

# Original Research Article

## SUCCESSION OF MAJOR PESTS AND PREDATORY FAUNA IN OKRA

### ABSTRACT

Investigations on pest succession in okra crops were carried out during *kharif*, 2023 at the Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand. Pest succession based on crop growth stages showed that the population of sucking insect-pests viz., jassid (*Amrascabiguttulabiguttula* Shida), aphid (*Aphis gossypii* Glover), whitefly (*Bemisia tabaci* Gennadius.) observed from vegetative stage and remained up to crop matured while, red spider mite, *Tetranychus cinnabarinus* incidence appeared from reproductive stage to maturity stage. Among the lepidopteran pests, the infestation of semi-looper, *Anomis flava* (Fabricius) started in the second week after germination and remained till maturity of the crop whereas, shoot and fruit borer (*Earias insulana* Boisduval) and fruit borer (*Helicoverpa armigera* (Hubner) Hardwick) damaged the crop from the vegetative stage and remained up to crop maturity. Coccinellids and spider activity initiated with sucking insect-pest incidence and remained up to crop maturity. The weather parameters, Bright sunshine hours and maximum minimum temperature had significant relationships with *A. biguttulabiguttula*, *T. cinnabarinus*, *E. vittella* and *H. armigera*. Whereas, relative humidity significantly negatively influenced the activity of red spider mite, *E. vittella*, *H. armigera* and positively on predator coccinellids. Furthermore, windspeed had a significant positive association with *A. biguttulabiguttula* and *E. vittella* (shoot damage) while, negative with *H. armigera* larva.

**Keywords:** Abiotic factors, correlation, insect-pests, okra, predatory fauna, succession

### 1. INTRODUCTION

Cultivated okra [*Abelmoschus esculentus* (L.) Moench], a member of the Malvaceae family, is an important vegetable crop grown in India. However, insect-pest attacks and disease infestation are the important limiting factors in okra production, with total yield losses of approximately 35-40% (Mohankumar et al. [1]; Rai [2]). The major reported insect-pest include jassid (*Amrascabiguttulabiguttula* Shida), aphid (*Aphis gossypii* Glover), whitefly (*Bemisia tabaci* Genn.), shoot and fruit borer (*Earias insulana* Boisduval) and (*Earias vittella* Fab.) and fruit borer (*Helicoverpa armigera* Hubner) (Kanwar and Ameta, [3]). Among these, shoot and fruit borers are reported to cause 16 to 26 per cent damage to okra shoots and 40 to 60 per cent losses of fruits in India (Pareek and Bhargava, [4]). Jassid nymphs and adults suck plant sap from the lower surface of the leaves and inject anecrotic toxin, limiting photosynthesis and causing browning, bronzing, cupping, wilting, and necrosis of the leaves (Raghuwanshi et al. [5]) which results in severe yield losses of about 40-56 percent in okra (Krishnaiah, [6]). Jassids and aphids are known to infest during the early stage of crop growth, leading to about 54.04 per cent (Chaudhary and Dadeech, [7]). Whitefly is also responsible for the yield loss of about 80 to 90 per cent. The red spider mite, (*Tetranychus cinnabarinus* Boisduval) also has assumed the status of a major pest and caused a 17.46 per

cent yield loss in okra. (Sarkar et al. [8]). The okra semilooper, *Anomis flava*, primarily causes significant damage to the leaves of host plants. The larvae's feeding behavior not only affects the immediate health of the plant but also has implications for overall crop yield and management strategies in agricultural settings. Developing effective strategies for pest control requires a detailed understanding of the presence and succession patterns of insect-pests throughout diverse morphological and physiological stages of crop development, taking into careful consideration the influence of abiotic factors. In light of this, a critical imperative emerges to delve into the intricate dynamics of insect-pest populations in conjunction with weather parameters. This comprehensive study becomes instrumental in acquiring detailed insights into the timing and culmination of peak phases of insect-pest infestation. Such precise knowledge, thus garnered, plays a pivotal role in facilitating the formulation and implementation of targeted pest management strategies precisely tailored to the distinct requirements and vulnerabilities of the crops at various stages of their growth cycle. Moreover, in the context of environmental sustainability and climate change, the need to understand these dynamics becomes even more pressing. Climate change is increasingly recognized as a significant factor influencing the behavior and distribution of insect pests. Shifts in temperature, humidity, and precipitation patterns directly impact the life cycles, population dynamics, and geographical range of these pests, often leading to more frequent and severe infestations. Additionally, climate-induced changes in the timing of crop development stages can create windows of increased susceptibility to pest attacks, further complicating pest management efforts. This study, therefore, is not only vital for optimizing pest control in okra cultivation but also for addressing the broader challenges posed by a changing climate. By examining the interactions between insect-pest populations and weather parameters, we can better predict how climate variability and long-term climate change might influence pest behavior and crop vulnerability. This information is crucial for developing resilient pest management strategies that can adapt to the evolving environmental conditions, ensuring sustainable agricultural practices that are both environmentally friendly and effective in the face of climate change. Incorporating these insights into pest management strategies will not only enhance the efficiency of pest control measures but also contribute to the broader goals of environmental conservation and climate change mitigation. By reducing the reliance on chemical pesticides and promoting integrated pest management approaches, we can help to minimize the environmental impact of agriculture and support the transition to more sustainable farming practices. Keeping this in view, the present studies were undertaken to succession and incidence of insect pests and their natural enemies on okra.

