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Assessment of various integrated pest management modules to manage the incidence of okra shoot and fruit borer for adaptation to climate change: A review

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Abstract
Okra (*Abelmoschus esculentus*) is the most significant crop produced worldwide, which has a variety of uses for human requirements and is a significant crop in subtropical regions and semiarid tropical regions. Climate change is the major problem of low production of okra in worldwide. Okra production is affected by a number of climatic conditions, including temperature, relative humidity, and rainfall. Due to the changing climatic conditions, okra get affected by various insect pests like thrips (*Thrips tabaci*), whitefly (*Bemisia tabaci*), aphid (*Aphis gossypii*), jassid (*Amrasca biguttula biguttula*) and shoot and fruit borer (*Earias vittella*). As per report around 70 percent of yield loses due to attack of shoot and fruit borer (*Earias vittella*) on okra. For the control of okra shoot and fruit borer need to find Various Integrated Pest Management Modules like bio-intensive module, chemical module Integrated module, etc. for management of the incidence of okra shoot and fruit borer. These IPM modules can prove very useful for farmers to increase the marketable yield of okra.

Keywords: *Earias vittella*, okra, IPM modules, climate change

Introduction
Okra (*Abelmoschus esculentus*), Commonly known as ladies' finger is an important vegetable crop and it's belonged to Malvaceae family. Its grow in tropical and sub-tropical region in world. okra is the most popular vegetable in India, Japan, Pakistan, Burma, Iraq, Turkey, Bangladesh, Ghana and Afghanistan. It is grown in summer as well as throughout the rainy season in India; however, it can be grown all year in central and southern India. It is widely grown in India because of its ease of cultivation, consistent yield, and ability to adapt to variable moisture conditions. In India Okra mainly grown in Punjab, Gujarat, Haryana, Punjab, Maharashtra and West Bengal. In India okra Grown in 523 Hector area and Total Production is 6416 Metric Tonnes (Anonymous, 2021) [5].

Okra is a valuable nutritionally vegetable fruit crop. Okra has a better nutritional value than tomatoes, egg plants, and most other cucurbits. Protein, vegetable oil, vitamins A and B, as well as Calcium, Protein, phosphate and iodine, all are present in okra seeds. Okra is a high-nutrient superfood. Because of its nutritional and health benefits, okra is an essential part of the human diet. Okra is good for your intestines and lowers your chance of colorectal cancer. Okra is a source of income for farmers and a solution to the malnutrition problem.

Vegetables currently account for only eight to ten percent of the total food consumption of Indian vegetarians. It is essential to popularize vegetables as a key component of the diet, particularly among the poorer members of society. The lack of grains could be reduced by emphasising the importance of vegetables in the diet. Most vegetables are short duration crops that can be harvested in a short amount of time, allowing farmers to increase their income per unit area by cultivating three to four crops every year.

Despite a massive growing area and a large range of cultivars, the supply of okra in the Indian market does not fulfil the demand. Lower productivity would be one of the main causes of such differences in demand and supply. The major portion of the fruits produced is being harmed by hated insect pests, according to a critical examination for such low productivity.

Climate change in particular region it indicates a change in rainfall, temperature and relative humidity, it is a big impact in insect life. An important prerequisite for the creation of a successful pest management programme is the analysis of pest behaviour and population dynamics in relation to meteorological variables (Yadav, *et al*., 2007) [37]. In the present time of climate change, the insect pest situation is also being changed with the inequality in abiotic factors. Understanding previous behaviour and population dynamics in connection to weather parameters is important for an effective management strategy for insects.

Okra attracts a large number of insect pests like shoot and fruit borer (Earias vittella), whitefly (Bemisia tabaci), mealy bug (Phenacoccus solenopsis), aphid (Aphis gossypii), leaf roller (Sylepta derogata), Thrips (Thrips tabaci).

