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Biopesticides approaches for okra pest management– A review

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Abstract
Okra is the most valuable economic and high valued crop, which is inherently carry the biotic fauna as notorious pests that drastically reduces the yield of okra. Chemicals creates resistance, resurgence in insects and residues in fruits cause various cryptic health hazard to humans. Hence, right choice to combat these all problems is the biorationals for management of okra pests. Biorationals are naturally occurring organic contaminants that are used to manage a wide range of agricultural pests that infest okra plants. These biorationals like entomopathogenic fungi *viz*., *B. bassiana* and *V. lecanii* naturally develop and continuously attacking the okra borers and sucking pests. Biorational application of nitrogenous fertilizers crunches the leafhopper population down. Plant products *viz*., azadirachtin, neem oil, Karanja oil, application at the initiation of the pest infestation prove immense in deterring pests from its host plant. *B. thuringiensis*, *P. fluorescens*, HaNPV, SNPV are the prime biorationals for the management of okra borers. Biorationals not only manage the pests at a time on the crop but many of them increase themselves in the nature and constantly attack on the harmful insect pests in the field and helps the consumer with safe food.

Keywords: biopesticide, *Beauveria bassiana*, *M. anisopliae*, pest management, okra, resistance

Introduction
Vegetables are good elemental source of our food because they provide all the essential require nutrient eg.vit, carbs, and minerals that are necessary for a healthy diet. Their importance is especially essential in developing nations such as India, where malnutrition is a serious issue for both children and adults. (Khan Masood *et al.*, 2001; Randhawa, 1974). Okra (*Abelmoschus esculentus* (Moench) is Malvaceous crop grown in tropical and subtropical regions around the world. This crop can be grown as a domestic garden crop or on big, high-tech commercial farms.
Many factors influence okra production in India, one of which being insect pest invasion. 72 insect species have been identified on okra. The infestation of sap suckers (leaf hopper, aphid, whitefly, mealybug) stem and shoot feeder (shoot and fruit borer and leaf roller) causing major damages (Ali *et al.*, 2005) [4]. The most serious insect pests and major limiting factors in okra farming are Jassid (*A. bigutulla bigutulla* Ishida) and okra shoot and fruit borer (OSFB) (*Earias vittella* Fabricius). Jassid are a serious okra pest during the seedling and vegetative stages. They feed on the sap from leaves, stems, and growing fruits, transmit viral diseases, and inject harmful substances into the plant, slowing its growth (Bi *et al.*, 2001) [8]. Presence of bore hole on shoot and fruit is the common symptoms of damage (Rahman *et al.*, 2013) [31]. Infested shoots wilt and dry, causing damage to the plant, which causes it to damage growing branches and yield or smaller fruits. Infected fruit identified with the presence of larva with excreta inside which leads to reduce marketable quality.
To protect their crops, farmers regularly utilize harmful insecticides, however this process leads to pest resistance, revival, chemical traces, extinction of beneficial brute creation, and damage to nature (Adilakshmi *et al.*, 2008). As a result, the use of other practices needs to incorporate in pest management programmer. Biorationals are supposed to be good alternative for the chemical and safe to environment and and humans and other non-target species. In these conditions, using bio rationales in pest management is seen as an environmentally sustainable solution for addressing the aforementioned issues.

Bio-Pesticides
According to the United States Environmental Protection Agency (EPA), Pesticides originating from natural sources such as animals, plants, microbes, and certain minerals are known as biopesticides (www.epa.gov). Biopesticides are naturally occurring biochemical insecticides that control pests through harmless processes. Living organisms (natural enemies) or their products (phytochemicals, microbial products) or by products (semio chemicals) can be utilized as biopesticides to control pests that damage plants. Biopesticides play a significant role in crop protection, however they are usually used in combination withz other pesticides, such as chemical pesticides, as part of Bio-intensive Integrated Pest Management. Biopesticides, or biological pesticides based on pathogenic microorganisms unique to a target pest, are as environmentally friendly and effective pest control approach. They are less harmful to the environment and to people's health. Living organisms that are pathogenic