## 2. MATERIALS AND METHODS

The research work was carried out at the Entomology farm, Anand Agricultural University, Anand, Gujarat (22.56 °N and 72.95 °E) during *Kharif* - 2023. The land was ploughed to a fine tilth at a depth of 20-25 cm. Clods, stubbles and weeds are removed mechanically and by manual labours. Well rotten FYM @ 20 25 t ha<sup>-1</sup> was added at the time of land preparation. Half dose of nitrogen and full dose of phosphorus and potash was applied. Field was levelled and an experimental plot of 116.64 m<sup>2</sup> was divided into six equal quadrates (5.4 x 3.6 m). Okra cultivar Gujarat Anand Okra-5 (GAO-5) was sown by adopting dibbling. Observations on various pests and predatory fauna were

done at weekly intervals on randomly selected ten plants per quadrat. The incidence of *A. biguttulabiguttula*, *A. gossypii* and *B. tabaci* population were counted from three (upper, middle and lower) leaves whereas; *T. cinnabarinus* population was recorded from the same leaves of 1 cm<sup>2</sup> area of the same selected plants in each quadrat. The incidence of *E. vittella* was recorded based on the number of healthy and damaged shoots and fruits starting from one week after germination to crop termination whereas, the incidence of *H. armiger* in okra was observed based on the number of the larva(e) as well as the number of healthy and damaged fruits. Damaged fruits due to fruit borer were recorded at each picking by counting the number of healthy and damaged fruits. Thus, data on healthy and damaged shoots and fruits were converted into percentage by adopting the formula given by Mandal et al. [9]. The population of predatory fauna (coccinellids and spiders) was also recorded from the randomly selected same ten plants starting from one week after germination until the crop termination. To study the effect of weather parameters on population fluctuation of various pests, the data of physical factors of the environment viz., bright sunshine hours (BSS), rainfall (RF), wind speed (WS), maximum (MaxT) and minimum (MinT) temperature, morning (RH<sub>1</sub>) and evening (RH<sub>2</sub>) relative humidity were correlated. Week-wise data on various parameters were recorded by the Department of Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand during *kharif*, 2023. A simple correlation between various pests and their predatory fauna as well as with weather factors was worked out using their weekly mean incidence by adopting a standard statistical procedure (Steel and Torrie, [10]). The statistical analysis was carried out using SPSS software version 22.0 (IBM, New York, USA).

### 3. RESULTS AND DISCUSSION

#### 3.1 Succession of pests and predatory fauna in okra crop

The data presented in Table 1 revealed that about seven species of pests and two species of predatory fauna were observed with various growth stages of the okra crop. The okra crop was first attacked by semilooper, *Anomis flava* at the early stages of the okra crop i.e. vegetative stage whereas, the population of *A. biguttulabiguttula*, *A. gossypii* and *B. tabaci* occurred at the succeeding stages and persisted till the maturity of the crop. The next incidence in the okra crop was fruit borer *H. armiger* which caused damage to okra leaves during vegetative stage and was observed feeding on the flowers as well as fruits during the reproductive stage. While, shoot and fruit borer (*E. vittella*) infestation had occurred first in plant shoots and later on bored inside the fruits. Both the lepidopteran pests persisted till the maturity of the crop. The late pest to occur in the okra crop was red spider mite (*T. urticae*) which occurred during the reproductive stage and remained in the crop up to termination of the crop. In the case of predatory fauna in the okra crop, various species of coccinellids and spiders were recorded from vegetative to maturity. The present findings were in agreement with the studies conducted by Pandey and Koshta [11], Raghuwanshi et al. [5], Das et al. [12], Chandra [13] and Anjana et al. [14] who documented the activity of *A. biguttulabiguttula* and *B. tabaci* from the vegetative to the maturity stage whereas, *E. vittella* infestation was prominent from the reproductive to the maturity stage in the okra crop. Similarly, Chaturvedani et al. [15] also reported the incidence of *A. gossypii*, *A. biguttulabiguttula* and *B. tabaci* during the vegetative stage of the crop.

### 3.1.1 Jassid, *Amrasca biguttulabiguttula*

The *A. biguttulabiguttula* population commenced from the 3<sup>rd</sup> week after germination (WAG), i.e., the first week of August [31<sup>st</sup> Standard Meteorological Week (SMW)], and persisted till the 42<sup>nd</sup> SMW i.e., 3<sup>rd</sup> week of October (Table 2). The population of *A. biguttulabiguttula* ranged from 0.68 to 7.32 with a mean population of 4.36 per leaf. The first peak population (7 jassid/leaf) was obtained during the 2<sup>nd</sup> week of September (9<sup>th</sup> WAG and 37<sup>th</sup> SMW) whereas a second peak of 7.32 jassid per leaf was observed during the 3<sup>rd</sup> week of October (42<sup>nd</sup> SMW). These results are in agreement with the findings of Raghuwanshi *et al.* [5] observed peak activity of *A. biguttulabiguttula* during the 2<sup>nd</sup> and 4<sup>th</sup> week of September, respectively. Similarly, the findings of Pathan and Bharpoda [16] recorded two peaks of *A. biguttulabiguttula* infestation i.e. during the 37<sup>th</sup> SMW and 42<sup>nd</sup> SMW of the okra crop, these results were also aligned with the results of our present investigation.

