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Effect of abiotic and biotic factors on growth parameters of *Henosepilachna vigintioctopunctata* (Coccinellidae: Coleoptera) and *Lucinodes orbonalis* (Crambidae: Lepidopetera) in brinjal

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Abstract
Henosepilachna vigintioctopunctata (hadda beetle) and *Lucinodes orbonalis* (Brinjal shoot and fruit borer) are two highly destructive pests that result in considerable harm to brinjal crops, leading to substantial reductions in yield. In India, yield losses for both of these pests have been documented with a range of 50-70% for brinjal shoot and fruit borer and 60% for hadda beetle. Agro-climatic conditions are very important for the control of these destructive pests, as it can affect the population in greater scale. Numerous non-living variables, such as temperature, relative humidity, rainfall, and photoperiod, hold significance in the growth and development of the hadda beetle and brinjal shoot and fruit borer. Consequently, it becomes imperative to examine these factors comprehensively to effectively manage the population of these pests. Various types of predators, parasitoids, botanicals, and entomopathogens have been observed targeting distinct life stages of *E. vigintioctopunctata* and *L. orbonalis*. Among these, certain species have demonstrated a notable contribution to naturally curbing the pest population. This comprehensive review aims to compile and present information about the various abiotic factors that contribute to the prevalence of these pests, as well as the biotic factors like parasitoids. This knowledge can be instrumental in devising strategies for managing these pests successfully.

Keywords: Abiotic factors, biotic factors, brinjal, brinjal shoot and fruit borer and hadda beetle.

1. Introduction

Solanum melongena L., also known as brinjal or eggplant, is a member of the solanaceous vegetable family. This highly nutritious plant is rich in essential vitamins and minerals such as phosphorous, calcium, iron, dietary fiber, folate, vitamin C, vitamin K, niacin, vitamin B6, among others (Ghosh, 2022) [24]. As per FAOSTAT data, the global eggplant production in 2020 reached 56,618,843 metric tonnes, showing a 2.2% increase from 2019's 55,376,521 tonnes. In the fiscal year 2022, India's brinjal production is estimated to have reached around 12.98 million metric tons, marking a growth from the previous fiscal year. Approximately 750 thousand hectares of agricultural land were dedicated to brinjal cultivation in India during the fiscal year 2021. Brinjal covers the 7% of total vegetable production and area in India (Agarwal and Kumar, 2018) [49]. Within India, the state of West Bengal stands as the leading producer of brinjal, achieving a production of 3,029.02 tonnes during the 2021-2022 year and holding a notable share of 23.72%. Following closely are Orissa with a 16.66% share and Gujarat with a 12.01% share in brinjal production (National Horticulture Board, Anon. 2017, Ajabe *et al.* 2019) [9, 3]. Brinjal is a perennial crop that is cultivated annually across the nation. There are lot of pests which are deteriorating the brinjal crop and causing serious loss in the crop production. Several significant pests that affect brinjal include brinjal shoot and fruit borer, hadda beetle, aphids and ash weevils. Thrips, mealy bugs, whiteflies, termite, leaf roller are some minor pests of brinjal (Madhu, 2019) [45]. Most destructive insect pest affecting brinjal crop is *Lucinodes orbonalis*, which belongs to the Crambidae family within the Lepidoptera order (Soto *et al.* 2010; Eswara and Srinivasa 2001) [74, 23]. This pest's damaging behavior involves initial internal feeding on the shoots which lead to wither and eventual dries down. Further, it then bore into the young fruits, creating holes within them (Alam *et al.* 2003, and Kumar *et al.* 2019) [4, 44].