Chemicals are used to control shoot and fruit borers; however excessive chemical pesticides are toxic to people's health and the environment. This not only increased the cost of cultivation, but it also frequently resulted in issues such as insecticide resistance, the emergence of sucking insects, and secondary pest outbreaks, as well as harmful residues in the final yield, contamination of groundwater, negative side effects, and non-targeted organisms are widely killed.

Understanding the behaviour of important insect pests and their seasonal abundance in relation to weather parameters is critical for developing successful management strategies against pests. Excessive pesticide use is also to blame for the presence of insecticide residues in okra. As a result, several bio-pesticides could be used to combat significant insect pests on okra during the Kharif season, when the climatic circumstances are ideal for their application.

We view today's era to be an era of IPM, where all control methods are likely to be integrated, and insect resistant plants provide optimum pest damage control, low production costs, and are environmentally beneficial. As a result, the vegetable crop has the most potential for developing pest-resistant varieties. The current trend in insect management is to reduce the use of traditional insecticides, not only to save money, but also to reduce pollution and the spread of chemical resistance in insect pests.

Methodology

The information for this review article was obtained from related research paper, thesis, survey reports, books, review reports and other related published sources.

Incidence of Okra Shoot and Fruit Borer

Incidence of okra shoot and fruit borer depends on the climatic conditions and the availability of the host in the premises.

According to Ahmad *et al*. (2000) [2], the maximum larval population of the shoot and fruit borer (Earias vittella) in okra fruits was in 1st fortnight of july (29.9 °C temperature), (84 + 5 % RH) and (61.4 precipitation). Minimum population of shoot and fruit borer was in 2nd fortnight of may (31.6 + 7.7 °C temperature), (54 + 2.1 % RH) and no rainfall. Highest temperature showed a negative correlation with the larval population of the Shoot and Fruit Borer, whereas the lowest temperature showed a significant positive link.

Pareek *et al*. (2001) [26], researched the population dynamics of shoot and fruit borer (Earias vittella) in relation to major abiotic parameters, finding that shoot borer incidence peaked in the fourth week of July and peaked again in the second week of October. Fruit borer infestations began in the first week of September and continued until the last harvest. In the third week of October, the most fruit borer infestation was documented. The population growth of the shoot and fruit borer was negatively correlated with the minimum temperature, relative humidity, and rainfall.

According to Acharya (2002) [1], the fruit borer first appeared in the fourth week of August, laying eggs on developing shoots. In the latter week of August and the first week of September, respectively, damage to growing shoots and fruits began. The first week of September, first week of October, and end week of September, respectively, saw the highest number of eggs, larvae, and damaged fruits.

According to Mohapatra *et al*. (2004) [23], spotted bollworm activity began in the 31st standard meteorological week and peaked in the 46th. There was a positive correlation between the growth of the shoot and fruit borer (Earias vittella) population and the mean maximum, minimum, and average temperature. The early and evening relative humidity, as well as rainfall, had a negative impact.

The infestation of shoot and fruit borer (Earias vittella) on the shoots of okra began in the first 15 days of August, progressively increased, and peaked in the second 15 days of October, but continued throughout the crop season, according to Meena and Kanwat (2005) [22].

Yadav *et al*. (2007) [37] conducted tests in Kanpur, Uttar Pradesh during the kharifs of 2005 and 2006 to assess the population dynamics of the shoot and fruit borer (Earias vittella) infesting okra cv. Azad bhindi-1 in response to meteorological conditions. During both consecutive years, the incidence of shoot and fruit borer (Earias vittella) began in the third week of August on five-week-old plants on fruits and lasted until the fourth week of October on 12-week-old plants. In 2005, the worst fruit damage was reported in the third week of September.

According to Aziz *et al*. (2009) [8], maximum and average temperatures had a substantial and beneficial effect on shoot and fruit borer (Earias vittella) infestation on 'okra,' but relative humidity and rainfall showed a negative significant link. Multiple linear regression models found that the highest temperature was the most relevant factor, accounting for 60.50 and 53.20 percent of fruit and shoot (Earias vittella) infection in 2006 and 2007. For fruit and shoot (Earias vittella) infestation, the combined impact of all factors was determined to be 67.00 and 55.50 percent, respectively.