### 3.1.2 Aphid, *Aphis gossypii*

The data presented in Table 2 indicate that the incidence of *A. gossypii* appeared in the 3<sup>rd</sup> WAG i.e. first week of August (31<sup>st</sup> SMW) and continued till the 2<sup>nd</sup> week of October (41<sup>st</sup> SMW and 13<sup>th</sup> WAG). The population of *A. gossypii* ranged from 0.88 to 17.28 per leaf during the season with a mean population of 6.24 per leaf. The peak activity of this pest (17.28 aphids/ leaf) was recorded during the 4<sup>th</sup> week of August i.e. 34<sup>th</sup> SMW (6<sup>th</sup> WAG). In the subsequent weeks, the *A. gossypii* population gradually declined and eventually disappeared by 3<sup>rd</sup> week of October (42<sup>nd</sup> SMW and 14<sup>th</sup> WAG). These results align with the findings of Pathan and Bharpoda [16] who reported that *A. gossypii* activity began in the 3<sup>rd</sup> week after germination (WAG) and continued until the 11<sup>th</sup> WAG, with peak activity occurring during the 5<sup>th</sup> week of August.

### 3.1.3 Whitefly, *Bemisia tabaci*

*B. tabaci* population was initiated in the okra crop from the 3<sup>rd</sup> WAG i.e. 31<sup>st</sup> SMW (First week of August) and continued till the 2<sup>nd</sup> week of October i.e. 41<sup>st</sup> SMW and 13<sup>th</sup> WAG (Table 2). Throughout the crop period, the *B. tabaci* population fluctuated between 0.06 and 3.00 per leaf with a mean population of 0.97 per leaf. The highest activity of *B. tabaci* i.e. 3.00 per leaf was recorded in the 2<sup>nd</sup> week of September (37<sup>th</sup> SMW and 9 WAG) and then gradually declined. The population of *B. tabaci* disappeared after the 2<sup>nd</sup> week of October i.e. 41<sup>st</sup> SMW and 13<sup>th</sup> WAG. The present findings are in agreement with Pathan and Bharpoda [16] who reported that whitefly incidence occurred in the 3<sup>rd</sup> week of sowing in the okra and recorded higher activity in the 9<sup>th</sup> and 10<sup>th</sup> week of sowing. Khating *et al.* [17] also stated that the highest activity of *B. tabaci* was observed during September. However, Patel [18] noted that the incidence of *B. tabaci* started in the 4<sup>th</sup> week after sowing and reached its peak level in the 8<sup>th</sup> week after sowing. These findings were more or less similar to present investigations.

### 3.1.4 Red spider mite, *Tetranychus cinnabarinus*

The population data for *T. cinnabarinus*, as presented in Table 2, indicated that they occurred during the latter part of the crop season. The population of *T. cinnabarinus* marked its first appearance during the 3<sup>rd</sup> week of September (39<sup>th</sup> SMW and 11<sup>th</sup> WAG) and gradually increased in trend till the

crop termination *i.e.* 3<sup>rd</sup> week of October (42<sup>nd</sup> SMW and 14<sup>th</sup> WAG). *T.cinnabarinus* densities ranged from 3.45 to 15.00 per 1 cm<sup>2</sup> leaf area with a mean population of 10.22 mites per 1 cm<sup>2</sup> leaf.

**Table 1: Succession of pests and predatory fauna in okra crop during kharif,2023**

| <b>Sr. No</b> | <b>Common name</b>    | <b>Scientific name</b>   | <b>Crop growth stage</b>     | <b>Occurrence</b> | <b>Economic status</b> |
|---------------|-----------------------|--|------------------------------|-------------------|------------------------|
| <b>1</b>      | Jassid                | <i>Amrasca biguttula biguttula</i> (Ishida)<br>(Cicadellidae, Hemiptera) | Vegetative to maturity stage | Regular           | Major                  |
| <b>2</b>      | Aphid                 | <i>Aphis gossypii</i> (Glover)<br>(Aphididae, Hemiptera)                 | Vegetative to maturity stage | Regular           | Major                  |
| <b>3</b>      | Whitefly              | <i>Bemisia tabaci</i> (Gennadius)<br>(Aleyrodidae, Hemiptera)            | Vegetative to maturity stage | Regular           | Major                  |
| <b>4</b>      | Red spider mite       | <i>Tetranychus urticae</i> (Koch)<br>(Tetranychidae, Trombidiformes)     | Flowering to maturity stage  | Regular           | Major                  |
| <b>5</b>      | Shoot and fruit borer | <i>Earias vittella</i> (Fabricius)<br>(Noctuidae, Lepidoptera)           | Vegetative to maturity stage | Regular           | Major                  |
| <b>6</b>      | Fruit borer           | <i>Helicoverpa armigera</i> (Hubner)<br>(Noctuidae, Lepidoptera)         | Vegetative to maturity stage | Regular           | Major                  |
| <b>7</b>      | Semilooper            | <i>Anomis flava</i><br>(Erebidae, Lepidoptera)                           | Vegetative to maturity stage | Regular           | Major                  |
| <b>8</b>      | Coccinellids          | -  | Vegetative to maturity stage | Regular           | -                      |
| <b>9</b>      | Spiders               | -  | Vegetative to maturity stage | Regular           | -                      |

