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RESEARCH ARTICLE

Development of a checklist of Insecta and Arachnida fauna associated with okra (*Abelmoschus esculentus* L. Moench), in the Indo-Gangetic plains of India

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Abstract

A study on development of pest succession list of arthropods (pest and predators) associated fauna in okra ecosystem was made during the *Kharif* seasons from July to October 2023 and 2024. The studies revealed that a total of 12 pest species and three natural enemies were associated with okra crops during their different growth stages. The presence of jassids (*Amrasca biguttula biguttula* (Ishida, 1913)), whitefly (*Bemisia tabaci* (Gennadius, 1889)) and okra shoot and fruit borer (*Earias vittella* (Fabricius, 1794)) were recorded from the vegetative to maturity stage of the crop and considered as a major pest, while tobacco caterpillar (*Spodoptera litura* (Fabricius, 1775)), red spider mite (*Teytranychus spp.* (Dufour, 1832)) and mealy bug (*Phenacoccus solenopsis* Tinsley, 1898)) were present during vegetative to reproductive stage of the crop. Aphid (*Aphis gossypii* Glover, 1877)) and red cotton bug (*Dysdercus cingulatus* (Fabricius, 1775)) were found only during reproductive to maturity stages of the crop. Other insect pests also recorded on the crop were less significant and extent of damage caused by them. Other insect pests also recorded on the crop were less significant and extent of damage caused by them. Among these major insect-pests are observed jassid, whitefly, okra shoot & fruit borer and minor insect-pests, fruit borer, red spider mite, mealybug, short horned grasshopper, red cotton bug, tobacco caterpillar, cotton aphid and occasional insect-pests, okra semilooper and ash weevil. Results provide a baseline understanding of pest dynamics, highlighting critical infestation periods and predator activity. These findings underscore the potential of ecological pest regulation and support the development of location-specific Integrated Pest Management (IPM) strategies. Further, the presence and activity patterns of biological control agents emphasize the importance of their conservation and augmentation through habitat management. Incorporating these ecological insights into predictive models and decision-support tools can significantly enhance the sustainability, resilience and productivity of okra cultivation systems.

Keywords: damage; insect pests; natural enemies; okra; pest succession

Introduction

Okra (*Abelmoschus esculentus* L. Moench) is one of the highly valuable malvaceous vegetables and important commercial crop in India commercially cultivated in both summer as well as *kharif* seasons. Okra commonly referred to as lady's finger or bhindi, is one of India's most significant traditional vegetables (1). It is a native of tropical Africa and widely cultivated in India (2, 3). Nutritionally, okra is a rich source of dietary fibre, antioxidants, ascorbic acid and foliate. It is also a good source of calcium, phosphorus and potassium. India is the largest producer of okra in the world, cultivated under the area of 534 thousand hectares with annual production is 6371 thousand metric tonnes (4). States that cultivate the maximum okra in India include West Bengal, Gujarat, Bihar, Odisha, Uttar Pradesh, Chhattisgarh, Jharkhand, Madhya