According to Sharma *et al*. (2010) [34], okra shoot and fruit borer (Earias vittella) infestation began in the 29th standard week and peaked at 91.6 percent in the 45th standard week. The 42nd standard week saw the highest number of larvae (7.5 larvae/10 plant).

Shoot and fruit borer (Earias vittella) incidence began in the 2nd week of September, according to Laichattiwar *et al*. (2014) [20], with an intensity of 0.33 larvae per 5 plants. In the 1st week of October, it achieved its peak population (5.17 larvae/5 plants).

According to Nenavati and Ashwani Kumar (2014) [24], the incidence of shoot and fruit borer (Earias vittella) on okra started in the 3rd week of August with an average population of infestation 2.4 percent, gradually increased to a peak level of infestation 45.7 percent in the 2nd week of October, and then declined as the temperature dropped.

Singh *et al*. (2015) [36], observed the occurrence of shoot and fruit borer (Earias vittella) on okra fruits from the fourth week of August on 35-day old plants to the fourth week of October on 14-week-old plants. In the third week of September, the maximum number of shoot and fruit borer was found. Bright daylight hours, maximum and minimum temperatures all had a non-significant favourable effect on shoot and fruit borer (Earias vittella), whereas relative humidity and rainfall had a negative non-significant and significant effect, respectively.

According to Dhandge *et al*. (2018) [12], Pest activity of the shoot and fruit borer (Earias vittella) began in the 11th standard week (0.9 larva per plant) and continued until the 24th standard week (0.93 larva per plant), with the next season beginning in the 11th standard week (0.7 larva per plant) and ending in the 24th standard week (0.10 larva per plant).

Parijatha *et al*. (2018) [27], observed the occurrence of the shoot and fruit borer (Earias vittella) began at 36th SMW (2.758 %). The population of shoot and fruit borers (Earias vittella) grew steadily, reaching a peak of infection (43.917 %) at 43rd standard weeks. The population of shoot and fruit borers (Earias vittella) rose as the maximum temperature climbed and was found to be strongly associated with maximum temperature.

Javed *et al*. (2019) [14] study in two-year field trial was an IPM (bio-intensive) module developed by selecting through in-situ evaluation and incorporating the most effective pest control options along with the biological (parasitoid Trichogramma chilonis egg cards) and cultural techniques against okra shoot and fruit borer (Earias vittella). Maximum infestration in shoot (19.86%) and fruit (15.63%) by okra shoot and fruit borer (Earias vittella). Earias vittella infestation were recorded in control module was 6.76%.

Earias vittella infestation were recorded in IPM module was 2.89%. Shoot and fruit borer (Earias vittella) infestations farmer's routine module recorded shoot (13.91%) and fruit (10.83%). Mean of okra shoot and fruit borer (Earias vittella) infestations in (2017) was IPM module (7.62%), farmer's routine module (14.16%) and control module (19.52%) recorded. Higher yield found in IPM module than farmer's module and control module.

Kumar and Singh, (2021) [18], observed that shoot infestation started in the 29th standard week at a rate of 3.84 percent and peaked at 10.09 percent in the following week. Fruit deterioration was first noted in the 31st standard week (4.91%), continued through the 41st standard week (6.44%), and peaked (29.30%) in the 34th standard week. During the 31st standard week, there were a maximum number of larvae on fruit (7.13 larvae/25fruit).

Integrated Pest Management Modules

Das *et al*. (2001) [11], investigated the bio-efficacy of several pesticides against shoot and fruit borer (Earias vittella), including imidacloprid 17.8 Sl, acetamiprid 20 SP, acephate 75 WSP, and profenophos 50 EC. After the third week of final treatment with acetamiprid, acephate, imidacloprid, and profenophos, there was a considerable reduction in fruit borer infestation, with infection levels of 12.42, 14.25, 15.36, and 15.70 percent, respectively, compared to the control plot (44.26 percent). Acephate-treated plots had the maximum yield (46.78 ha-1), while profenophos produced the lowest yield. Acephate was likewise shown to have the highest cost-benefit ratio (5:58).