### 3.1.5 Shoot and Fruit borer, *Earias vittella*

The periodic activity of *E. vittella* was observed based on shoot damage and fruit damage (Table 2). The incidence of *E. vittella* on shoots has occurred in 2<sup>nd</sup> week of August (32<sup>nd</sup> SMW and 4<sup>th</sup> WAG) with 4.52 per cent shoot damage. The maximum (10.42%) shoot damage was recorded during in 5<sup>th</sup> week of August (36<sup>th</sup> SMW and 5<sup>th</sup> WAG) and then declined. The incidence of shoot and fruit borer was observed in okra shoots up to 3<sup>rd</sup> week of September (38<sup>th</sup> SMW). Shoot and fruit borer infestation in fruits of okra (Table 2) started from 5<sup>th</sup> week of August (36<sup>th</sup> SMW and 5<sup>th</sup> WAG) with 6.00 per cent damage and endured up to crop cessation i.e. 3<sup>rd</sup> week of September (38<sup>th</sup> SMW and 14 WAG). The highest (20.12%) fruit damage was recorded during 3<sup>rd</sup> week of September (38<sup>th</sup> SMW and 10 WAG) and then subsequently declined. In the last week before crop termination, 7.88 per cent incidence of *E. vittella* was observed on fruits. The present findings are in close proximity with earlier investigations by Raghuwanshi et al. [5] who reported that the incidence of okra fruit and shoot borer on fruits started in the 3<sup>rd</sup> week of September and remained active up to the last picking of the fruits. Sheoran et al. [19] observed the infestation of *E. vittella* on shoots from 32<sup>nd</sup> SMW with its peak on 39<sup>th</sup> SMW while, the highest fruit damage (35.68%) due to *E. vittella* was recorded on 39<sup>th</sup> SMW by Bisen et al. [20]. and 3<sup>rd</sup> week of September and again attained a second peak (2.14 larva/ plat) in 3<sup>rd</sup> week of October (42<sup>nd</sup> SMW and 14 WAG). More or less the same trend was observed in fruit damage due to the larva of *H. armigera* (Table 2). The incidence in okra fruits started at 2.24 per cent from the 5<sup>th</sup> week of September (35<sup>th</sup> SMW and 7 WAG) and gradually increased to 44.62 per cent fruit damage on the 3<sup>rd</sup> week of October (42<sup>nd</sup> SMW and 14<sup>th</sup> WAG). Pathan and Bharpoda [16] stated that fruit infestation of *H. armigera* started in the first week of September and reached its peak in the third week of October. Chandra [13] recorded the initiation of *H. armigera* at 7 WAS. In the present finding, *H. armigera* was first perceived in the fourth week after germination i.e., the second week of August (32<sup>nd</sup> SMW) and reached its highest peak in the third week of October. Thus, the present study is in accordance with the above conclusions drawn by earlier researchers.

### 3.1.7 Semilooper, *Anomis flava*

The observations on *A. flava* larva per plant in okra crop are presented in Table 2. The occurrence of *A. flava* began in the 2<sup>nd</sup> week after germination, specifically during the 3<sup>rd</sup> week of July (30<sup>th</sup> SMW) and persisted until the 2<sup>nd</sup> week of October (41<sup>st</sup> SMW and 13 WAG). The larval population of *A. flava* occurred between 0.04 to 2.32 per plant during the season. During 5<sup>th</sup> week of August (35<sup>th</sup> SMW and 7WAG), the activity of this pest was recorded highest with 2.32 larvae per plant. In the subsequent weeks, the semilooper population gradually declined and eventually disappeared by the 2<sup>nd</sup> week of October. The present investigations could not be discussed here due to the lack of published literature on *A. flava* in okra. **3.1.8 Coccinellids**

The activity of coccinellids as a predator is presented in Table 2. The population of coccinellids began with 0.32 per plant in the crop after the third week of germination i.e. 1<sup>st</sup> week of August (31<sup>st</sup> SMW) and persisted until the second week of October (41<sup>st</sup> SMW and 13 WAG). The coccinellid population was recorded in the plot during the season from 0.32 to 4.12 per plant with a

mean of 1.50 per plant. The highest activity of this natural enemy was recorded during the 1<sup>st</sup> week of September