Pradesh and Maharashtra. Despite its immense agricultural and economic potential, okra cultivation is hindered by substantial crop losses caused by insect pests, posing a significant challenge to overall production and productivity (1). The successful cultivation of this crop is often hampered by 72 different insect pests starting from its germination. Consequently, continuous monitoring of insect pests and their natural enemies under field conditions is imperative for timely prevention and the implementation for effective pest management strategies. From seed sowing to harvest, the insect pests infesting okra include the shoot and fruit borers *Earias insulana* Fabricius and *Earias vittella* Fabricius (Noctuidae: Lepidoptera); fruit borer, *Helicoverpa armigera* Hübner (Noctuidae: Lepidoptera), semilooper, *Anomis flava* Fabricius (Erebidae :Lepidoptera), leaf roller *Sylepta derogate* Fabricius (Crambidae: Lepidoptera); leafhopper or jassid, *Amrasca biguttula biguttula* Ishida (Cicadellidae: Hemiptera); whitefly *Bemisia tabaci* Gennadius (Aleyrodidae: Hemiptera); aphid *Aphis gossypii* Glover (Aphididae: Hemiptera); red cotton bug, *Dysdercus koenigii* Fabricius (Pyrrhocoridae: Hemiptera) and the acarine pest including red spider mite *Tetranychus spp.* (Trombidiformes: Tetranychidae) are serious causing havoc damage (5, 6) and predators such as Spider *Amblyseius longispinosus* (Lycosidae: Araneae), Spider *Neoscons theisis* Walckenaer (Araneidae: Araneae), *Oxyopes javanus* Latreille (Oxyopidae: Araneae) and *Cheiracanthium approximatum* Villers (Cheiracanthiidae: Araneae). Among these major insect-pests are observed jassid, whitefly, okra shoot & fruit borer and minor insect-pests, fruit borer, red spider mite, mealybug, short horned grasshopper, red cotton bug, tobacco caterpillar, cotton aphid and occasional insect-pests, okra semilooper and ash weevil (7, 8). The yield loss due to leafhopper desapping in okra amounts to 54 - 66 % (9). The whitefly is most notorious among top hundred insect pests having a pandemic distribution and damaging many important crops including vegetables, tubers, fibre crops and ornamentals (10). Leafhoppers, a polyphagous pest have been a serious pest on okra causing heavy loss during these years. High population of leafhoppers significantly sucks cell sap usually from ventral surface of the leaves and injects toxic saliva into plant tissues, turning the leaves yellowish and curling upward (11). Whitefly nymphs and adults remove significant amount of cell sap from the leaves to reduce the plant vigour. They are responsible for transmitting yellow vein mosaic viruses also. The OSFB larvae affect both the vegetative and reproductive phases of okra. The resulting early death of the infected shoots (12). Fruits with infestations develop distorted shapes, which significantly reduces their market value. Just OSFB in Bangladesh damages 52.33 - 70.75 % of okra fruits (13, 14). Seasonal abundance of the insect pest provides not only the information of initiation of the pest but also provides the peak activity of the pest. Most farmers who are engaged in okra production lack technical knowledge and farm management practices. Present studies have been conducted to record the incidence of pests and natural enemies during cropping season and the results may be useful for sustainable management practices of okra crop. Therefore, documenting seasonal dynamics and species-specific abundance of insect pests and their natural enemies is vital for the development of pest forecasting models and location-specific IPM strategies. This checklist serves as a baseline for developing timely and targeted interventions, enabling better preparedness among farmers and extension agencies. Understanding pest incidence patterns allows the anticipation of outbreaks, informed pesticide applications and conservation of beneficial arthropods, ultimately contributing to sustainable okra cultivation. Further, the results of the current study can support future research on ecological pest regulation, resistance breeding and decision-support systems to enhance productivity and reduce reliance on chemical controls. The presence of key biological control agents highlights the considerable potential for leveraging the conservation and augmentation of natural enemies as a core component of ecologically based pest management. To advance this approach, future research should focus on rigorously quantifying the regulatory effects of natural enemies on pest population dynamics and systematically evaluating habitat management interventions that support their in-situ conservation. Incorporating these ecological insights into predictive models and decision-support systems holds promise for enhancing the sustainability, resilience and long-term productivity of okra-based agro-ecosystems.

Materials and Methods

To make a checklist of insect pests and other arthropod fauna associated with okra, the research work was carried out at experimental farm of ICAR-Indian Institute of Vegetable Research, Varanasi, Uttar Pradesh, India during *Kharif* seasons from July to October 2023 and 2024. Okra seeds (cv. Kashi Pragati) were soaked in water for 24 hrs and treated with fungicides like *Trichoderma viride* @ 4 g per kg seed. The experiment was laid out in a Randomized Block Design with replicated thrice. The plot size was 7.0 × 6.3 m with a spacing of 60 x 45 cm. The seeds of okra were sown directly in the soil. The line sowing method was followed. Standard agronomical practices were followed without any insecticidal application to study the succession of insect pests associated with okra crop. The regular monitoring daily for arthropod fauna associated with okra during morning and evening hours (between 8 - 9 am and 4 - 5 pm) from seed germination to till maturity of the crop. Insect pest samples were collected from the okra ecosystem using a camel-hair brush and placed in round plastic Petri dishes (100 mm diameter). The collected arthropod samples were brought to the entomological laboratory of Division of Crop Protection, ICAR- IIVR and stored in 70 % ethanol and a Samsung Galaxy A31 mobile equipped with a 48-megapixel camera was used to capture pictures of the insects. In addition, some arthropod samples specially spiders were sent to ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, India for taxonomic identification and they were as follows: Four species of spider *viz., Amblyseius longispinosus* (Berlese, 1914), *Neoscona theisi* (Walckenaer, 1841), *Oxyopes javanus* (Latreille, 1804) and *Cheiracanthium approximatum* (Villers, 1789) were recorded from the okra ecosystem during the study.

Results and Discussion

Studies on incidence of arthropod fauna in okra revealed that twelve different species of insect-pests and 3 species of natural enemies were observed from sowing to crop maturity during the *Kharif* seasons 2023 and 2024 at Varanasi, Uttar Pradesh (Table 1a & b). Effects were also made to arrange the insect-pests with their systematic position by incorporating the information on their common name, scientific name, family, order, age and stage of the crop and damage symptoms as well. They grouped as major, minor and occasional pest, based on their abundance. Those insects which occurred in good numbers for longer periods and hence found to be causing appreciable damage (10 % or more)

Table 1a. Succession of major insect pests and their predators in okra at Varanasi, Uttar Pradesh during *Kharif*, 2023-2024

