AF-898
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RESEARCH ARTICLE Indian Journal of Agricultural Research

# Pests of *Helicoverpa armigera* (Hübner) and *Spodoptera exigua* (Hübner) in Pepper Fields in Armenia

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10.18805/IJARe.AF-898

## ABSTRACT

**Background:** Between 2021-2023, the harmfulness of Helicoverpa armigera (Hübner) and *Spodoptera exigua* (Hübner) on different varieties of pepper was studied in the pepper fields of Khoronk community.

**Methods:** Studies on the harmfulness of *H. armigera* (Hübner) and *S. exigua* (Hübner) were carried out in 2021-2023 in the pepper fields of Khoronk community of Armavir marz. Experiments were carried out on the main 7 varieties cultivated in the community, to the methodology adopted in entomology.

**Result:** As a result of studies, it was revealed that both pests damage plants in the larval stage. They feed on the vegetative and generative organs of the plant. Young larvae of *S. exigua* (Hübner) feed on newly opened leaves, enter into the leaves, cover them with a web and feed inside it. They then come out and spread over the plant and feed on leaves of different heights, as a result of which scratches of irregular shape and size occur on the leaves. Most mature larvae enter the fruit, feed on the seeds, because of which the fruit rot. Larvae of *H. armigera* (Hübner) initially feed on flowers and flower buds, and after some time they move on to leaves. Larvae feed on the upper and epidermis of the leaf, leaving the lower unharmed. As a result of the damage, the dries up, falls off, and the leaves look porous. Mature larvae mostly damage the fruit. Larvae enter the fruit from anywhere in the fruit, opening deep holes. They feed on seeds in the fruit. Damaged fruits begin to ripen prematurely, various harmful pathogens penetrate from the damaged areas, as a result of which the fruits rot. According to the results of studies carried out on 7 different varieties of pepper during the period of intensive development of *H. armigera* (Hübner) and *S. exigua* (Hübner), the most significant damage by pests was recorded in Hayk variety, and the least in Arevaham variety.

**Key words:** Damage, Fruit, Larva, Leaf, Variety.

## INTRODUCTION

*S. exigua* (Hübner) and *H. armigera* (Hübner) belong to the Noctuidae family of the Lepidoptera order. They damage both in the open field and in the greenhouse (Han *et al.*, 2014, Kumar *et al.*, 2020).

*S. exigua* (Hübner) is an omnivorous pest (Guerrero *et al.*, 2014, Chena *et al.*, 2019, Hafeez *et al.*, 2021, Rajesh Chowdary *et al.*, 2024). Due to its global distribution and omnivorous behavior, this pest causes significant economic losses in crop production worldwide (Hafeez *et al.*, 2021), causing yield reduction.

*S. exigua* (Hübner) damages the leaves and fruits of many crops (Rabelo *et al.*, 2022), including vegetables, field crops, ornamental plants (Pogue, 2002, Capinera, 2024). They prefer leguminous plants as well as the plants of family Solanaceae, Poaceae, Malvaceae (Artokhin *et al.*, 2017), Liliaceae, Rubiaceae, Umbellíferae, Asteráceae (Shankar *et al.*, 2014, Mehta *et al.*, 2021).

Damages more than 185 species of plants belonging to 50 families (Kuznetsov, 1999 ) including 133 species of cultivated plants. In North America alone, it damages more than 90 species of plants in 18 families (Greenberg *et al.*, 2001, Navasero *et al.*, 2019) . They feed on crops such as tomato, corn, (Zhang *et al.*, 2021), broccoli, peanut, melon (Dalip, 2014), chickpea, maize, sunflower, spinach (Rajesh Chowdary *et al.*, 2024), cabbage, alfalfa (Shankar *et al*, 2014), pepper (Terlemezyan and Ghazaryan, 2023), eggplant (Mehrkhou *et al.*, 2015), onion (Navasero *et al.,* 2019), tobacco, cotton (Hafeez *et al.,* 2021), potato (Kumar *et al.*, 2020), *etc.* Larvae also feed on a number of weeds during their development (Capinera, 2024).