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**Table 2: Occurrence of pests and predatory fauna in okra crop (kharif,2023)**

| Block | SMW              | WAG | No. of sucking insect-pests/leaf |                       |                      | <i>Tetranychuscinnabarinus</i> /<br>1 cm <sup>2</sup> leaf area | <i>Eariasvittella</i> |                  | <i>Helicoverpaarmigera</i> |                  | No. of <i>Anomis flava</i> larva(e)/ plant | Predator fauna/plant |              |
|-------|------------------|-----|----------------------------------|-----------------------|----------------------|---|-----------------------|------------------|----------------------------|------------------|--|----------------------|--------------|
|       |                  |     | <i>Amrascabiguttulabiguttula</i> | <i>Aphis gossypii</i> | <i>Bemisiatabaci</i> |   | Shoot damage (%)      | Fruit damage (%) | No. of larva(e) / plant    | Fruit damage (%) |  |                      | Coccinellids |
| I     | III              | 29  | 1                                | -                     | -                    | -   | -                     | -                | -                          | -                | -  | -                    |              |
|       | IV               | 30  | 2                                | -                     | -                    | -   | -                     | -                | -                          | -                | 0.08                                       | -                    |              |
|       | I                | 31  | 3                                | 0.68                  | 1.24                 | 0.12  | -                     | -                | -                          | -                | 0.12                                       | 0.32                 |              |
|       | II               | 32  | 4                                | 1.44                  | 3.68                 | 0.28  | -                     | 4.52             | -                          | 0.06             | -  | 1.20                 | 0.56         |
|       | III              | 33  | 5                                | 2.82                  | 8.76                 | 0.46  | -                     | 6.26             | -                          | 0.15             | -  | 1.76                 | 1.34         |
|       | IV               | 34  | 6                                | 3.96                  | 17.28                | 0.68  | -                     | 8.44             | -                          | 0.30             | -  | 2.08                 | 2.80         |
| II    | V                | 35  | 7                                | 4.28                  | 12.58                | 1.46  | -                     | 10.42            | 6.00                       | 0.45             | 2.24                                       | 2.32                 | 3.36         |
|       | I                | 36  | 8                                | 6.32                  | 11.98                | 2.26  | -                     | 6.88             | 10.22                      | 1.00             | 6.32                                       | 0.86                 | 4.12         |
|       | II               | 37  | 9                                | 7.00                  | 10.11                | 3.00  | -                     | 3.36             | 15.68                      | 0.70             | 14.48                                      | 0.11                 | 3.38         |
|       | III              | 38  | 10                               | 4.46                  | 4.56                 | 2.00  | 3.45                  | 1.76             | 20.12                      | 0.85             | 22.28                                      | 0.12                 | 1.13         |
| III   | IV               | 39  | 11                               | 3.00                  | 2.00                 | 0.88  | 6.44                  | 0.00             | 16.72                      | 1.36             | 28.12                                      | 0.28                 | 0.86         |
|       | I                | 40  | 12                               | 4.48                  | 1.82                 | 0.38  | 12.00                 | 0.00             | 12.22                      | 1.60             | 32.16                                      | 0.08                 | 0.08         |
|       | II               | 41  | 13                               | 6.54                  | 0.88                 | 0.06  | 14.22                 | 0.00             | 9.34                       | 1.88             | 37.98                                      | 0.04                 | 0.05         |
| IV    | III              | 42  | 14                               | 7.32                  | 0.00                 | 0.00  | 15.00                 | 0.00             | 7.88                       | 2.14             | 44.62                                      | 0.00                 | 0.00         |
|       | <b>Mean ± SE</b> |     |                                  | 4.36±<br>2.06         | 6.81<br>±5.59        | 1.05±<br>0.99   | 10.22±5.05            | 3.79±<br>3.78    | 12.29±<br>4.84             | 0.95±<br>0.71    | 23.53±<br>15.03                            | 0.83±<br>0.75        | 1.50 ± 1.00  |

**Notes:1.** SMW = Standard Meteorological Week

**2.** WAG = Week After Germination

(36<sup>th</sup> SMW, 8 WAG), reaching a peak of 4.12 grubs/adults per plant. However, the coccinellids population gradually declined in the subsequent weeks and eventually disappeared by the 2<sup>nd</sup> week of October (41<sup>st</sup> SMW, 13 WAG). Das et al. [12] illustrated that the incidence of coccinellids in okra was observed at 19 days after sowing and the population persisted till the harvest of the crop during the summer season. This report is more or less in accordance with the present findings.

### 3.1.9 Spiders

The data presented in Table 2 indicated that the population of spiders started to appear during 1<sup>st</sup> week of August (31<sup>st</sup> SMW). The population of spiders ranged from which 0.08 to 3.12 per plant. The peak activity (3.12 spiders/plant) was observed during the 4<sup>th</sup> week of September (39<sup>th</sup> SMW and 12<sup>th</sup> WAG). The present findings are consistent with the results of Khating et al. [17] who reported peak activity of spiders during the 4<sup>th</sup> week of September.