Name of the pest	Scientific name	Family: Order	Pest status	Age and stage of the crop during 2023	Age and stage of the crop during 2024	Damage symptoms
Jassid/ Leaf hopper	*Amrasca biguttula biguttula* (Ishida, 1913)	Cicadellidae: Hemiptera	Major	8-88 DAS onwards till crop maturity	10-93 DAS onwards till crop maturity	Both nymphs and adults suck the sap from the underside of leaves, leading to curling, yellowing and potentially reduced yields. This causes the leaves to curl upward along the tip and margins and develop necrotic areas which extend over entire surface resulting in hopper burn.
Whitefly	*Bemisia tabaci* (Gennadius, 1889)	Aleyrodidae: Hemiptera	Major	9-87 DAS onwards both vegetative and reproductive stages	11-83 DAS onwards both vegetative and reproductive stages	Adults suck the sap from the phloem, the food-conducting tissues in plant stems and leaves. Chlorotic spots on the leaves which later coalesce forming irregular yellowing of leaves tissue. Development of sooty-mould, vector of yellow vein mosaic virus (YVMV).
Okra shoots and fruit borer (OSFB)	*Earias vittella* (Fabricius, 1794) and *Earias insulana (Boisduval, 1833)*	Noctuidae: Lepidoptera	Major	18-83 DAS onwards both vegetative and reproductive stages	26-93 DAS onwards both vegetative and reproductive stages	Larva bores into tender shoots during the vegetative stage and later become the flower buds and tender fruits. The damaged shoots droop, wither, dry up and feed causing deformed fruits.
Okra semilooper	*Anomis flava* (Fabricius, 1775)	Erebidae: Lepidoptera	Minor	14-63 DAS onwards both vegetative and reproductive stages	18-71 DAS onwards both vegetative and reproductive stages	Chew irregular holes on leaves, giving them a ragged appearance. In severe incidence entire leaves were eaten away giving a skeletonized appearance.
Fruit borer	*Helicoverpa armigera* (Hübner, [1808])	Noctuidae: Lepidoptera	Minor	Incidence observed during 13-73 DAS vegetative and reproductive stages of crop	Incidence observed during 12-81 DAS vegetative and reproductive stages of crop	Young larvae feed on leaf foliage and later bore in developing fruits.
Red spider mite	*Tetranychus spp.* (Dufour, 1832)	Tetranychidae: Trombidiformes	Major	Incidence observed during 32-92 DAS onwards vegetative and reproductive stages of crop	Incidence observed during 30-86 DAS onwards vegetative and reproductive stages of crop	Nymphs and adults feed on ventral leaf surface, under protective cover of fine silken webs. As a result of their feeding numerous minute yellow spots appear on dorsal side of leaves. Affected leaves gradually start curling, finally wrinkled and crumpled.
Mealy bug	*Phenacoccus solenopsis* (Tinsley, 1898)	Pseudococcidae: Hemiptera	Major	34-78 DAS onwards vegetative and reproductive stages	30-75 DAS onwards both vegetative and reproductive	Suck the sap from plant phloem, reducing plant vigor and they excrete sticky honeydew which reduces plant and fruit quality, especially when black sooty mold grows on these honeydews.
Short horned grasshopper	*Oxya nitidula* (Walker, 1870)	Acrididae: Orthoptera	Minor	49-55 DAS onwards and reproductive	17-25 DAS onwards and vegetative	Both nymphs and adults irregular feeding on leaf blades and flower buds. Later feeds on potentially leading to defoliation and stunted growth, especially in young plants.
Aphid	*Aphis gossypii* (Glover, 1877)	Aphididae: Hemiptera	Minor	40-81 DAS onwards and reproductive stage to till crop maturity	46-89 DAS onwards and reproductive stage to till crop maturity	Both nymphs and adults suck the sap from the tender shoots and the undersides of leaves, leading to leaf curling, crinkling and overall stunted plant growth. Subsequently, the pests excrete honeydew, which facilitates the development of sooty mold on plant surfaces.
Red cotton bug	*Dysdercus cingulatus* (Fabricius, 1775)	Pyrrhocoridae: Hemiptera	Major	53-93 DAS onwards and during reproductive, (fruit maturity) stage	48-86 DAS onwards and during reproductive, (fruit maturity) stage	Both nymphs and adults suck the sap from developing seeds, resulting in diminished yield and quality. Subsequently, infested seeds become shriveled, discolored and poor germination.
Ash weevil	*Myllocerus viridanus* (Fabricius, 1775)	Curculionidae: Coleoptera	Minor	42-91 DAS onwards and reproductive	48-88 DAS onwards and reproductive	Notching of leaf margins by the adults whereas grubs feed on roots and rootlets causing wilting of plants.
Tobacco caterpillar	*Spodoptera litura* (Fabricius, 1775)	Noctuidae: Lepidoptera	Minor	36-89 DAS onwards both vegetative and reproductive stages	23-78 DAS onwards and vegetative, reproductive	The young larvae first feed gregariously and scrape the leaves, older larvae spread out and may completely devour the leaves resulting in poor growth and yield of plants.