In some instances, the detrimental impact of this pest on crop yield has been assessed at levels exceeding 80% in Bangladesh (Dhandapani *et al.* 2003; Chakraborti and Sarkar 2011, and Islam *et al.* 2019) [20, 16, 30]. Similarly, in India, yield losses have been documented at rates of 85.8%, 75%, and 95% (Mannan *et al.* 2015) [47], along with a range of 50-70% (Shankar and Tripathi 2021) [68], and 11-93% (Kodandaram *et al.* 2014) [39]. Another destructive insect pest that infest brinjal crops is *Henosepilachna vigintioctopunctata*, a member of the Coccinellidae family within the Coleoptera order. This pest significantly diminishes crop yields by consuming leaves through scraping. The adult beetles mainly consume the upper surface of the leaves, whereas the larvae are restricted to the underside of the leaves (Maurice and Ramteke 2013, Mishra and Regmi 2022) [50, 52]. The hadda beetle holds one of the top position as the most damaging crop pest nationwide, causing an 80% loss in leaf damage and a 60% reduction in fruit yield (Kumar *et al.* 2022) [41]. The beetle known as the 28-spotted beetle has a wide distribution across India, as documented by Anam *et al.* (2006) [7] and Rahman *et al.* (2008). It is commonly found in the elevated regions of Jammu and Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, Karnataka, Bengal, as well as certain flat regions, as reported by Jamwal *et al.* (2017) [32] and Sivasankari *et al.* (2021) [72]. Numerous non-living factors, such as temperature, relative humidity, rainfall, and photoperiod, hold significance in the growth and development of the hadda beetle and the brinjal shoot and fruit borer (BSFB). Consequently, it becomes imperative to examine these factors comprehensively to effectively manage the population of these pests (Qamar and Haseeb 2019) [59]. The population of BSFB is greatly affected by mild temperatures and elevated humidity levels (Shukla and Khatri 2010; Bhushan *et al.* 2011, and Ayyanar *et al.* 2022) [71, 12, 10]. Various types of predators, parasitoids, and pathogens have been observed targeting distinct life stages of *E. vigintioctopunctata*. Among these, certain species have demonstrated a notable contribution to naturally curbing the pest population (Reddy and Mandal 2016) [62].

1.1 Effect of abiotic factors on hadda beetle (*Henosepilachna vigintioctopunctata*) population

The occurrence of the hadda beetle fluctuates depending on the location and the environmental conditions prevalent in a given year (Konar and Mohasin, 2002) [41].

1.2 Temperature

The highest occurrences of egg clusters were observed at an average maximum temperature of 36.38°C, with the corresponding minimum temperature recorded as 24.15°C. The optimal temperature range for the grub population was identified as maximum temperature 33.37°C and minimum atmospheric temperature 23.74°C. The majority of adult specimens were found to thrive in conditions characterized by maximum and minimum atmospheric temperatures of 32.08°C and 21.46°C (Jamwal *et al.* 2017) [32], 33.17°C and 25.40°C (Pal *et al.* 2019) [58], and within the range of 24-31°C (Ghosh and Senapati, 2001; Venkatesha, 2006) [25, 80]. Temperature significantly contributes to the rapid proliferation of the *H. vigintioctopunctata* abundance. Among all the stages of the pest, the grub stage typically exhibits greater resilience to elevated temperatures (Kalaiyarasi *et al.* 2017) [37].

1.3 Relative humidity (morning and evening)

The majority of larvae were discovered to thrive under morning and evening relative humidity conditions of 87.36% and 61.50%, respectively. Adult beetles exhibited preference for morning relative humidity at 80.93% and evening relative humidity at 59.86% (Jamwal *et al.* 2017) [32], 75.93% (Pal *et al.* 2019) [58], and 58-75% relative humidity (Ghosh and Senapati 2001 and Venkatesha 2006) [25, 80]. The development of different stages of the pest beetle remained unaffected by variations in relative humidity (Chaudhary and Saravanan., 2011) [18].

1.4 Rainfall

The majority of grub population was observed at a recorded rainfall of 4.20 mm, while the adult beetle population was prevalent at a recorded rainfall of 8.39 mm (Jamwal *et al.* 2017) [32], 78.8 mm (Pal *et al.* 2019) [58]. Rainfall usually shows positive correlation with the hadda beetle population. (Table 1)

2. Effect of biotic factors on Hadda beetle (*Henosepilachna vigintioctopunctata*) population

2.1 Parasitoids

Among the observed parasitoids, specifically egg parasitoid, *Tetrastichus sp.* and pupal parasitoid, *P. foveolatus. Tetrastichus sp.* was more commonly identified within the hadda beetle population (Halder *et al.* 2011 and Jamwal *et al.* 2017) [27, 32]. The life cycle duration of the *P. foveolatus* spans from 10 to 13 days, with average 11.63 days (Reddy and Mandal 2016) [62]. Notably, *P. foveolatus* emerged as the predominant and social parasitoid of the hadda beetle, capable of parasitizing both larval and pupal stages (Kernasa *et al.* 2002) [38]. However, in a study conducted by Jamwal *et al.* (2017) [32], *Tetrastichus sp*. exhibited a higher percentage of parasitization on the hadda beetle compared to *P. foveolatus*. This suggests that, in their research area, *Tetrastichus sp*. could be the more common parasitoid that prey on hadda beetle, potentially due to variations in agro-climatic conditions.