Patra *et al*. (2007) [29] investigated the shoot and fruit borer (Earias vittella) was resistant to five insecticides: lufenuron, emamectin benzoate, indoxacarb, methoxyfenozide, and spinosad. All of the pesticides were found to decrease shoot and fruit borer (Earias vittella) infestation and produce higher yields than the control. Other insecticides, such as emamectin benzoate spray, resulted in a significant decrease in the number of borer infestations, leading to the highest fruit yield of 97.25 q/ha, which was comparable to spinosad's (96.1 q/ha) but significantly higher than indoxacarb's (92.8 q/ha), methoxyfenozide's (84.2 q/ha), and lufenur.

Gosalwad and Kawathekar (2009) [13], studied the efficiency of newer insecticides against the shoot and fruit borer (Earias vittella) and found that spinosad 45 SC @ 30 g a.i. ha-1 followed by abamectin 1.9 EC @ 30 g a.i. ha-1 resulted in the least amount of okra fruit infestation (5.56 percent) (7.25 percent). The effect of several treatments on marketable fruit production of okra revealed that yields from fipronil (30 g a.i. ha-1) and spinosad (30 g a.i. ha-1) were significantly higher than the rest of the insecticidal treatments.

According to Dabhi *et al*. (2012) [10], indoxacarb @ 0.007% was considerably superior to the other treatments in suppressing shoot and fruit borer (Earias vittella) in okra. The plot sprayed with indoxacarb produced a significant maximum yield of marketable okra fruits. The largest net profit was 38371 ha-1 for lndoxacarb and 37460 ha-1 for chlorpyriphos, respectively.

According to Nigade *et al*. (2013) [25], Emamectin benzoate @ 10 g a.i./ha was highly efficient against shoot and fruit borer (Earias vittella). Thiodicarb (468.5 g a.i./ha), indoxacarb (72.5 g a.i./ha), and profenophos (250 g a.i./ha) came next in order of effectiveness. The plots treated with emamectin benzoate at 10 g a.i./ha had the highest fruit output (1408 kg/ha), which resulted in the highest net profit of Rs. 17,700/ha. The plots treated with cypermethrin @ 62.5 g a.i./ha (1:4.61) and then thiodicarb @ 468.75 g a.i./ha (1:4.61) yielded the highest incremental cost-benefit ratio (1:4.26).

Kumar *et al*. (2013) [19], investigated the efficacy of newer insecticides and bio pesticides against okra infestations by (Earias vittella). The lowest shoot and fruit damage was 1.6 percent and 3.3 percent, respectively, after treatment with indoxacarb. Carbosulfan, lambda cyhalothrin, and cartap hydrochloride, with yield values of 89.26, 86.79, and 83.73 q ha-1, respectively, were followed by carbosulfan, lambda cyhalothrin, and cartap hydrochloride with yield levels of 89.26, 86.79.

Emamectin benzoate 5 SG @ 3 doses, 5.00, 6.75, and 8.50 g a.i./ha, was the new product that Mandal and Jena (2013) [21] examined to assess for its bioefficacy in controlling (Earias vittella) in okra. The novel product @ 8.5 g a.i./ha was the most efficient treatment, reducing the larval population by (74.18-88.01 percent), causing (93.72 percent) shoot damage, (92.82 percent) fruit damage, and increasing fruit yield to (72.13 percent) over untreated check. On the basis of larval population, this treatment was comparable to its lower dose of 6.75 g a.i./ha and the comparison insecticide Proclaim (emamectin benzoate 5 SG @ 6.75 g a.i./ha).

Kamble *et al*. (2014) [15] conducted an experiment to assess the efficacy of newer insecticide combinations against the shoot and fruit borer (Earias vittella), and found that indoxacarb 14.5 SC + acetamiprid 7.7 SC @ 400 ml ha-1, profenophos 40 EC + cypermethrin 4 EC @ 1000 ml ha-1, and chlorpyriphos 50 EC + cypermethrin 5 EC @ 1000 m.