## 3.2 Succession between/among Pests and Natural Enemies in Okra based on Association

The data on correlation study (Table 3) between/among various pests of okra indicated that the *A. biguttulabiguttula* population had a significantly positive correlation with larva of *H. armigera* and its damage on okra fruit ( $r = 0.703^*$  and  $0.595^*$ , respectively). Populations of *A. gossypii* exhibited a highly significant positive correlation with shoot damage by *E. vittella* ( $r = 0.901^{**}$ ) and *A. flava* ( $r = 0.764^{**}$ ) indicating that pests appeared concurrently on okra whereas, the population of aphid had a significant negative association with *T. cinnabarinus* ( $r = -0.672^*$ ) and fruit damage by *H. armigera* ( $r = -0.646^*$ ). Further, *A. gossypii* and coccinellids association showed a significant highly positive correlation ( $r = 0.858^{**}$ ), illustrating that the increase in *A. gossypii* population also increases the coccinellid predators or vice-versa. The incidence of *B. tabaci* showed a significant positive correlation with coccinellids ( $r = 0.781^*$ ). The population of *T. cinnabarinus* established a highly significant positive correlation with larvae of *H. armigera* ( $r = 0.966^{**}$ ), whereas a significant positive correlation with fruit damage by *H. armigera* and *E. vittella* ( $r = 0.995^*$  and  $0.943^*$ , respectively) and significant negative correlation with coccinellids ( $r = -0.984^*$ ). Infestation of shoot by *E. vittella* had a highly significant positive correlation with *A. flava* ( $r = 0.927^{**}$ ) and highly significant negative correlation with larva of *H. armigera* and its damage on okra fruit ( $r = -0.812^{**}$  and  $-0.915^{**}$ , respectively). Whereas, there was a significant positive correlation with the population of coccinellids ( $r = 0.804^*$ ). Infestation of fruit by *E. vittella* had a highly significant positive correlation with spiders ( $r = 0.820^*$ ). The incidence of *H. armigera* showed a highly significant positive correlation with fruit damage by *H. armigera* ( $r = 0.956^{**}$ ) and a highly significant negative correlation with *A. flava* ( $r = -0.758^{**}$ ). In the case of fruit damage by *H. armigera*, a significant negative correlation was observed with the population of coccinellids and *A. flava* ( $r = -0.935^*$  and  $-0.611^*$ , respectively). Earlier, Pathan and Bharpoda [16] reported a highly significant association of *A. biguttulabiguttula* with *H. armigera* and a highly significant positive association between the activity of *A. gossypii* and coccinellids as well as the co-existence of *H. armigera* and *T. cinnabarinus*. Pandey and Koshta [11] reported a significant positive correlation between *A. biguttulabiguttula* and fruit damage by *E. vittella*. Thus, the present results about the association are confirmed by the conclusion made by the above researchers.

**Table 3: Correlation coefficient (r) between incidence of pests in okra and their predatory fauna**

| Insect-pests/<br>natural enemies      | Sucking insect-pests                  |                                |                           | <i>Tetranychuscinnab<br/>arinus</i> /<br>1 cm <sup>2</sup> leaf area | <i>Eariasvittella</i> |                     | <i>Helicoverpaarm<br/>igera</i> |                     | No. of<br><i>Anomis<br/>flavalarv<br/>a(e)/<br/>plant</i> | Predatory<br>fauna/plant |             |
|---------------------------------------|---------------------------------------|--------------------------------|---------------------------|--|-----------------------|---------------------|---------------------------------|---------------------|---|--------------------------|-------------|
|                                       | <i>Amrascabiguttulabi<br/>guttula</i> | <i>Aphis<br/>gossy<br/>pii</i> | <i>Bemisiata<br/>baci</i> |  | Shoot<br>dama<br>ge   | Fruit<br>dama<br>ge | Larva                           | Fruit<br>dama<br>ge |   | Coccinel<br>lids         | Spide<br>rs |
| <i>Amrascabiguttulabi<br/>guttula</i> | -                                     | -                              | -                         | -  | -                     | -                   | -                               | -                   | -   | -                        | -           |
| <i>Aphis gossypii</i>                 | 0.091                                 | -                              | -                         | -  | -                     | -                   | -                               | -                   | -   | -                        | -           |
| <i>Bemisiatabaci</i>                  | 0.392                                 | 0.518                          | -                         | -  | -                     | -                   | -                               | -                   | -   | -                        | -           |
| <i>Tetranychuscinnab<br/>arinus</i>   | 0.479                                 | -<br>0.672<br>*                | -0.473                    | -  | -                     | -                   | -                               | -                   | -   | -                        | -           |
| Shoot damage by<br><i>E.vittella</i>  | 0.057                                 | 0.901<br>**                    | 0.342                     | -0.678   | -                     | -                   | -                               | -                   | -   | -                        | -           |
| Fruit damage<br>by <i>E.vittella</i>  | 0.507                                 | -<br>0.222                     | 0.569                     | 0.995*   | -<br>0.594            | -                   | -                               | -                   | -   | -                        | -           |
| <i>H. armigeralarva</i>               | 0.703*                                | -<br>0.499                     | -0.150                    | 0.966**  | -<br>0.812<br>**      | -<br>0.237          | -                               | -                   | -   | -                        | -           |
| Fruit damage<br>by <i>H. armigera</i> | 0.595*                                | -<br>0.646<br>*                | -0.203                    | 0.943*   | -<br>0.915<br>**      | 0.022               | 0.956**                         | -                   | -   | -                        | -           |
| <i>Anomis flava larva</i>             | -0.295                                | 0.764<br>**                    | 0.010                     | -0.718   | 0.927<br>**           | -<br>0.586          | -<br>0.758**                    | -<br>0.611<br>*     | -   | -                        | -           |
| Coccinellids                          | 0.270                                 | 0.858<br>**                    | 0.781*                    | -0.984*  | 0.804<br>*            | 0.011               | -0.501                          | -<br>0.935<br>*     | 0.549   | -                        | -           |

|                |       |            |       |        |            |            |       |            |        |        |   |
|----------------|-------|------------|-------|--------|------------|------------|-------|------------|--------|--------|---|
| <b>Spiders</b> | 0.023 | -<br>0.110 | 0.388 | -0.858 | -<br>0.357 | 0.820<br>* | 0.177 | -<br>0.106 | -0.198 | -0.164 | - |
|----------------|-------|------------|-------|--------|------------|------------|-------|------------|--------|--------|---|