2.2 Entomopathogens

Experiments were conducted on various treatments, both microbial and botanical, namely, *Beauveria bassiana*, *Metarhizium anisopliae*, *Lecanicillium lecanii*, *Bacillus subtilis*-2 and neem oil, individually as well as in combination with neem oil against the hadda beetle. The results showed that *M. anisopliae* emerged as the most effective option in controlling the hadda beetle population (Halder *et al.* 2016) [28]. The mortality of *E. vigintioctopunctata* was evident 18 hours after the application of *B. bassiana* in laboratory conditions, while it took 72 hours for the effects to be visible in the field, as observed by Thurkathipana and Mikunthan (2008) [78]. The black muscardine fungus, *M. anisopliae*, is highly successful in managing the beetle population, with reports of causing a 62% mortality rate in 2nd instar grubs of *H. vigintioctopunctata*. Additionally, *Beauveria bassiana* was responsible for a mortality rate of 60.3% (Kodandaram *et al.* 2014) [39].

2.3 Botanicals

There are several plant extracts which can be used for pest reduction without harming the environment. Neem extract is found to be useful for repelling pests (Shankar and Tripathi, 2021) [68]. Azadirachta indica, not only hampers oviposition

(Isman 2002) [31], but also disrupts the digestive system of the hadda beetle (Nisbet *et al.* 1996) [57]. This makes A. indica a promising choice for controlling the pest population (Murugesan and Murugeshcides, 2008; Mondal and Ghatak, 2009; Rukhsana *et al.* 2010) [54, 53, 65]. A. indica leads to the maximum number of deaths among the pest population (Isman, 2002; Koul and Wahab, 2004) [31, 42]. Sharma and Saxena (2012) [69] utilized floral extract from *Eucalyptus globulus* and seed extract from *Nerium indicum* due to which the deformed adults displaying malformed wings, elytra, and appendages were noted. Extracts of neem, eucalyptus, and lemon were tested individually out of which *A. indica* proved to be the most efficient botanical for the mortality rate of *H. vigintioctopunctata* (Hanif *et al*., 2021) [30].

2.4 Bio-pesticides

The utilization of bio-pesticides offers a potent and environmentally friendly strategy for managing pests. Furthermore, these solutions are cost-effective, simple to formulate, and do not impose any negative effects on plants, natural predators, or in humans (Barčić *et al.* 2006; Kodandaram *et al.* 2010; Adalbert *et al.* 2013; Elshafie 2013; Miresmailli and Isman 2014; Stevenson *et al.* 2017 and Revathi, 2021) [11, 39, 2, 22, 51, 76]. One example of a microbial pesticide is spinosad, derived from the bacterium *Saccharopolyspora spinosa*, which has shown effectiveness in controlling hadda beetle populations (Buntin *et al.* 2004; Elliot *et al.* 2007; Jha *et al.* 2014; Reddy *et al.* 2016 and Shrestha *et al.* 2020) [15, 21, 33, 62, 70]. (Table 2)

3. Effect of abiotic factors on brinjal fruit and shoot borer (*Lucinodes orbonalis*) population

During the kharif season, the onset of BSFB infestation typically begins in the first week of August, with a peak infestation of 86.67% occurring at the highest point of the crop's flowering stage. Around the 9th week of the plant's growth, coinciding with the fruiting phase and under favorable weather conditions., the population reaches its highest point, marked by a 96.97% infestation rate (Saha *et al.* 2020) [66]. Similarly, Nandi *et al.* (2017) [63] noted the attack of BSFB in August, with shoot damage at 25.55%, peaking in September with shoot damage escalating to 43.43%. Soren *et al.* (2020) [82] noted the highest shoot infestation at 9.8% during the 2nd standard meteorological week and the highest fruit infestation at 20.5% during the 35th standard meteorological week. In the winter season, the infestation was identified in November and December, reaching its highest point in February during the 6th and 7th standard weeks (Indirakumar *et al.* 2016) [29]. Kadgonkar *et al.* (2017) [34] also recorded the occurrence of BSFB in November and December, with the highest infestation observed in January. Similarlly, Nayak *et al.* (2014) [56] had same findings with the first peak infestation in the 3rd and 1st week of December, and the second peak infestation in the 3rd week of February.

3.1 Temperature

The highest occurrence of fruit infestation by BSFB was documented at the end of December. During this period, the highest temperature reached 24.9°C, and the lowest temperature was recorded at 11.7°C (Borkakati *et al.* 2021) [13]. The pest population was observed to thrive most effectively at temperatures exceeding 30°C (Pal *et al.* 2019) [58]. During the summer months, the peak infestation of the pest (66.66%) was noted during the first week of May, characterized by daytime and nighttime temperatures ranging from 20°C to 40°C, along with a maximum RH of 60% (Deole, 2015) [19].