Table 1b. Succession of preadtors of major insect pests in okra at Varanasi, Uttar Pradesh during *Kharif*, 2023-2024

Spider	*Amblyseius longispinosus* (Berlese, 1914)	Lycosidae: Araneae	Major	28-95 DAS onwards and vegetative, reproductive	9-88 DAS onwards and vegetative, reproductive	Being polyphagous, spiders feed on soft- bodied insects like aphids, jassids, whitefly and neonate and early instar larvae of Lepidoptera.
	Neoscona theisi (Walckenaer, 1841)	Araneidae: Araneae				
	Oxyopes javanus (Latreille, 1804)	Oxyopidae: Araneae				
	Cheiracanthium approximatum (Villers, 1789)	Cheiracanthiidae: Araneae				
Green lacewings	*Chrysoperla zastrowiisillemi* (Steinmann, 1964)	Chrysopidae: Neuroptera	Minor	41-87 DAS onwards and reproductive	32-83 DAS onwards both vegetative and reproductive	Adults feed on nector, pollen and aphid honeydew, the larvae are active predators and feed on aphids, jassids, whitefly and other small insects.
Lady bird beetle	*Coccinella septempunctata* (Linnaeus, 1758)	Coccinellidae: Coleoptera	Major	46-91 DAS onwards and reproductive	42-88 DAS onwards and reproductive	Both grubs and adults feed on soft-bodied insects like aphid, jassid, whitefly, mealy bugs and lepidopteran larvae.

Date of sowing: 15/07/2023 and 14/07/2024; Date of harvesting : 26/10/2023 and 23/10/2024; DAS: Days after sowing

were designated as major pests while those which appeared for a short period of time in fairly low number were considered as minor and those occasionally recorded were designated as occasional pests. The details of these pests and associated predator were classified and described in the following sections:

Order: Hemiptera

Jassid, *Amrasca biguttula biguttula* (Ishida, 1913)

The incidence of jassid was first observed from fourth week of July (*i.e.,* 30th SMW) in the both 2023 and 2024, which gradually increased and reached its peak at second week of October (41st SMW) in 2023 and at third week of October (42nd SMW) (Table 1) in 2024.The present findings are in close agreement with the result of who observed that the incidence of jassids on okra were started during 32nd SMW and gradually increased and reached maximum population during 37th SMW (second week of September), whereas first week of October (40th SMW) onwards its population started declining (9). Similarly, documented that the infestation of jassid started from third week of August 2018 (34th SMW) and first week of August 2019 (32nd SMW) and continued up to the maturity of the crop (10). The current results are consistent with the jassid population began to emerge on the 30th SMW of the 2024 *kharif* season. From the 35th SMW, the jassid population steadily declined until increasing once again and peaking in the final the 44th SMW, or the week of October (11). However, the jassid infestation began a week later, during the 29th SMW (third week of July). The population showed a gradual increase, attaining a peak of jassids per plant by the 34th SMW (third week of August). This trend suggests that mid-season climatic conditions were conducive for jassid multiplication and survival (12). Similarly, present findings are in accordance with those of showed incidence of the jassid started with 31st SMW and it gradually increased and reached up to 36th SMW of the year and it again gradually decreased with the crop period (13).

Whitefly, *Bemisia tabaci* (Gennadius, 1889)

Whitefly infestations in *Kharif*, 2023 crops were initially noticed on 9 days after sowing (30th SMW) and continued till the end of crop *i.e.,* 87 days after sowing (41st SMW) (Fig. 1). Similarly in 2024, the first observation noticed from 11 days after sowing (30th SMW) (Fig. 2) and continued till the end of crop *i.e.,* 83 days after sowing (40th SMW) (Fig. 2). Present findings are in accordance with those of showed whitefly occurrence between second week of August and third week of October with peak in 38th SMW (14). Reported the infestation of whiteflies on okra started from second week of August (32nd SMW) and gradually increased and reached maximum population during second week of September (37th SMW) (9). Findings are also corroborated with the number of whiteflies on the okra crop monitored all season long during the 2024 *kharif*. The infestation first started from second week of July *i.e.,* 29th SMW. The 37th SMW had the most number. After then, a steady decline in population was seen (11). The infestation of whiteflies commenced on the 28th SMW, corresponding to the second week of July. A progressive increase in population was observed in subsequent weeks, reaching a during the 37th SMW (second week of September). The rise in population may be attributed to favourable environmental conditions during this period, particularly high temperatures and relative humidity (12). Moreover, the incidence of the whitefly was reported in 30th SMW of year and it gradually increased to 35th SMW and it decreased with the application of treatment (13).