for the pest of interest are the most widely utilized biopesticides. Bio fungicides (Trichoderma), bioherbicides (Phytopthora), and biopesticides are among them (*Bacillus thuringiensis*). The potential benefits of using biopesticides in agriculture and public health programmers are enormous (Chang *et al.*, 2003) [9] Biopesticides are developed mass-produced substances obtained from natural sources live microorganisms and commercialized for use in pest control, according to the Organization for Economic (Cooperation and Development, 2009).
According to statistics, the US Environmental Protection Agency accepted 1,401 biopesticide registrations by the end of 2019, involving roughly 400 active components, with biochemical pesticides accounting for 57.5 %, microbial pesticides %, and other miscellaneous 6.5 %.
Currently, there are 970 biopesticide products registered with the Central Insecticides Board and Registration Committee (CIBRC) which is the major governing body related to all types of usage of biopesticides in India.

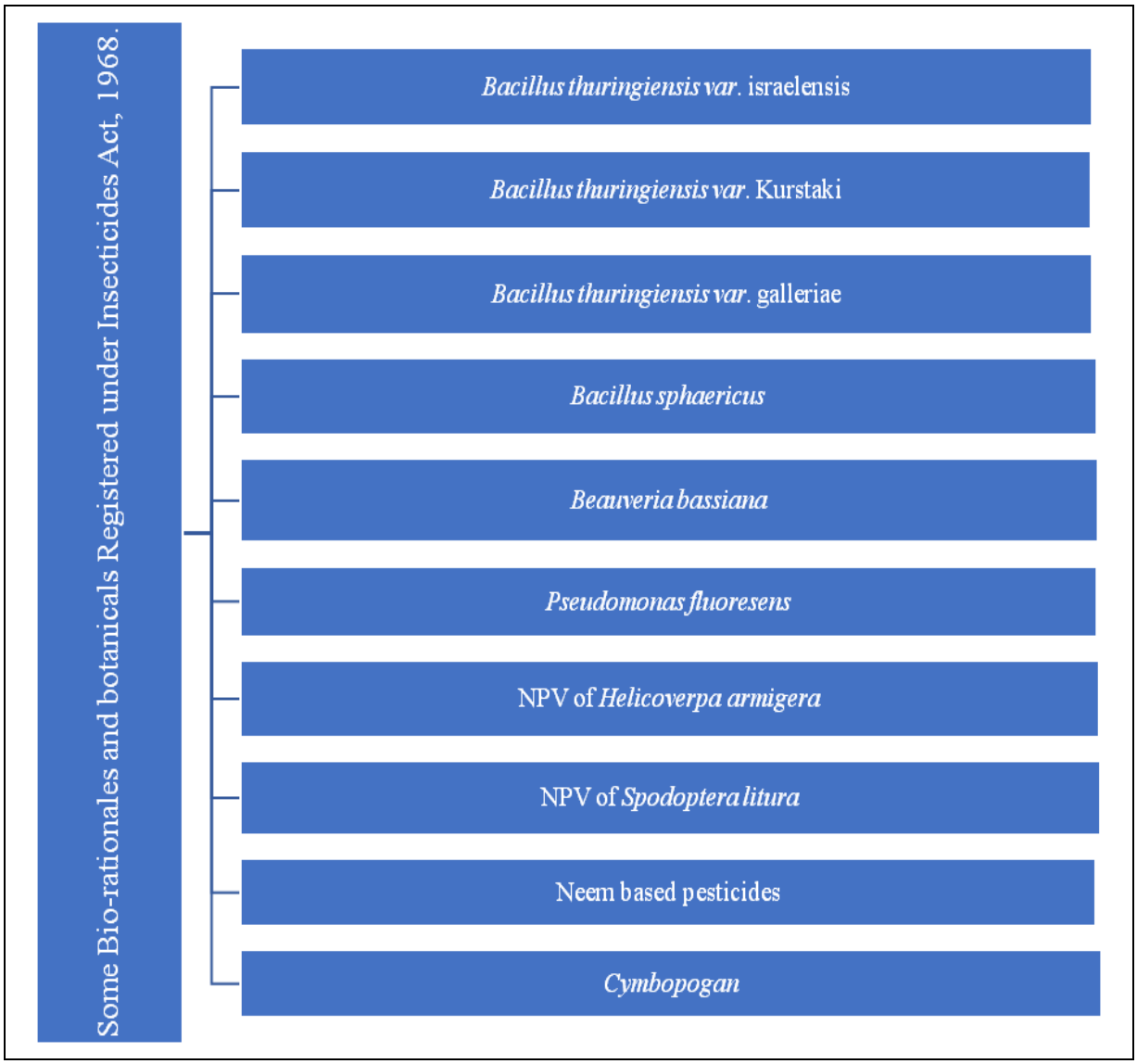

Fig 1

Non-chemical method for pest control
With nearly 25 years of study on biorational insecticides, we've produced a unique and stand-alone biorational pesticides, such as biorational insecticides, fungicides, nematicides, and herbicides, that have proven to be excellent alternatives to dangerous chemicals. Natural ingredients obtained from bacteria, plants, minerals, and other sources are used to make biorational insecticides. Microbial pesticides are made up of living creatures (viruses, bacteria, fungi, or protozoa) and are considered a type of biological control because they use living organisms to kill target pests (Eilenberg *et al.*, 2001; Wahengbam*et al.*, 2021) [11]. Insecticide activity can be found in a range of plant-derived compounds.These naturally occurring substances are part of the protection chemistry that helps plants protect themselves against insects, herbivores, and pathogens by interfering with their physiological processes. Because these components are naturally occurring chemicals, they can be used to make environmentally friendly pesticides (Isman and Akhtar 2007) [19]. Azadirachtin is the key bioactive ingredient in the neem base foundation, and it's an effective natural product that operates on insects in a similar way to insect growth regulators. To produce appropriate power, however, a large number of applications are necessary.