**Note:** \* Correlation is significant at 0.05 level; \*\* Correlation is significant at 0.01 level

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### 3.3 Succession of Pests and Predatory Fauna in Okra Based on Weather Factors

#### 3.3.1 Jassid, *Amrasca biguttulabiguttula*

The correlation study in Table 4 revealed that *A. biguttulabiguttula* population showed a significant positive correlation with bright sunshine hours (BSS) and maximum temperature (MaxT) ( $r = 0.640^*$  and  $0.613^*$ , respectively). While, significant negative correlations with wind speed (WS) and minimum temperature ( $r = -0.623^*$  and  $-0.576^*$ , respectively). However, abiotic factors viz., morning relative humidity (RH<sub>1</sub>) and evening relative humidity (RH<sub>2</sub>) were non-significantly negatively correlated whereas, rainfall (RF) showed a non-significant positive correlation. These results were in close accordance with the findings of Biswas et al. [21] and Pandey and Koshta [11] who reported that jassid population had a significant positive correlation with MaxT. Satyarth et al. [22] reported that the activity of leafhoppers had a positive and significant correlation with bright sunshine hours.

#### 3.3.2 Aphids, *Aphis gossypii*

There was no significant association between abiotic factors and population of *A. gossypii* (Table 4). However, WS, RH<sub>2</sub> and MinT were non-significantly positively correlated whereas, BSS, RF, MaxT and RH<sub>2</sub> were non-significant negatively correlated.

#### 3.3.3 Whiteflies, *Bemisia tabaci*

The population of *B. tabaci* showed no significant association with abiotic factors (Table 4). However, WS, RF, MinT, RH<sub>1</sub> and RH<sub>2</sub> showed a positive correlation whereas, Bright Sunshine (BSS) and Maximum Temperature (MaxT) showed a negative association.

These results were similar to the findings of Das et al. [12], who reported that MaxT, MinT, RF, RH<sub>2</sub> and BSS were positively and non-significantly related to whitefly populations. These findings were similar to our results. Pathan and Bharpod [16] reported that there was no significant impact of all abiotic factors under study on the incidence of the whitefly population. However, RF, WS, MaxT and RH<sub>1</sub> showed a negative correlation, whereas BSS, MinT and RH<sub>2</sub> had a positive association with the pest. According to Kumar and Singh [23] MaxT had positive non-significant association with the *B. tabaci* population. These findings are in corroboration with the present findings.

#### 3.3.4 Fruit damage by *Earias vittella*

Fruit infestation by *E. vittella* showed a highly significant negative correlation with MaxT ( $r = -0.848^{**}$ ) and a highly significant positive correlation with RH<sub>2</sub> ( $r = 0.823^{**}$ ) (Table 4). Whereas, fruit infestation due to shoot and fruit borer illustrated a significant positive association with RH<sub>1</sub> ( $r = 0.910^*$ ) and a significant negative correlation with BSS ( $r = -0.783^*$ ). The remaining physical factors showed no significant correlations.

#### 3.3.5 Fruit borer, *Helicoverpa armigera*

The correlation studies (Table 4) revealed that both WS and MinT exhibited highly significant negative correlations with *H. armigera* activity, with correlation coefficients ( $r$ ) of  $-0.956^{**}$  and  $-0.856^{**}$ , respectively. Whereas, significant negative correlations with RH<sub>2</sub> ( $r = -0.705^*$ ). Bright Sunshine (BSS)

**Table 4: Correlation coefficient (r) between weather factors and pests infesting okra crop as well as their predatory fauna**