*S. exigua* (Hübner) damages plants in the larval stage (Greenberg *et al.*, 2001, Kumar *et al.*, 2020, You *et al.*, 2020, Rajesh Chowdary *et al.*, 2024). Young larvae feed in groups (Simon *et al.*, 2021). The caterpillars feed mainly on the reverse side of the leaves, leaving behind small silk webs. They feed in such a way that the leaves become skeletonized, all the tissues of the leaves are destroyed,

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**How to cite this article:** Terlemezyan, H.L., Manvelyan, A.A., Harutyunyan, H.R., Mkrtchyan, H.N. and Ghazaryan, M.H. (2024). Pests of *Helicoverpa armigera* (Hübner) and *Spodoptera exigua* (Hübner) in Pepper Fields in Armenia. Indian Journal of Agricultural Research. 1-6. doi: 10.18805/IJARe.AF-898.

**Submitted:** 11-07-2024 **Accepted:** 10-10-2024 **Online:** 13-01-2025

only the leaf veins remain, which preserve the shape of the leaf. Sometimes the larvae connect several leaves together with a silk thread to make a temporary cocoon, in which they can feed safely (Capinera, 2006, Natwick *et al.*, 2012).

When feeding on fruits *S. exigua* (Hübner) larvae leave not deep wounds on the surface (Showler 2001, Natwick *et al.*, 2012). Sometimes *S. exigua* (Hübner) larvae even eat each other, especially when food supplies are scarce (Hua *et al.*, 2013).

Their feeding and behavior are directly or indirectly dependent on temperature fluctuations (Rathore *et al.*, 2013).

*H. armigera* (Hübner) is an omnivorous pest (Kriticos *et al.*, 2015). It is one of the most dangerous pests of agricultural crops in the world (Karim, 2000, Krinski and Godoy, 2015), causing a global economic loss of 2-3 billion USD annually (Tay *et al.*, 2013, Riaz *et al.*, 2021).

*H. armigera* (Hübner) damages 68 plant families (Cunningham and Zalucki, 2014). According to Tai *et al.* (2013), the *H. armigera* (Hübner) damages more than 180 plant species belonging to 45 families; according to Krinsky and Godoy (2015) - 67 plant families; according to Kuznetsov (1999) damages more than 350 species of plants.

The main damage is caused by larvae (Artokhin *et al.*, 2017, Suzana-Milan *et al.*, 2022, Trujillo *et al.*, 2024), which feed on vegetative parts of plants: upper parts of shoots, leaves of different heights (Salvadori *et al.*, 2013) and with generative organs: buds, inflorescences, fruits, pods (Suzana-Milan *et al.*, 2022).

Insect damage has been reported on both cultivated and uncultivated plants (Salvadori *et al.*, 2013), which belonged to Solanaceae, Fabaceae, Asteraceae, Malvaceae and Poaceae families (Krinski and Godoy, 2015). It also causes economic damage to agricultural crops such as corn, tomato, legumes, tobacco, sorghum, fruit trees (Lammers and MacLeod, 2007, Specht *et al.*, 2013), pumpkin, zucchini, alfalfa (Artokhin *et al.*, 2017), pigeon pea (Pandey 2016; Amit *et al.*, 2022), pepper (Ghazaryan, 2023), as well as flowers: Carnation, Gerbera, Gladiolus, Chrysanthemum (Pal and Sarkar, 2009), Rosa (Eswara Reddy *et al.*, 2021), Pelargonium (Lammers and MacLeod, 2007). They also damage some types of weeds (CABI, 2007).

*H. armigera* (Hübner) causes serious economic damage, especially in open field conditions. In 2003, this type was a serious pest of pepper in the Metaponto region of Italy, with reported plant damage of 30% fruit and 70–80% (Lammers and MacLeod, 2007). Second and third instar larvae can cause cotton yield losses of up to 65% (Ting, 1986). Chickpea crop loss is 20-90% (Tripathi *et al.*, 2023). In South Asia, East Africa and Latin America, it is the only pest that causes the loss of pea crops to 100%, which is about 300 million dollars annually (Thomas *et al.*, 1997).

In recent years, a significant increase in the damage to the leaves and fruits of pepper caused by *H. armigera* (Hübner) and *S. exigua* (Hübner) has been observed in Armenia. Almost all varieties cultivated in the country are damaged. Global climate change, incorrect timing of control measures and wrongly applied preparations have greatly contributed to the rapid development of pests.