This commodity is commercially unviable due to its high cost and quick degradation (Isman 2004). also, some other compounds like Semiochemicals are a class of signaling molecules released by plants and insects that cause behavioral changes in organisms of the same or different species and can be employed as efficient pest management targets (Wahengbam *et al.* 2021) [41].

Eco-friendly management of sucking and borer pests of okra.

B. bassiana and M. anisopliae, in their wet powder form, eliminated 96.67 % of leaf hoppers 10 days after treatment, according to (Naik and Shekharappa 2009), whereas *V. lecanii and B. bassiana* WP eliminated 93.33 % of leafhoppers. Aphid death was93.33 % in oil-based *V.lecanii* formulations, followed by *V. lecanii* WP (96.67 %), *B. bassiana* oil, and wettable powder formulations (93.33 %). Plant growth that promotes rhizobacterium (PGPR) Pseudomonas B-25 isolate was found to be the most efficient biocontrol-regulating agent against aphids and leafhoppers, reducing population by 79 and 81 %, respectively, in okra, according to (Jagadeesh *et al.,* 2007) [20]. (Satpathy*et al.*,2012) found that one *Chrysoperla grape* can consume 185-leafhopper (A. *biguttula biguttula*) leaves to complete its life cycle. To treat this absorbent bug in an environmentally responsible manner, appropriate conservation measures should be taken. It was effective in lowering the frequency of insect bites in okra by releasing predator *C. carnea* (25,000 worms / ha / release) and Eco neem 0.3 % (0.5 l / ha) sprayed three times over a period of 15 days from 45 days after sowing (Praveen and Dhandapani, 2001) [29]. There are some biorationals and their originated source which are effective against okra pest. Insecticides containing azadirachtin and neem are well-known for their safety and effectiveness (Schmutterer, 2002) [37]. Several studies (Naqvi, 1996; Aslam and Naqvi, 2000) [27, 5] have backed up their usefulness in managing a variety of pests. Spinosad, which is made up of spinosyns compounds produced from the naturally occurring soil bacterium *Saccharopolyspora spinosa* through aerobic fermentation, has both contact and stomach poisoning activity against a variety of insect species. Emamectin is a foliar insecticide derived from abamectin, which is obtained from Streptomyces avermitilis, a naturally occurring soil actinomycete, through fermentation. It has been approved for use on fruits, vegetables, cereals, tree nuts, oilseeds, herbs, and tea crops in a number of nations (Ishaaya*et al.,* 2001).

