific set of host crops. Temperature increases that cause farmers not to grow the host crop any longer would decrease the populations of insect pests specific to those crops. The same environmental factors that impact on pest insects can also impact their insect predators and parasites as well as the disease causing organisms, resulting in increased attacks on insect populations.

Defoliating pests: Pest incidence of the defoliating species had a negative correlation with the maximum temperature of the study location except the species like *E. fraterna* and *A. passalis* (Table 7). The highly significant negative correlation was recorded between the incidence of pest infestation and maximum temperature for the species such as *D. pulverulentalis* (r = -0.669), *S. obliqua* (r = -0.801) and *A. mori* (r = -0.737) etc. The greatest effect of temperature, especially of the minimum, on the build up of leaf roller populations, demonstrated their greater sensitivity to these conditions, within the thermal range found during the study period. Such conditions favored the population decrease of adults, which occurred greater number in the summer. The minimum and average temperatures were the factors, which had the greatest influence on the population dynamics. Maximum temperature also had exhibited a significant positive effect on the incidence of pest population in all the years. However, a significant positive correlation was recorded for *A. passalis* (r = 0.666) and *E. fraterna* (r = 0.896) with maximum humidity recorded from the study location and pest incidence of defoliating pests except few species. A significant positive correlation was recorded for species like *Amata passalis* (r = 0.461), *Myllocerus subfaciatus* (r = 0.524) and *Hollotricha serrata* (r = 0.598), similarly, most of the defoliating pest had a significantly higher positive correlation with maximum humidity recorded; *D. pulverulentalis* (r = 0.605), *S. obliqua* (r = 0.623) and *M. subfaciatus* (r = 0.593). Persistent relative humidity (maximum) imparted a significantly positive impact on the abundance of defoliating insect population in all the years, especially at the growth stage. The relationship between minimum humidity and pest incidence revealed that most of the species had a positive correlation with minimum humidity except *E. fraterna* and *A. passalis*. The species like *D. pulverulentalis* (r = 0.849), *E. fraterna* (r = 0.640), *S. obliqua* (r = 0.849) and *M. subfaciatus* (r = 0.817) had a highly significant positive correlation with minimum humidity. From the data it could be observed that the highest and lowest relative humidity was conducive for the incidence of the defoliating larvae. It was also reported that rainfall data of the location had a significant association with pest incidence of defoliating pest (Table 4).

Borers and termites: The pest incidence of borers and termite population had an association with environmental factors recorded from the study location. Significant negative correlation was recorded between the pest incidences of species like *S. grisator* (-0.659) and *Odontotermes* sp (-0.247) with maximum temperature (Table 8). However, highly significant positive correlation was recorded for species such as *T. ludeni* (r = 0.550) and *T. equitorius* (r = 0.681). Maximum and minimum humidity had a positive correlation with the incidence of *S. grisator* (r = 0.635 and 0.668, respectively). The pest incidence of species such as *T. ludeni*

Table 8: Correlation coefficient (r) value between incidence of borers /termites/mites pest species and environmental factors

Borer/termites pest species	Maximum temperature	Minimum temperature	Maximum humidity	Minimum humidity	Rain fall
Sthenias grisator	-0.659**	0.362*	0.635**	0.668**	0.540**
Apriona	-0.211	0.449*	-0.130	0.410*	0.511*
Tetranychus ludeni	0.550**	-0.373*	-0.528**	-0.775**	-0.607**
Tetranychus equitorius	0.681**	-0.215	-0.403*	-0.842**	-0.367*
Odontotermes sp obesus	-0.247	0.063	0.192	0.371*	0.311*
Odontotermes indicus	-0.231	0.042	0.123	0.421*	0.267

*Significant at 5% level, **Significant at 1% level

and *T. equitorius* had a significantly high value of negative correlation was observed with maximum humidity, minimum humidity and rainfall.

CONCLUSION

The incidence and development of important mulberry pests are very much dependent upon the prevailing environmental factors and crop stand. Minimum temperature and high humidity along with rainfall showed significant and positive correlation with the pest infestation of defoliators ($p<0.01$). Similarly, high temperature and low humidity along with scattered rainfall is favourable for the population builds up of the most the sapsuckers. It may be concluded that climatic factors determine seasonal activity and population dynamics of mulberry pests. The data generated in the present study would be useful for developing efficient pest management strategies against insect pests of mulberry for increased production of leaf and subsequent silk production.

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