The aim of the research is to study the degree of harmfulness of *H. armigera* (Hübner) and *S. exigua* (Hübner) on different varieties of pepper, the nature of the damage they cause.

As a result of the research, we will also record the varieties that are most damaged by *H. armigera* (Hübner) and *S. exigua* (Hübner) and as well as the more resistant ones, which in turn will contribute to the correct organization of further work.

## MATERIALS AND METHODS

Studies on the harmfulness of *H. armigera* (Hübner) and *S. exigua* (Hübner) were carried out in 2021-2023 in the pepper fields of Khoronk community of Armavir marz. Experiments were carried out on the main 7 varieties cultivated in the community, 4 of which are sweet varieties: Hayk, Zmrukht, Milli, Mira and 3 are spicy varieties: Haykakan sabi, Arevaham, Arevaashogh.

Enumerations of damaged plants in the fields were conducted according to the methodology adopted in entomology (Forecast of occurrence and accounting of pests and diseases of agricultural crops, 1958). Data calculations were conducted in the entomology laboratory of Armenian National Agrarian University.

Damage of plants by pests was determined according to the ratio of plants inhabited by pests to the total number of examined plants. The degree of damage by individual pests was determined by checking 300 plants from each variety (fruit, leaf) arranged in a checkerboard pattern. The degree of harmfulness of the plants was evaluated on the following point scale:

1 point - Very weakly damaged plants (up to 5%).
2 points - Slightly damaged plants (from 5 to 25%).
3 points - Moderately damaged plants (from 25 to 50%),
4 points - Heavily damaged plants (from 50 to 75%).
5 points - Very heavily damaged plants (75% or more).

The degree of plant damage was determined using the following formula:

$$V = \frac{\sum abc}{C \times 5} \times 100$$

V = Degree of average damage.
$\sum$ abc = Sum of points.
C = Total number of counted plants.
5 = Highest point (Pikushova and Veretelnik, 2009).

## RESULTS AND DISCUSSION

During the vegetation period of 2021-2023, the harmfulness of *H. armigera* (Hübner) and *S. exigua* (Hübner) on different varieties of pepper was studied in the pepper fields of Khoronk community. The latter damage plants in the larval stage. They feed on the vegetative and generative organs of the plant.

According to our research, *S. exigua* (Hübner) larvae go through 5 instars or molts during their development.

The first, second and third instar larvae mainly damage the leaves, buds and flowers of plants, while the fourth and fifth instar larvae damage the fruits.

The newly hatched larvae feed on the newly opened leaves, enter them, cover them with a web and start feeding inside. Some of the larvae continue their development in the web, passing through several molts, while others emerge, spread on the plant and start active feeding. Second instar larvae prefer to feed on newly opened young leaves, causing skeletonization of the leaves.Third instar larvae feed on leaves of various ages, both old and young. Scratches of irregular shape and size appear on the damaged leaves (Fig 1).

Third instar larvae molt after feeding, after which some part of them climbs to the upper part of the plant and continues feeding there. Some of the larvae continue to feed on the fruit and some on the leaves. Larvae find a suitable place on the fruits, gnaw the flesh and enter them. They feed on the seeds in the fruit, causing the fruit to rot and become unfit for consumption (Fig 2).

According to our research, *H. armigera* (Hübner) larvae feed on the vegetative and generative organs of the plant. The newly hatched larvae initially feed on flowers and flower buds and after some time they move to the leaves. Young larvae feed on the upper leaf blade and epidermis, leaving the lower leaf intact. However, after some time, the leaf blade dries up and falls off and the leaves take on a porous appearance (Fig 3). In case of strong infection, they can destroy the whole plant.

Mature caterpillars mostly damage the fruit, although there are cases when small caterpillars also damage the fruit, but the newly formed and small fruits. Larvae enter the fruit from anywhere in the fruit, opening deep holes. They feed on the seeds in the fruit, filling the fruit with their excrement (Fig 4). Damaged fruits begin to ripen prematurely, various harmful pathogens penetrate from the damaged areas, as a result of which the fruits rot. Damaged fruits remain on the plant and subsequently fall off at the slightest touch.

During June-August months of 2021-2023, during the period of rapid development of *H. armigera* (Hübner) and *S. exigua* (Hübner), the degree of their harmfulness was studied on 7 varieties of pepper (Table 1, 2). 300 plants of each variety were studied.