Yadav (2015) [38] investigated the efficacy of insecticides against shoot and fruit borer (Earias vittella) infestations in okra crops and found that indoxacarb (0.01 percent) was the most effective and caused the least amount of damage to shoots and fruits, followed by spinosad (0.01 percent) and emamectin benzoate (15 g a.i./ha). Fipronil (0.01 percent), acetamiprid (0.004), acephate (0.037 percent), dimethaote (0.03 percent), and NSKE (5 percent) were among the most effective therapies. The plots treated with indoxacarb had the maximum yield of 87.75 q ha-1. In the therapy of acephate, the benefit-to-cost ratio was highest (58.74).

According to Sarkar *et al*. (2015) [32], the plot treated with spinosad had the lowest fruit damage (1.10 and 1.05 percent) and the highest marketable okra output (1.10 and 1.05 percent) (53.67q ha-1). Azadirachtin 1% 2 ml l -1fruit damage was observed (2.90 and 8.74 percent). Damage to untreated control fruit was observed (3.65 and 15.81 percent). Azadirachtin was given as a yield (37.92 q ha-1). The yield of the untreated control plot was (24.81 q ha-1).

In order to against the shoot and fruit borer in okra, Kodandaram *et al*. (2017) [16] claim that they used pest management modules such as the biointensive module, chemical module, and integrated module. In the integrated module, there was a considerable increase in yield (177.7 q/ha) compared to the control, with fruit borer damage (71.74%) and yellow vein mosaic disease (17.75%).

Adaption to Climate Change and Behaviour

According to Kumar *et al*. (2009) [17], Shoot and fruit borer (Earias vittella) damage was found to have a substantial positive association with temperature, but a significant negative relationship with wind velocity. Fruit damage had a substantial negative relationship with minimum temperature and a positive relationship with relative humidity and sunshine hour.

Showkat *et al*. (2010) [35] Studied that the results of the correlation revealed a substantial negative link between minimum temperature (-0.765) and percent fruit infection, as well as a non-significant negative correlation between maximum temperature, minimum humidity, and rainfall. Maximum humidity, on the other hand, showed a positive but non-significant association.

According to Sharma *et al*. (2010) [34], shoot and fruit borer (Earias vittella) population was negatively correlated with mean temperature and mean relative humidity, but non significantly and negatively correlated with rainfall in terms of larval population and percentage of infested plants, according to correlations between pest population and weather parameters.

Maximum, minimum, and average temperatures had a substantial favourable effect on the growth of the pest population in okra, according to Aziz *et al*. (2011) [7]. Rainfall and relative humidity, on the other hand, had a negative impact on the population of the (Earias vittella) and other okra insect pests. They also discovered that maximum temp had the greatest impact on the infestation of the (Earias vittella).

According to Laichattiwar *et al*. (2014) [20], maximum relative humidity (r= -0.66), minimum relative humidity (r=-0.82), and mean relative humidity (r=-0.83) all demonstrated a significant negative connection with shoot and fruit borer (Earias vittella) population. The link between pest population and sunshine hours was positive (r= 0.60), but not significant with temperature or rainfall.

According to Bajad and Chamroy (2016) [9], sunshine and temperature had a positive significant effect on shoot and fruit borer (Earias vittella) population on okra, whereas rainfall and relative humidity had a negative non-significant and significant effect, respectively.

According to Patel *et al*. (2017) [28] Maximum temp has a considerable detrimental impact on the population of okra shoot and fruit borers (Earias vittella), while evening relative humidity has a significant favourable impact.

Satyarth *et al*. (2018) [33], found a substantial negative link between evening rh, wind velocity, minimum temperature, rainfall, and number of wet days and Shoot and Fruit Borer (Earias vittella) population (-0.64, -0.81, -0.94, -0.67, and -0.69), although sunshine had a substantial favourable effect (0.82).