Red cotton bug, *Dysdercus cingulatus* (Fabricius, 1775)

Both nymphs and adults of red cotton bug appeared for the first time on 36th SMW during 2023 on the okra. During 2024, they observed initially in 35th SMW on the crop. It remained up to 42nd SMW during first year and 41st SMW second year on the crop (Table 1). The findings of present study contrasted with was recorded from in the month of September and its peak population was during the month of October, in both the years (15). The incidence of the red cotton bug started with 32nd SMW, it reached its peak population during 44th SMW observed (16). The red cotton bug appeared relatively later in the season, with its first occurrence noted during the 33rd SMW (third week of August). The population gradually escalated and reached a maximum 39th SMW (fourth week of September), indicating a preference for late-season conditions, possibly due to the maturation of okra pods that offer a suitable feeding and breeding site (11). The incidence of the red cotton bug that was a sucking pest started 32nd SMW and it gradually increased and reached up to 37th SMW of the year and decreased with crop period and application of the treatments (12).

Mealy bug, *Phenacoccus solenopsis* (Tinsley, 1898)

The Solenopsis mealy bug (*Phenacoccus solenopsis*) has been reported as an exotic pest of cotton and recently considered as an emerging pest on vegetable crops. In the Varanasi region, it was first recorded on tomato in 2010-11 and later observed infesting brinjal, chillies, pointed gourd, pumpkin, okra and weeds like *Parthenium*. Both nymphs and adults suck the sap from growing points, leading to stunted growth, yellowing, drying and eventual death of plants. The pest also excretes honeydew, which fosters black sooty mold on leaves, reducing normal photosynthesis of the plants (17-19). Mealy bug infestation was initially observed 34 days after sowing (DAS) (vegetative stage) and persisted up to the reproductive stage, *i.e.,* 18 August to 1 October 2023 (33rd SMW to 40th SMW) (Fig. 1). Similarly, when the crop age reached 30 days (vegetative stage) the following year, the incidence of mealy bug was observed from 14 August to 27 September 2024 (33rd SMW to

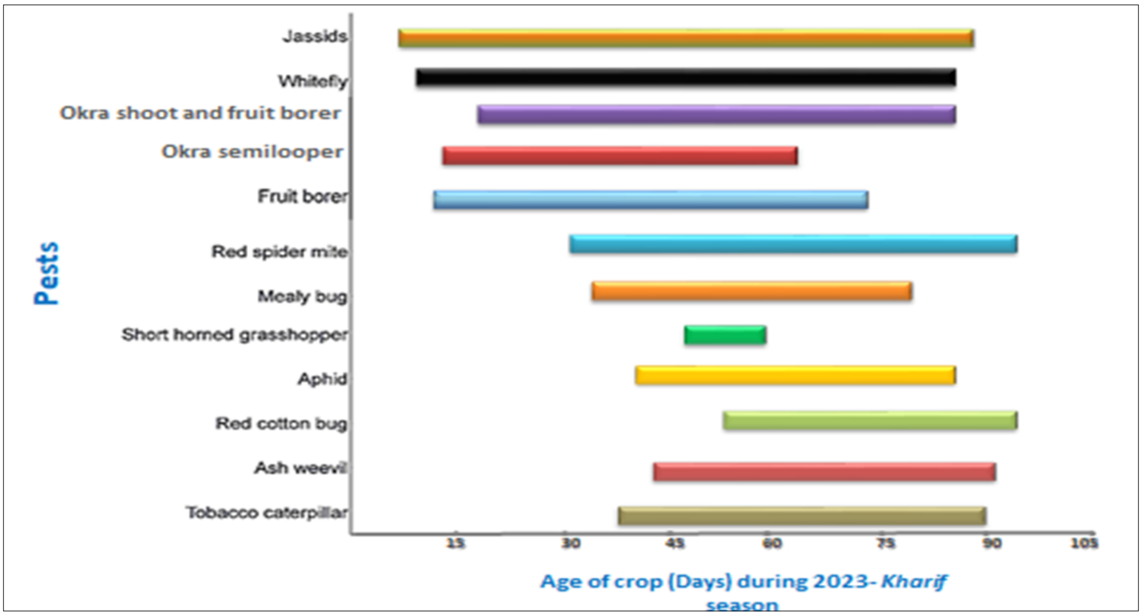

Fig. 1. Succession of insect pests in okra during *Kharif*, 2023.