From the data in Table 1, we can see that the most damage by *S. exigua* (Hübner) was observed in the Hayk variety in all 3 years and the least in the Arevaham variety.

**Fig 1:** *S. exigua* (Hübner) larvae damage to pepper leaves.

**Fig 2:** Fruit damage caused by *S. exigua* (Hübner) larvae.

**Fig 3:** Damage caused by *H. armigera* (Hübner) larvae to pepper leaves.

**Fig 4:** The damage caused by *H. armigera* (Hübner) larvae to the pepper fruit.

**Table 1:** The average damage of different varieties of pepper by *S. exigua* (Hübner) (Khoronk Community, 2021-2023, average data).

| Variety | Degree of harmfulness, % | | | | | |
|---|---|---|---|---|---|---|
| | 2021 | | 2022 | | 2023 | |
| | Leaf | Fruit | Leaf | Fruit | Leaf | Fruit |
| Hayk | 58.2 | 53.0 | 60.4 | 54.3 | 52.6 | 47.4 |
| Zmrukht | 29.6 | 21.8 | 34.7 | 28.5 | 24.2 | 19.8 |
| Milli | 42.1 | 37.4 | 48.4 | 41.4 | 38.0 | 30.6 |
| Mira | 34.4 | 27.5 | 38.2 | 32.6 | 37.1 | 31.8 |
| Haykakan sabi | 52.7 | 46.2 | 56.2 | 50.8 | 48.3 | 44.2 |
| Arevaham | 19.8 | 14.1 | 24.5 | 18.5 | 16.2 | 11.9 |
| Arevashogh | 20.6 | 18.3 | 27.4 | 21.9 | 22.9 | 18.4 |

**Table 2:** The average damage of different varieties of pepper by *H. armigera* (Hübner) (Khoronk community, 2021-2023, average data).

| Variety | Degree of harmfulness, % | | | | | |
|---|---|---|---|---|---|---|
| | 2021 | | 2022 | | 2023 | |
| | Leaf | Fruit | Leaf | Fruit | Leaf | Fruit |
| Hayk | 54.4 | 49.5 | 56.2 | 52.0 | 53.4 | 48.1 |
| Zmrukht | 29.2 | 24.3 | 32.6 | 26.6 | 27.6 | 21.9 |
| Milli | 46.5 | 40.0 | 40.1 | 36.4 | 40.6 | 32.3 |
| Mira | 38.9 | 32.8 | 39.5 | 35.2 | 41.3 | 35.8 |
| Haykakan sabi | 49.3 | 44.7 | 51.3 | 45.3 | 47.1 | 41.6 |
| Arevaham | 17.6 | 14.7 | 26.4 | 15.7 | 18.6 | 13.7 |
| Arevashogh | 21.4 | 19.1 | 27.7 | 20.8 | 23.8 | 17.5 |

Based on the data in the table, we can see that during the 3 years of the test, the most damaged by *H. armigera* (Hübner) was again observed in the Hayk variety and the least in the Arevaham variety.

## CONCLUSION

*H. armigera* (Hübner) and *S. exigua* (Hübner) cause serious damage to pepper plants in Armenia. These pests damage plants only in the larval stage.They feed on the vegetative and generative organs of the pepper plant. As a result of their nutrition, irregularly shaped scratches appear on the leaves, sometimes complete skeletonization of the leaf mass of the plant is observed. While feeding on fruits, they gnaw the flesh, open deep holes, enter them and feed on the seeds. As a result of the damage, the fruits rot and become unfit to use.

During the vegetation period of 2021-2023, the degree of damage of *H. armigera* (Hübner) and *S. exigua* (Hübner) on 7 different varieties of pepper was studied in the pepper fields of Khoronk community, during the period of intensive development of pests (June-August). According to the results of the experiments, Hayk variety was the most damaged by pests in all 3 years and Arevaham the least.

## ACKNOWLEDGEMENT

We express our gratitude to the Research Centre of Risk Assessment and Analysis in Food Safety Area of the RA Ministry of Economy, the Scientific Center of Vegetable and Technical Crops of the RA Ministry of Economy, the Armenia National Agrarian University and the farm of Khoronk community where the experiments were conducted.

### Conflict of interest

The authors declare that there is no competing interest.