Management of Major pest complex of okra by using biorationals

Infestation of okra crops by lepidopterous borers *Earias vittella* and *Helicoverpa armigera* (Noctuidae: Lepidoptera) is one of the most immediate concerns among Indian farmers. (Javed *et al.*,2019) [21] For the control of okra shoot and fruit borers, indigenous okra growers rely only on a variety of standard synthetic insecticides (Iqbal *et al.,* 2014). The majority of these insecticides are dangerous and long-lasting, posing a variety of environmental and health risks. (Edwards, 2013) [10]. Similarly, field populations of *E. vittella* and *H. armigera* have been shown to be resistant to the majority of commonly used conventional pesticides (Ahmad and Arif, 2009; Qayyum *et al.,* 2015) [3, 30]. Other biorational pest management options, such as resistant or tolerant plant material, novel-chemistry synthetic pesticides, botanical and microbial pesticides, and insect predators and parasitoids, are less harmful and more environmentally benign than standard synthetic insecticides (Rosell*et al.,* 2008).

Bio rational and botanical used in management of *Earias vittella* in okra.

According Hegde and Nandihalli (2009) [15] plant extract like Garlic Chilli Kerosone Extract (GCKE) recorded best result (1.40 eggs per plant) followed by Neem Seed Kernel Extract (NSKE) alternated with cow dung% (1.71 eggs per plant). Also, according to Barakzai and Lyall (2014) [7], treatments with botanical insecticides such as neem oil 1 %, datura leaf extract 10%, garlic bulb extract 3%, and green chilli extract 1% are particularly effective against the shoot and fruit borer of okra. The best and most cost-effective treatment was Spinosad 45 % SC@ 0.05 0%, followed by Imidacloprid 17.8% SL@ 0.3 ml/l, Neemoil@3%, *Verticillium lecanii*, *Beauveria bassiana*, NSKE %, and Neem leaf extract %. (Pachole and colleagues, 2017) [28] So, when we compare the results of biopesticide (spinosad 45SC) with insecticides, we can see that bio pesticides perform well.

Bio rational and botanical used in management of *Helicoverpa armigera* in okra.

annonin 1% EC, karanjin 2% EC, Azadirachtin 1% EC, *Metarrhizium anisopliae*, *Verticillium lecanii*, *Beauveria bassiana*, *Bacillus thuringiensis* var Kurstaki, spinosad 45 % SC, and imidacloprid 17.8% SL are some of the plant extracts and EPF. Spinosad had the best result when compared to chloromycetin class pesticides, followed by *Bacillus thuringiensis*. Spinosad also had the highest marketable yield of okra, followed by B.t (Sarkar *et al*., 2015) [35]. So, according to studies, the effect of some biorational is comparable to that of chemical insecticides, so in the field and for okra borer pest management, utilizing bio rationales is effective and produces the same results as chemical insecticides while causing less harm to natural eco systems.

Botanical extracts against lepidopterous borers (Shoot and fruit borer of okra and fruit borer of okra) in okra. (Javed *et al*., 2019) [21]

Table 1

Common name	insecticidal constituent	Plant parts extracted
Turmeric	Turmerone and ar-turmerone	Rhizomes
Tobacco	Anabasinenicotine and nornicotine (neonicotine),	Leaves
Garlic	Salkyl-cysteine sulphoxides (allicins)	Bulbs
Bitter apple	Colocynthin, cucurbitacins and lepidine	Fruits and leaves
Sour orange	Flavanones and limonenes	Peels and seed
Onion	Flavonoids and dimethyl trisulfides	Bulbs
Lemon-eucalyptus	Eucalyptol (1,8-cineole) and citronellal	Leaves and seeds
Ginger	Monoterpenes (1,8-cineole, α -pinene, myrcene) and sesquiterpenes (zingiberene, zingiberol)	Rhizomes
Neem	Azadirechtins and triterpenoids	Leaves and seeds