3.2 Relative humidity

The average relative humidity for the BSFB (Brown Shoot and Fruit Borer) was documented as 84.65% (Borkakati *et al.* 2021) [13]. The optimal conditions for the pest population growth are 60% and 65% relative humidity (Pal *et al.* 2019) [58]. This finding aligns with the observations of Deole (2015) [19], where a relative humidity of 60% was recorded during the height of pest infestation. In another scenario, there was an average humidity of 69.43% during the peak fruit infestation period (40.86%), and an average humidity of 72.36% during the peak shoot infestation period (32.20%). (Vijayalakshmi *et al.* 2021) [81].

3.3 Rainfall

During the peak shoot infestation period (9.92%), Gupta *et al.* (2021) [26] documented a rainfall of 12.8mm at 40 SMW (Standard Meteorological Weeks). However, the presence of rainfall did not have a substantial impact on fruit infestation caused by BSFB. Similarly, when shoot infestation was at its highest (40.86%), the average recorded rainfall was 2.43mm, and during the period of high fruit infestation (32.20%), the recorded rainfall was 0.29mm. There was an inverse relationship between rainfall and both shoot and fruit infestation occurrences (Vijayalakshmi *et al.* 2021) [81].

3.4 Sunshine

The presence of BSFB coincided with bright sunshine hours, amounting to 5.8 hours, as noted by Borkakati *et al.* (2021) [13]. In the case of peak shoot infestation (9.92%), Gupta *et al.* (2021) [26] observed 4 hours of sunshine, while during the height of fruit infestation (46.84%), the recorded sunshine duration was 3.7 hours.

4. Effect of biotic factors on the population of *Lucinodes orbonalis*

4.1 Predators

Predators that contribute to controlling BSFB include species like the mirid bug (*Campyloneura sp*), ladybird beetles such as *Cheilomenes sexmaculata* and *Coccinella septempunctata*, seven-spotted beetle, *Brumoides suturalis*, three-striped beetle, lacewings like *Chrysoperla carnea*, birds like King crows and common mynahs, as well as other insects like wasps, dragonflies, spiders, robber flies, reduviid bugs, praying mantises, fire ants, big-eyed bugs (*Geocoris sp*), pentatomid bugs (*Eocanthecona furcellata*), earwigs, ground beetles, and rove beetles (Shankar and Tripathi, 2021 [68]. In the context of *L. orbonalis*, predators that play a role in its control consist of the Coccinelid beetle, syrphid fly, dragonfly, damselfly, and spiders (Roy *et al.* 2016) [64]. Among these, the most prevalent predators for *L. orbonalis* are the ladybird beetle and lynx spider (Manna and Chakraborty, 2022) [46].

4.2 Parasitoids

Various parasitoids play a crucial role in controlling BSFB (Brown Fruit and Shoot Borer). These include *Trichogramma chilonis* (targeting eggs), *Pseudoperichaeta sp.* (targeting larvae), *Phanerotoma sp.* (targeting larvae), *Itamoplex sp.* (targeting larvae), *Eriborus argenteopilosus* (targeting larvae), *Diadegma apostata*, *Pristomerous testaceus*, *Trathala flavo-orbitalis* (targeting larvae and pupae), *Cremastus sp*. (targeting larvae), *Bracon greeni* (targeting larvae), *Iphiaulax sp.* (targeting larvae), and *Goryphus nursei* (targeting pupae) (Shankar and Tripathi, 2021) [68]. Regarding the BSFB, the most effective parasitoids are *Trichogramma chilonis* (egg parasitoid) and *Bracon habetor* (larval parasitoid) (Alam *et al.* 2006) [5]. Among the six species studied by Ranjith *et al.* (2020) [70], *Trathala flavoorbitalis* (79.4%) stood out as the most abundant parasitoid species, followed by *Bracon sp*. (11.2%) and *Phanerotoma sp*. (5.6%). For the prevention of shoot infestation by BSFB, *T. chilonis* Ishii was identified as the most effective egg parasitoid. (Abhishek and Dwivedi, 2021) [1].