## REFERENCES

Amit, Y., Ram, K. and Abhishek Y. (2022). Evaluation of insecticides and biopesticides against *Helicoverpa armigera* in different modules of short duration pigeonpea. Legume Research. 45(9): 1190-1193. doi: 10.18805/LR-4313.

Artokhin, K.S., Poltavskiy, A.N., Matov, A.Yu. and Shkurov, V.I. (2017). Noctuid moths - pests of agricultural crops and forest plantations. Publ. “Foundation”. - Rostov-Don. 376 p.

CABI. (2007). Crop Protection Compendium. Commonweath Agricultural Bureau, International. http://www.cabicompendium.org/.

Capinera, J. (2006). “Beet Armyworm (EENY-105)” (On-line). Featured Creatures. Accessed October 21, 2012 at http://edis.ifas.ufl.edu/in262.

Capinera, J.L. (2024). Beet armyworm, *Spodoptera exigua* (Hübner) (Insecta: Lepidoptera: Noctuidae). University of Florida’s Institute of Food and Agricultural Sciences Extension.

Chena, J., Jianga, W., Hua, H., Maa, X., Lia, Q., Songa, X., Rena, X. and Maa, Y. (2019). Joint toxicity of methoxyfenozide and lufenuron on larvae of Spodoptera exigua Hübner (Lepidoptera: Noctuidae). Journal of Asia-pacific Entomology. 22 (3): 795-801.

Cunningham, J.P. and Zalucki, M.P. (2014). Understanding heliothine (Lepidoptera: Heliothinae) pests: what is a host plant? J. Economic Entomology. 107: 881-965. doi: 10.1603EC14036.

Dalip, K.M. (2014). Biological Control Programme. Strengthening a national beet armyworm (Spodoptera exigua) management Programme in Jamaica. Food and Agriculture Organization of the United Nations. 18 p.

Eswara Reddy, S.G., Rana, Sh., Rana, A. and Kumar, R. (2021). Seasonal incidence and monitoring of *Helicoverpa armigera* Hübner on damask rose (*Rosa×damascena* Herrm.) by sex pheromone traps in western Himalaya (India). Journal of applied research on medicinal and aromatic plants. Volume 20.

Forecast of Occurrence and Accounting of Pests and Diseases of Agricultural Crops. (1958). Publishing House of the USSR Ministry of Agriculture. Moscow. 682p.

Ghazaryan, M.H. (2023.) Chemical control of *Helicoverpa armigera* and *Spodoptera exigua* and its effects on the qualitative indicators of peppers. SABRAO J. Breed. Genet. 55(5): 1713-1718. http://doi.org/10.54910/sabrao2023.55.5.23.

Greenberg, S.M., Sappington, T.W., Legaspi, B.C. and Setamou, M. (2001). Feeding and life history of *Spodoptera exigua* (Lepidoptera: Noctuidae) on different host plants. Annals of the Entomological Society of America 94: 566-575.

Guerrero, A., Malo E.A., Coll-Toledano, J. and Quero, C. (2014). Semiochemical and natural product-based approaches to control *Spodoptera* spp. (Lepidoptera: Noctuidae). Journal of Pest Science. 87: 231-247. doi: 10.1007/s10340-013-0533-7.

Hafeez, M., Ullah, F., Khan, M.M., Li, X., Zhang, Z., Shah, S., Imran, M., Assiri, M.A., Fernández-Grandon, G.M. and Desneux, N. (2021). Metabolic-based insecticide resistance mechanism and ecofriendly approaches for controlling of beet armyworm *Spodoptera exigua*: A review. Environ. Sci. Pollut. Res. 29: 1746-1762.

Han, J.H. , Jin, B.R. , Kim, J.J. and Lee, S.Y. (2014). Virulence of entomopathogenic fungi etarhizium anisopliae and Paecilomyces fumosoroseus for the microbial control of *Spodoptera exigua*. Mycobiology. 42(4): 385-390.

Hua, W., Zemerov, S. and Wason, E. (2013). “*Spodoptera exigua*” (On-line), Animal Diversity Web. Accessed June 14, 2024 at https://animaldiversity.org/accounts/Spodoptera_exigua/.

Karim, S. (2000). Management of *Helicoverpa armigera*: A Review and Prospectus for Pakistan. Pakistan Journal of Biological Sciences. 3: 1213-1222.