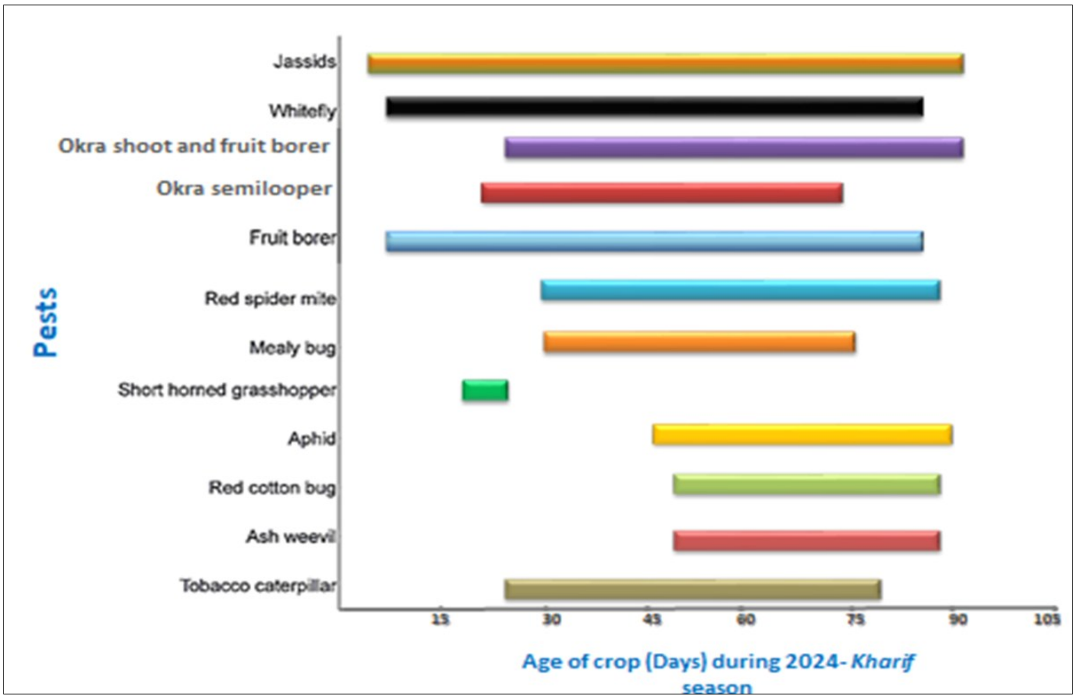

Fig. 2. Succession of insect pests in okra during *Kharif*, 2024.

39th SMW) (Fig. 2). The present findings are in conformity with the findings of who recorded the maximum mealy bug population on okra in the fourth week of September during 2017 and three peaks of activity in the last week of July, first week of September and the first week of October respectively during 2018 season (20).

Lepidoptera

Okra shoots and fruit borer, *Earias vittella* (Fabricius, 1794)

This insect is considered the most serious pest of okra infesting from 18 days of crop stage (31st SMW) and continued till the end of the crop season *i.e.,* 12 October 2023 (41st SMW). During 2024, the occurrence of OSFB infestation in the okra crop was first observed from second week of August (32nd SMW) and it was present on the crop after that shift to the fruit from third week of October (42nd DAS) (Table 1). Larva bores into tender shoots during the vegetative stage and later become the flower buds and tender fruits. The damaged shoots droop, wither, dry up and feed causing deformed fruits. The present findings are in accordance with those concluded both shoot and fruit borers *i.e., Earias vittella* (Fabricius) and *Earias insulana* (Boisduval) dominated in the mid and later crop growth stages of okra (21). Noticed shoot damage from vegetative stage and continued up to fruit formation stage. Whereas the damage on fruits was first observed at crop age of 45 days and was observed till the last picking of the crop (10). The shoot and fruit borer was first observed during the 34th SMW (third week of August). The pest population continued to rise and peaked at 37th SMW (second week of September) (11). The present findings agree with that of who stated that the incidence of the okra shoots and fruit borer that caused the infestations on fruit started with the 33rd SMW of the year and the maximum population of the okra shoot and fruit was found 37th SMW of year which decreased with the application of plant protection measures (12).

Fruit borer, *Helicoverpa armigera* (Hübner, [1808])

The infestation was recorded from last of July (30th SMW) to end of September (39th SMW) during 2023 (Fig. 1). However, in 2024, the activity of fruit borers initiated during 30th SMW (12 DAS) with gradual increase in population and then declined during the maturity of crop *i.e.,* 40th SMW (81 DAS) (Fig. 2). The present studies are supported by the observations recorded by who documented a quite low population of fruit borer was observed on the crop from 33rd SMW onwards with its peak egg and larval counts recorded between 36th and 38th SMW (first and third week of September) (22). Recorded fruit borer attack was higher on 7th June (23).

Tobacco caterpillar, *Spodoptera litura* (Fabricius, 1775)

Tobacco caterpillar attack was patchy and started at the 36 DAS stage from the vegetative stage and persisted up to the end of the crop season, *i.e.,* 20 August to 12 October 2023 (34th SMW to 41st SMW). Similarly, during the next year, the caterpillar of this pest was recorded feeding on leaves during 32nd SMW (23 DAS) onwards on the crop. The larvae were found feeding continuously on the crop till 39th SMW (78 DAS) during 2024 (Table 1). The present findings agree with that of who stated that the pest commenced from the 35th SMW and continued till 47th SMW in the field. However, the highest peak activity was recorded at 43rd SMW coinciding with the fourth week of October (24). In another study reported that incidence of tobacco caterpillar increased gradually after their first incidence on 30th SMW and continued till the crop maturity in both the years (25).