Sucking pests and their management

Target specificity, self-perpetuality is the main reason for the development of sucking pest complex infestation in to the field. The pest like leaf hopper, *B. tabaci* are generally attacks at early stage of crop growth and confined still the maturity. Biological pest control is most effective management practices without causing harmful effect to the environment and now a days entomopathogens are getting more popularity in the pest control programme.

B. bassiana, M. anisopliae, L. lecanii. and *V. lecanii,* are known as potential entomopathogenic fungi as it having no report of resistance development still now. EPF are act with the wide mode of action with varieties of pest population. EPF are easily available less expensive. Neem oil also getting more popularity in the categories of botanicals due to low cost of manufacturing (Halder *et al.,* 2012) [14]. Very limited literatures are available for the compatibility of EPF with other biorationals and botanicals for the management of sucking pests complex in okra. The purpose of the study is to know the most promising bioagents for the management of sucking pests complex and their compatibility with neem oils.

Raheem and Al-Keridis 2017, reported that the combination of neem oil with three EPF is effective for the mangement of okra sucking pest complex. The single and combine application of *L. lecanii* was shown the great result as compare with other treatment. The half combination than the recommended dose of neem with *L. lecanii* was effective for the management of jassids and white fly in okra. *L. lecanii* shows virulence against *B. tabaci* in green house condition (Scorsett *et al.,* 2008). The application of *V. lecanii* @7gm/l shows the maximum mortality of okra jassids. The similar finding was also observed by Baladiniya *et al,* 2010. CKM-048 strain of Basinym (*E. anisopliae*) with different concentration effectively control the jassids in egg plant. Mixture of *B. bassiana, M. anisopliae* and *L. lecanii* in two-in one tank mixed with sufficient sub lethal concentration of neem oil successfully used against numerous target pests with good selection pressure.

Islam *et al*., 2010 studied that the combine effect of neem and *B. bassiana* against white fly in their investigation. It was discovered that the combination of neem oil with *B. bassiana* gaves ADI and ODI with 80.15 and 88.25 respectively. Halder et al observe that the combine effect of neem with EPF effective against Hadda beetle and sting bug of brinjal. The compatibility of nimbicidine with *B. bassiana* and *L. lecanii* also checked by (Subbulakshmi *et al.,* 2012.) [40]

Many local farmers were also concerned by Imidacloprid 17.8 percent SL's decreased efficacy in recent years. Microbial insecticides like EPF, on the other hand, are rarely utilized for pest control in the area. The reason for this could be a shortage of adequate biocontrol chemicals on the local market, as well as a lack of understanding about how to use them (Roy *et al.,* 2017) [34]. So, the superior result could be due to the use of a relatively modern management strategy in the region, namely, spraying EPF alone or in combination with neem oil against sucking pests of okra.

Conclusions

Pesticides used indiscriminately have a wide range of negative consequences on the environment, including secondary pest problems, pest return, and resistance, as well as negative effects on human health and the environment. Researchers have been experimenting with safer, more diversified approaches to control these hazardous insects as a result of these disasters. In addition to parasitoid-like bioagents and field storage, promising control strategies include the use of microbiological agents such as entomopathogenic fungi and nematodes. Many of the other ways of control are inexpensive. Bacteria can spread horizontally via infectious toxins, and the majority of them are naturally selective and resistant to indirect chemicals. In addition, a combination of entomopathogenic fungi such as *B. bassiana, M. anisopliae, L. lecanii,* and neem oil in its suggested concentration component can be an environmentally friendly effective solution for controlling okra, mammals and protecting natural enemies. All of these approaches or bio pesticides are eco-friendly and can help to reduce pesticide use on crops and the environment. They're simple to include into IPM systems, allowing them to be farmed safely and sustainably.

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