Krinski, D. and Godoy, A.G. (2015). First record of *Helicoverpa armigera* (Lepidoptera: Noctuidae) feeding on Plectranthus neochilus (Lamiales: Lamiaceae) in Brazil. Florida Entomol. 98(4): 1238-1240.

Kriticos, D.J., Ota, N., Hutchison, W.D., Beddow, J., Walsh, T., Tay, W.T., Borchert, D.M., Paula-Moreas, S.V., Czepak, C. and Zaluck, M.P. (2015). The Potential Distribution of Invading *Helicoverpa armigera* in North America: Is It Just a Matter of Time? PLOS ONE 10(7): e0133224.

Kumar, R., Chandel, R.S., Mehta, A. and Kalpana, H.S. (2020). *Spodoptera exigua* (Hübner), a newly emerging pest of potato in Himachal Pradesh. Indian Journal of Entomology. 82(4): 842-845.

Kuznetsov, V.I. (1999). Insects and mites are pests of agricultural crops. Volume III. Lepidoptera. Part 2. - St. Petersburg: Publishing house “Nauka”. 410 p.

Lammers, J.W. and MacLeod, A. (2007). Report of a Pest Risk Analysis: *Helicoverpa armigera* (Hübner, 1808). Plant Protection Service and Department for Environment, Food and Rural Affairs, Central Science Laboratory. 18 pp.

Mehrkhou, F., Mousavi, M. and Talebi, A.A. (2015). Effect of different Solanaceous host plants on nutritional indices of *Spodoptera exigua* (Lepidoptera: Noctuidae). Journal Crop Protection. 4 (3): 329-336.

Mehta, V., Jayaram, C.S., Koranga, R. and Negi, N. (2021). Developmental Biology of *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae) on Tomato under Mid hills (sub-humid) Conditions of India. Biological Forum-An International Journal 13(3a): 11-15.

Natwick, E., Stapleton, J. and Stoddard, C. (2012). “Armyworms” (On-line). UC Pest Management Guidelines. Accessed October 21, 2012 at http://www.ipm.ucdavis.edu/PMG/r116301311.html.

Navasero, M.M., Navasero, M.V., Candano, R.N. and De Panis, W.N. (2019). Comparative life history, fecundity and survival of *Spodoptera exigua* (Hübner) (LepidopterA: Noctuidae) on *Allium cepa* L. and other host plant in the Philippines. Philipp Ent. 33 (1): 75-86.

Pal, S. and Sarkar, I. (2009). Pests infesting ornamental plants in hilly region of West Bengal. The Journal of Plant Protection Sciences. 1(1): 98-101.

Pandey, A.S. and Das S.B. (2016). Evaluation of biopesticides against gram pod borer *Helicoverpa armigera* (HUB.) on pigeonpea. Legume Research. 39(3): 479-481. doi: 10.18805/lr.v0iOF.9484.

Pikushova, E.A. and Veretelnik, E.Y. (2009). Guidelines for educational practice in the course: “Plant protection” for 3rd year students. Krasnodar. 65 p.

Pogue, M. (2002). A World Revision of the Genus *Spodoptera* Guenée (Lepidoptera: Noctuidae). American Entomological Society: Philadelphia, PA, USA. 202 p.

Rabelo, M.M., Santos, I.B. and Paula-Moraes, S.V. (2022). *Spodoptera exigua* (Hubner) (Lepidoptera: Noctuidae) Fitness and Resistance Stability to Diamide and Pyrethroid Insecticides in the United States. Insects. 13(4): 365. doi: 10.3390/insects13040365.

Rajesh Chowdary, L., Suneel Kumar, G.V., Bharathi, S., Sarada, O., Nagaraju, Y., Keerthi, M.C. and Harish, G.N., (2024). Off-season survival and life history of beet armyworm, *Spodoptera exigua* (Hubner) on various host plants. *Sci Rep* 14, 13721. https://doi.org/10.1038/s41598-024-64639-8.

Rathore, L. S., Attri, S. D. and Jaswal, A. K. (2013). State level climate change trends in India. India Meteorological Department, New Delhi, pp 8-11.