Dhandge *et al*. (2018) [12], studied that bright sunshine had a negative and significant relationship with okra shoot and fruit borer (Earias vittella) population, while maximum and minimum temperatures had a significantly positive correlation with okra shoot and fruit borer (Earias vittella) population.

According to Archunan *et al*. (2018) [6] Earias vittella, the shoot and fruit borer, inflicted a percentage of shoot and fruit damage that was negatively correlated with the maximum and minimum temp. Rainfall and the percentage of okra shoot and fruit borer damage revealed a favourable, though not statistically significant, correlation. The RH and number of hours of sunlight have a negative correlation with the proportion of shoot and fruit damage brought on by the okra shoot and fruit borer.

Akhila *et al*. (2019) [3], studied that the minimum temperature has a bad correlation with the harm done by the shoot and fruit borer (Earias vittella). The lowest temperature during the study was between 15.1 and 22.6 °C. When the minimum temp was 19.6°C, the (Earias vittella) caused the most damage (12.5%). The frequency of fruit borer and the greatest temp on the shoot were both favourably negligible. Strongly positive correlations between the max relative humidity and shoot and fruit borers were found (Earias vittella). At the time of peak occurrence, the highest relative humidity values varied from 90 to 97 percent, while the lowest values ranged from 39 to 67%. Following the appearance of the shoot and fruit borer on okra plants, rainfall ranged over the course of the research period from 0 to 21.9 mm.

Rawat *et al*. (2020) [31], study that the maximum temperature indicated a non-significant positive correlation with okra shoot and fruit borer population; while wind velocity and morning RH also get a non-significant positive link between okra shoot and fruit borer, according to the correlation of okra shoot and fruit borer (Earias vittella) population with weather factors. The population of okra shoot and fruit borer (Earias vittella) was found to have a non-significant negative connection with rainfall, evening relative humidity, minimum temp, and sunshine hour when weather data were examined.

According to Kumar and Singh, (2021) [18] was fruit damage found to be positively correlated with the maximum and minimum temperatures and relative humidity at 7 hours. Larval counts showed a positive and significant relationship with maximum temperature, whereas they showed a positive and non-significant relationship with minimum temperature and relative humidity at 7 hours. In terms of shoot and fruit damage and larval counts, weather conditions were responsible for 64.10 and 87.90% of each, respectively.

Rathore *et al*. (2021) [30], found that when the temperature was reduced, the number of shoot and fruit borers (Earias vittella) declined. It was also discovered that when the temperature rises, so does the population of shoot and fruit borers.

According to Ankur *et al*. (2022) [4] the correlation study showed a positive and substantial relationship between shoot damage and relative humidity in the morning and evening. In contrast, there is a negative and significant relationship between maximum temperature and shoot damage. Minimum temperature, wind velocity, and meteorological characteristics have a negative and strong link with fruit damage.

Conclusion

Various environmental factors are there which is responsible for various insect's attack like shoot and fruit borer on okra like temperature, relative humidity, wind, sunshine, precipitation etc. To control these abiotic factors is next to impossible for human kind. By determine the population of shoot and fruit borer and then apply different treatments based on environmental condition can gave significant results. Application of various biological treatments like neem oil, neem seed kernel extract, karanja oil and Bacillus thuringiensis not only control shoot and fruit borer in okra, also it has no harm full effect on soil as well as environment with very much cheaper rate compare to other chemical pesticides. Different chemicals like indoxacarb, acephate, profenophos, emamectin benzoate, etc. has also popularity with in farmer community now a days. Those treatments have better results in controlling shoot and fruit borer but also have some hazardous impacts on whole environment. Application of combination of different biological and chemical treatment has been seen most effective in controlling shoot and fruit borer as well as less hazardous compare to chemical treatments. This kind of treatments can not only control pests but also it will lead to good quality of okra compare to chemical treatments. Adding of various biological products in conventional agricultural system can reduce the pest in okra with good quality production as well as it reduces the cost of cultivation.

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