Okra semilooper, *Anomis flava* (Fabricius, 1775)

The incidence of this pest was recorded as minor during early vegetative state (14 DAS) and after that present on the reproductive stage (63 DAS) (Fig. 1). Similarly in the next year *i.e.,* 2024, the larvae of semilooper appeared, from 29 July (30th SMW) to 24 September (39th SMW), 2024 (Fig. 2). The present findings of investigation were in close agreement with earlier work of the researcher such as semilooper was active from August to November with peak population in the second week of October (26). Recorded the young larvae of semilooper were feeding on leaves by making irregular holes. When grown up, they feed voraciously and skeletonize the plant. The incidence of this pest was recorded as a minor pest during September and October (27).

Trombidiformes

Red spider mite, *Tetranychus* spp. (Dufour, 1832)

The population build-up of red spider mite was seen from vegetative stage (33rd SMW) on the crop during first year and second year (Table 1). It remained present in the field till 42nd SMW on the crop during first year (Table 1) and 41st SMW second year (Table 1). Both nymphs and adults of red spider mites feed on ventral leaf surface, under protective cover of fine silken webs. As a result of their feeding numerous minute yellow spots appear on dorsal side of leaves. Affected leaves gradually start curling, finally wrinkled and crumpled. The present findings are conformity with the findings of investigated the red spider mite appearance from 37th SMW during both the years *i.e.,* 2016 and 2017 and found its highest infestation in 40th SMW (28). Observed first incidence spider mite of during 31st SMW *i.e.* first week of August with its peak incidence (38th SMW) in the third week of September (29).

Natural enemies in okra crop

Spider complex: Four species of spider *viz., Amblyseius longispinosus* (Berlese, 1914), *Neoscona theisi* (Walckenaer, 1841), *Oxyopes javanus* (Latreille, 1804) and *Cheiracanthium approximatum* (Villers, 1789) were recorded from the okra ecosystem during the study. The population buildup of spiders was seen from 28 DAS. It was apparent that being polyphagous predator, feed on soft-bodied insects like aphids, jassids, whiteflies and neonate and early instar larvae of lepidoptera present on the crop and are present at the end of the crop season reproductive stage (maturity stage) *i.e.,* 12 August to 18 October 2023 (32nd SMW to 42nd SMW) (Fig. 3). Like the previous year, during 2024 spider population was recorded for the first time in 30th SMW (9 DAS). The population of spiders increased gradually and reached its peak and there after showed decreasing trend till the maturity of crop (Fig. 4). The present findings are in accordance with who observed the first incidence of spiders in 33rd SMW. The predators attained their highest densities in the fourth week of September in the 39th SMW (30). Noticed spider existence was also initiated in 31st SMW. The highest spiders were noted in 39th SMW (29).

Lady bird beetle, *Coccinella septempunctata* (Linnaeus, 1758): The population build-up of coccinellids was seen from 46 DAS. It was apparent that the predator, both grubs and adults, feed on soft-bodied insects like aphids, jassids, whiteflies, mealy bugs and lepidopteran larvae present in the crop till 91 DAS, *i.e.,* 30 August to 14 October 2023 (35th SMW to 41st SMW) (Fig. 3). Like the previous year, the occurrence of ladybird beetles initiated *i.e.,* 34th SMW (42 DAS) on the crop. Thereafter, the population gradually decreased but persisted till maturity of the crop *i.e.,* up to 88 DAS during 2024 (Fig. 4). The present findings are similar with the findings of those who noticed the lady bird beetles (grubs and adults) from 31st SMW *i.e.* first week of August. The abundance of lady bird beetles continuously increased up to 38th

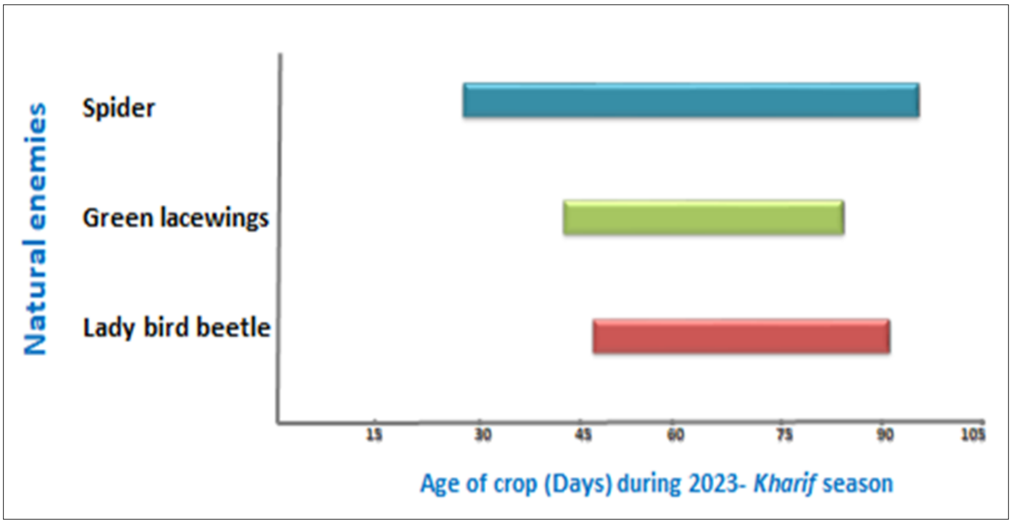

Fig. 3. Succession of predators in okra during *Kharif*, 2023.