Riaz, Sh., Johnson, J.B., Ahmad, M., Fitt, G.P. and Naiker, M. (2021). A review on biological interactions and management of the cotton bollworm, *Helicoverpa armigera* (Lepidoptera: Noctuidae). Journal of Applied Entomology: 145(6): 467-634.

Salvadori, J.R., Pereira P. R. V. da S. and Specht, A. (2013). *Helicoverpa armigera* no Sul. Cultivar Grandes Culturas. 176(15): 22-23.

Shankar, M., Ramesh Babu, T., Sridevi, D. and Sharma, H.C. (2014). Incidence and biology of beet armyworm, *Spodoptera exigua* in chickpea in Andhra Pradesh. Indian Journal of Plant Protection, 42(4): 324-332

Showler, A. (2001). *Spodoptera exigua* oviposition and larval feeding preferences for pigweed, *Amaranthus hybridus*, over squaring cotton, *Gossypium hirsutum* and a comparison of free amino acids in each host plant. Journal of Chemical Ecology. 27/10: 2013-2028.

Simon, S., Breeschoten, T., Jansen, H.J., Dirks, R.P., Schranz, M.E. and Ros, V.I. (2021). Genome and transcriptome analysis of the beet armyworm *Spodoptera exigua* reveals targets for pest control. G3 (Bethesda). Nov; 11(11): jkab311. doi: 10.1093/g3journal/jkab311.

Specht, A., Sosa-Gómez, D.R., Paula-Moraes, S.V. and Yano, S.A.C. (2013). Morphological and molecular identification of *Helicoverpa armigera* (Lepidoptera: Noctuidae) and expansion of its occurrence record in Brazil. Pesquisa Agropecuária. Brasileira 48: 689-692.

Suzana-Milan, C.S., Bruschi, L., Schaeffer, A.H., Fiorentin, F.J.R. and Salvadori, J.R. (2022). Feeding preference of *Helicoverpa armigera* larvae (Lepidoptera: Noctuidae) on vegetative and reproductive organs of soybean plants. Research, Society and Development. 11(4): e5311426 789. doi: 10.33448/rsd-v11i4.26789.

Tay, W.T., Soria, M.F., Walsh, T., Thomazoni, D., Silvie, P., Behere, G.T. anderson, G. and Downes, Sh. (2013). A Brave New World for an Old World Pest: *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Brazil. PLoS ONE 8(11): e80134. https://doi.org/10.1371/journal.pone.0080134.

Terlemezyan, H.L. and Ghazaryan, M.H. (2023). Control of *Spodoptera exigu*a which attacks pepper crop in Armenia using different chemical insecticides. Arab Journal of Plant Protection. 41(1): 37-39. https://doi.org/10.22268/AJPP-41.1.037039.

Thomas, C.S., Yoshida, M. and Peter, J. (1997). Survival, growth, fecundity and behavior of *Helicoverpa armigera* (Lepidoptera:Nocutidae) on pigeon pea and two wild Cajanus species. Journal of Economic Entomology 90(3): 837-841.

Ting, Y.C. (1986). An analysis on population fluctuation and damage characterization of cotton bollworm in cotton areas of north China. Acta Entomologica Sinica 29: 272-282.

Tripathi, V., Kumar, A., Singh, S., Singh, R., Baghel, K.S. and Pandey, A.K. (2023). Efficacy of new generation insecticides in comparison with biopesticides and their economics against chickpea pod borer (*Helicoverpa armigera* Hub.). Indian Journal of Agricultural Research. Volume 57(3): 394-398

Trujillo, D., Mastrangelo, T., Estevez de Jensen, C., Verle Rodrigues, J.C., Lawrie, R. and Massey, S.E. (2024). Accurate identification of *Helicoverpa armigera–Helicoverpa zea* hybrids using genome admixture analysis: implications for genomic surveillance. Front. Insect Sci. 4:1339143. doi: 10.3389/finsc.2024.1339143.

You, Y., An, C. and Li, C. (2020). Insect Feeding Assays with *Spodoptera exigua* on *Arabidopsis thaliana*. Bio Protoc. Mar 5;10(5): e3538. doi: 10.21769/BioProtoc.3538.

Zhang, J., Zhou S., Lin, Y., Liu, M., Wang, L. and Lyu Y. (2021). Determination of larval instars of *Spodoptera exigua* (Hübner). Acta Agriculturae Zhejiangensis. 33(6): 1035-1041.