| Weather factors                                 | Sucking insect-pests             |                      |                      | <i>Tetranychuscinnabarinus</i> / 1 cm <sup>2</sup> leaf area | <i>Eariasvittella</i> |              | <i>Helicoverpaarmigera</i> |              | No. of <i>Anomisflava</i> larva(e)/ plant | Predatory fauna/plant |         |
|---|----------------------------------|----------------------|----------------------|--|-----------------------|--------------|----------------------------|--------------|---|-----------------------|---------|
|   | <i>Amrascabiguttulabiguttula</i> | <i>Aphisgossypii</i> | <i>Bemisiatabaci</i> |  | Shoot damage          | Fruit damage | Larva                      | Fruit damage |   | Coccinellids          | Spiders |
| Bright Sunshine Hours (BSS), h/day              | 0.640*                           | -0.319               | -0.110               | 0.942*   | -0.400                | -0.783*      | 0.812*                     | 0.436        | -0.263                                    | -0.155                | 0.108   |
| Rainfall (RF), mm                               | 0.054                            | -0.017               | 0.530                | -0.873   | -0.160                | 0.771        | -0.048                     | -0.191       | -0.355                                    | 0.107                 | 0.564   |
| Wind Speed (WS), km/h                           | -0.623*                          | 0.415                | 0.203                | -0.846   | 0.714*                | 0.228        | -0.956*                    | -0.908**     | 0.409                                     | 0.344                 | -0.356  |
| Maximum Temperature (MaxT), °C                  | 0.613*                           | -0.232               | -0.201               | 0.931*   | -0.277                | -0.848**     | 0.754*                     | 0.357        | -0.116                                    | -0.085                | -0.032  |
| Minimum Temperature (MinT), °C                  | -0.576*                          | 0.478                | 0.437                | -0.968**   | 0.609                 | 0.439        | -0.856*                    | -0.834**     | 0.339                                     | 0.512                 | 0.064   |
| Morning Relative Humidity (RH <sub>1</sub> ), % | -0.183                           | -0.185               | 0.292                | -0.941*  | -0.369                | 0.910*       | -0.049                     | 0.062        | -0.406                                    | -0.151                | 0.672*  |
| Evening Relative                                | -0.561                           | 0.258                | 0.425                | -0.999**   | 0.271                 | 0.823**      | -                          | -0.524       | -0.017                                    | 0.268                 | 0.242   |

|                                     |  |  |  |  |  |  |        |  |  |  |  |
|-------------------------------------|--|--|--|--|--|--|--------|--|--|--|--|
| <b>Humidity (RH<sub>2</sub>), %</b> |  |  |  |  |  |  | 0.705* |  |  |  |  |
|-------------------------------------|--|--|--|--|--|--|--------|--|--|--|--|

**Note:** \* Correlation is significant at 0.05 level; \*\* Correlation is significant at 0.01 level

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Weeks After Germination (WAG)

**Fig. 1: Population of pests and predatory fauna in okra crop**

Hours and Maximum Temperature (MaxT) exhibited highly significant positive correlation ( $r = 0.812^{**}$  and  $0.754^{**}$ , respectively).

### 3.3.6 Fruit damage by *Helicoverpa armigera*

The correlation coefficients ( $r$ ) between abiotic factors and the percentage of fruit damage by *H. armigera* presented in Table 4 revealed that WS ( $r = -0.908^{**}$ ) and MinT ( $r = -0.834^{**}$ ) exhibited a highly significant negative correlation while, the remaining weather parameters did not show any significant impact. The present findings are similar to the results of Pathan and Bharpoda [16] who reported that the fruit damage by *H. armigera* exhibited a highly significant negative correlation with WS and MinT.

### 3.3.7 Semilooper, *Anomis flava*

According to the findings presented in Table 4, none of the abiotic factors significantly impacted the incidence of *A. flava* in okra. However, WS and MinT were positively correlated with semilooper incidence. In contrast, BSS, RF, MaxT, RH<sub>1</sub>, and RH<sub>2</sub> displayed negative correlation.

### 3.3.8 Coccinellids

In order to determine the effect of physical factors on the coccinellid population, a correlation study was attempted (Table 4) and found that all parameters under investigation showed a non-significant impact on the fluctuation of the coccinellid population. However, RF, WS, MinT and RH<sub>2</sub> showed a positive correlation, whereas, MaxT, RH<sub>1</sub> and BSS had a negative correlation with the activity of coccinellids. These results were similar to the findings of Das et al. [12] who reported that coccinellids had a non-significant negative association with BSS and RH<sub>1</sub>.

### 3.3.9 Spiders

The correlation data presented in Table 4 revealed that RH<sub>1</sub> ( $r = 0.672^*$ ) exerted a significant and positive association with the activity of spiders. Whereas other parameters did not show a significant impact on the existence of spiders. However, BSS, RF, MinT and RH<sub>2</sub> showed a positive correlation while, WS and MaxT had a negative correlation.

## 4. CONCLUSION

The present findings of this study revealed that the activity of various sucking pests and predatory fauna of okra commenced from the vegetative stage of the crop and remained in the field till the maturity of the crop except *T. cinnabarinus*, which appeared during the flowering stage of the crop. Whereas, *A. flava* appeared during the vegetative stage while okra fruit borer as well as okra fruit and shoot borer infestation started during the flowering stage of the crop. Weather parameters bright sunshine hours, maximum temperature, and minimum temperature had significant relationships with jassid, mite, *E. vittella*, and *H. armigera*. Rainfall did not influence the activity of okra insect pests and predatory fauna. Windspeed had significant positive association with *A. biguttulabiguttula* and *E. vittella* (shoot damage), while negatively affecting *H. armigera* larva. However, relative humidity significantly negatively influenced the activity of *T. cinnabarinus*, *E. vittella*, and *H. armigera*, but had a positive impact on coccinellids. This study was conducted to address the growing concerns of pest

management in okra cultivation, particularly in the context of changing climate patterns. The findings provide a foundation for developing integrated pest management (IPM) strategies that are tailored to specific environmental conditions and the phenological stages of the okra crop. By addressing these future prospects, the findings of this study could contribute significantly to improving the sustainability and productivity of okra cultivation in the face of evolving environmental challenges.

**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 writing or editing of manuscripts.

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