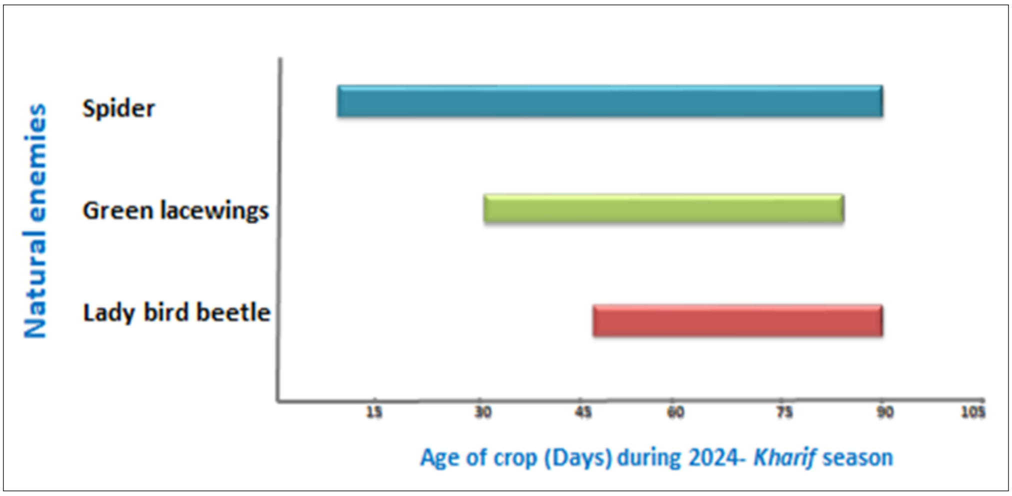

Fig. 4. Succession of predators in okra during *Kharif*, 2024.

SMW, there after decreased (29). In another study, observed the first appearance of lady bird beetles from third week of August (34^{th} SMW) in both 2018 and 2019, which gradually increased and reached its peak at first week of October in 2018 and at first week of September in 2019 (10).

Green lacewings, *Chrysoperla zastrowii sillemi* (Steinmann, 1964): The incidence of green lacewings was observed when the crop age was 41 DAS. The adults feed on nectar, pollen and aphid honeydew whereas the larvae were active predators and feed on aphids, jassids, whiteflies and other small insects from the reproductive stage and remain available up to the end of the crop season *i.e.,* from 20 August to 10 October 2023 (34^{th} SMW to 41^{st} SMW). Similarly, next year green lacewing infestation was initially observed during 32 DAS. It was noticed that the infestation on the crop was from the vegetative stage and persisted up to the maturity stage *i.e.,* 15 August to 5 October 2024 (33^{rd} SMW to 40^{th} SMW). The present findings are in accordance with the green lacewing that was recorded first time during 31^{st} SMW. The population increased gradually and attained its peak during 40^{th} SMW (31). The populations of green lacewings commenced in 33^{rd} and 32^{nd} SMW during 2013 and 2014 respectively and reached peak in the fourth week of September during both the years recorded (32).

Conclusion

The present study concluded that the insect pest succession and their natural enemies of okra crop ecosystem a total of twelve insect species and three natural enemies found associated with okra crops at different stages from growth to maturity of crops. Among the 12 insect pests' okra jassid, whitefly and OSFB were the major dominating pests at vegetative as well as flowering and fruiting stage of the crop. Among the three natural enemies' spiders and lady bird beetles are the most predominating species predating the whitefly, aphid, jassid and other soft-bodied insects. These findings provide critical baseline data for developing targeted IPM strategies in okra cultivation. We also have differentiated major and minor pests based on their damage severity i.e., 10 % > damage represents that it is a major pest. Understanding the temporal occurrence and dominance patterns of pests and their natural enemies allows for more precise and timely intervention, reducing reliance on indiscriminate pesticide use based upon their time of occurrence. Moreover, the presence of key biological control agents highlights the potential for conserving and augmenting natural enemies as part of an ecologically sound pest management approach. Future research should focus on quantifying the impact of natural enemies on pest population dynamics and assessing the efficacy of habitat management practices that enhance their in-situ conservation. Incorporating these ecological insights into decision-support tools can significantly improve the sustainability and resilience of okra production systems.

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Authors' contributions

APS and SS done the conceptualization, data analysis and data curation. UC, JH and SKS performed the supervision, methodology and review. Preparation of final draft and revision were done by LKM, PKS, DKR, PS, AKY and RKV. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that there is no conflict of interest regarding the publication of this research.

Ethical issues: None

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