4.3 Entomopathogens
Shankar and Tripathi (2021) [68] emphasized that *Bacillus thuringiensis* var. *kurstaki* and *Bacillus thuringiensis* var. *aizawai* demonstrate high efficacy in controlling pests belonging to the Lepidoptera order. They are particularly effective against these pests. Additionally, *Bacillus thuringiensis* (Bt) stands out as a highly efficient biological pathogen for managing the BSFB, with *Beauveria bassiana* and *Metarhizum anisopliae* also proving to be potent bio-pathogens for BSFB management (Abhishek and Dwivedi 2021) [1]. As highlighted by Raina and Yadav (2018) [61], *M. anisopliae* stands out as the most effective option for reducing shoot infestations while simultaneously maximizing crop yields. (Table 3)

Table 1: Abiotic factors impacting the growth of *H. vigintioctopunctata*, hadda beetle

Abiotic factors	Correlation with beetle population	Reference
Temperature	Positive	Chandrakumar *et al.*,(2008), Haldhar *et al*., (2013), Kumar *et al*., (2014) [17, 29, 42, 43]
Relative humidity	Positive	Haldhar *et al*., (2013), Kumar *et al*., (2014) [29, 42, 43]
Rainfall	Positive	Ali, (2017) [6], Haldhar *et al*., (2013) [29], Kumar *et al*., (2014)
Sunshine	Positive	Sharma and Tayde, (2013) [69]
Wind velocity	Positive	Chandrakumar *et al.*,(2008) [17]

Table 2: Biotic factors impacting the growth of *H. vigintioctopunctata*, hadda beetle

Parasitoids	*Tetrastichus spp.* (egg parasitoid)
	P. foveolatus (Pupal parasitoid)
Entomopathogens	*Metarhizum anisopliae*
	Beauveria bassiana
Botanicals	neem (*Azadirachta indica*)
	eucalyptus (*Eucalyptus camaldulensis* Dehn.)
	Nerium indicum
	lemon (*Citrus lemon* L.)
Biopesticides	Spinosad

Table 3: Biotic factors negatively impacting the growth of L. orbonalis, brinjal shoot and fruit borer (BSFB)

Predators	Mirid bug (*Campyloneura sp.*)
	Cheilomenes sexmaculata
	Coccinella septempunctata
	Brumoides suturalis
	Chrysoperla carnea
	Syrphid fly
	Dragonfly and damselfly
	Lynx spider
	King crows and common mynahs
Parasitoids	*Trichogramma chilonis* (egg parasitoid)
	Bracon habetor (larval parasitoid)
	Trathala flavoorbitalis
	Phanerotoma sp.
Entomopathogens	*Bacillus thuringiensis* var. *kurstaki*
	Bacillus thuringiensis var. *aizawai*
	Metarhizum anisopliae
	Beauveria bassiana

Conclusion
The presence of *H. vigintioctopunctata* and *L. orbonalis* is significantly influenced by various non-living factors. Hence, it can be deduced that the insect pest population is not typically influenced by a single weather parameter, as abiotic factors tend to have an impact when closely interacting with others. Therefore, establishing a connection between meteorological elements like maximum and minimum temperatures, morning and evening relative humidity, average relative humidity, average precipitation, wind speed, sunshine duration, etc., and pest populations is crucial for their management. Employing environmentally friendly methods for handling these pests involves utilizing bio-agents. Bio-agents encompass predators, parasitoids, and entomo-pathogens, offering a sustainable approach to mitigate the occurrence of the hadda beetle and BSFB. These bio-agents are capable of targeting specific pest species or acting during distinct life stages. The parasitoids *Tetrastichus sp.* and *P. foveolatus* were noted to effectively control the hadda beetle population (Kernasa *et al.* 2002; Halder *et al.* 2011; Reddy and Mandal 2016 [38, 27, 62]; Jamwal *et al.* 2017) [32]. Out of the 21 parasitoids documented from the BSFB, a significant one is *Trathala flavoorbitalis* Cameron (Sandanayake and Edirisinghe, 1992; Talekar, 2005;

Srinivasan, 2008; Kumar and Raghuraman, 2014). As a natural parasitoid, *T. flavorobitalis* cannot be easily produced on a large scale in a laboratory. However, this ichneumonid parasitoid has the capability to effectively control the population of *L. orbonalis* in the field. Exploring the feasibility of mass-producing this parasitoid could be explored to enhance the control of the primary pest in eggplant, the shoot and fruit borer. Therefore, acquiring knowledge about the physical characteristics, life cycle, and environmental interactions of these parasitoids would be valuable for managing the pest population in an environmentally sustainable way. Research focused on comprehending the behavior and characteristics of these bio-agents is imperative for enhancing our knowledge.

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