Research article

Ecology Journal

ISSN (Print): 2957-4471, ISSN (Online): 2957-448X, Website: https://journal.esbangladesh.org
Ecol. J. (2026) 8 (1) : 45-51

Functional composition and prevalence of arthropod communities in sweet corn-soybean intercropping system in Gazipur, Bangladesh

Tamanna Tabassum Tonu, Md. Mamunur Rahman, Farhana Yeasmin[1], Ishrat Jahan Maliha, Priyanka Roy, Hania Binta Aslam and Md Ruhul Amin*

Department of Entomology, [1]Department of Agricultural Extension and Rural Development, Gazipur Agricultural University, Gazipur 1706, Bangladesh

***Corresponding e-mail:** mramin@gau.edu.bd

Received: 12 April 2026, revised: 23 April 2026, accepted: 25 April 2026, DOI: https: //doi.org/10.59619/ej.8.1.6

Abstract

Sweet corn-soybean intercropping is a promising strategy to enhance crop productivity while promoting ecological balance through natural pest regulation. This study assessed the prevalence and functional roles of arthropods-categorized as major and minor pests, predators, pollinators, and casual visitors in a sweet corn-soybean intercropping system (BU Sweet Corn-1) in Gazipur, Bangladesh. Weekly surveys were conducted across vegetative and reproductive stages, with arthropods recorded on ten randomly selected plants per plot. A total of nine pest species from five Orders were recorded. *Spodoptera frugiperda* was the major pest, present throughout all growth stages (V_1-R_6). Minor pests showed stage-specific occurrence: grasshoppers (Orthoptera) on leaves, tassels, and cobs; thrips, aphids, and whiteflies on leaves and tassels; cob-feeding pests including maize weevil, rice bug, and brown stink bug; and corn silk flies on tassels and cobs. Eight predator species-including ladybird beetles, rove beetles, wolf spiders, green lacewings, and odonates-were observed across various growth stages, supporting natural pest suppression. Six pollinator species, namely honeybees, carpenter bees, butterflies, and syrphid flies, visited primarily tassels and leaves, facilitating pollination. Casual visitors such as houseflies, horseflies, midge flies, blowflies, fruit flies, and mosquitoes contributed minimally to ecosystem services. Community composition showed major pests were the most abundant (44%), followed by predators (18%), minor pests and pollinators (15% each), and casual visitors (8%). Taxonomically, Lepidoptera dominated (20%), followed by Orthoptera (13%), Coleoptera (12%), Arachnida (10%), and Neuroptera (9%), with smaller contributions from Diptera (6%), Odonata (4%), and Hymenoptera (3%). The findings show a diverse arthropod community with pests and beneficial species coexisting, emphasizing the value of conserving natural enemies and pollinators in sweet corn–soybean intercropping for sustainable pest management.

Keywords: BU Sweet Corn-1, casual visitor, *Glycine max,* predator, pollinator, *Zea mays*

Introduction

Sweet corn (*Zea mays* var. *saccharata*) is a variety of maize grown for its tender, sweet kernels, harvested at the milk stage before full maturity. It is an economically and nutritionally important crop, with a short growing cycle (approximately 90-100 days) that allows farmers quicker returns, particularly in areas with limited water and arable land (Sahoo and Mohanty 2020). Globally, sweet corn cultivation supports millions of smallholder farmers, contributing to both income and food security (FAO 2024). In Bangladesh, sweet corn production reached 4,876 thousand metric tons in 2023–2024 (BBS 2024). Several varieties are cultivated to suit different climatic conditions and market demands, among which BU Sweet Corn-1 is highly favored due to its sweetness, tender kernels, and early maturity, with potential yields of up to 12 t ha^{-1} under optimal conditions (Amin *et al*. 2023). Corn is a facultative short-day plant that initiates flowering after accumulating adequate growing degree days. Being sensitive to cold, it is most suitable for spring cultivation (Karl 2012).

Sweet corn production, however, is heavily influenced by biotic and abiotic factors. Among biotic constraints, insect pests are the most critical, causing substantial yield losses. The sweet corn ecosystem hosts a diverse arthropod community, including major and minor pests, predators, pollinators, and casual visitors, each playing distinct functional roles. Sweet corn fields therefore represent a dynamic ecosystem where beneficial and harmful species interact, influencing both yield and ecological stability. In

Bangladesh, earlier studies documented 12 insect species infesting maize, with fall armyworm and stem borer identified as the primary pests (Amin *et al*. 2023). More recent surveys, however, reported seasonal variations: Roy *et al*. (2024) recorded seven species during the Rabi season, while Moon *et al*. (2024) observed 10 species in the Kharif season, with fall armyworm consistently emerging as the dominant pest.

Fall armyworm (*Spodoptera frugiperda*) is recognized as the major pest in Bangladesh, infesting all growth stages and damaging leaves, tassels, and cobs. Minor pests, including thrips, aphids, whiteflies, grasshoppers, maize weevils, and stink bugs, exhibit stage-specific occurrence, with sap-sucking insects predominating during vegetative stages and grain feeders appearing during cob development (Goergen *et al*. 2016, Prasanna *et al*. 2018). Infestation levels of fall armyworm on leaves have been reported to range from 9.2% to 43.9% between 70 and 80 days after sowing, demonstrating the threat posed by this pest (Moon *et al*. 2023).

Intercropping sweet corn with legumes, particularly soybean (*Glycine max*), is a promising agronomic practice that enhances both productivity and ecological sustainability. Soybean serves as a nitrogen-fixing crop, improves soil fertility, its presence within corn rows disrupts pest life cycles, reduces herbivore pressure, and provides habitat and floral resources for predators and pollinators (Aziz *et al*. 2011, Huber *et al*. 2022). Its canopy and root system create microhabitats that further support arthropod diversity, including spiders, predatory beetles, and pollinators, which in turn maintain natural pest suppression.

Studies indicate that cereal-legume intercropping increases arthropod diversity, predator abundance, and pollinator activity, supporting natural pest regulation and ecological balance (Gerezihar 2025). Therefore, the present study aimed to evaluate the effect of soybean intercropping on arthropod communities in sweet corn fields, documenting the abundance and functional composition of major and minor pests, predators, pollinators, and casual visitors across different growth stages. The findings provide insights into pest dynamics, beneficial arthropod conservation, and the potential of intercropping as a sustainable approach for sweet corn cultivation.

Materials and methods

Study site and climatic conditions: The experiment was conducted during the period of July 2024 to June 2025 in the experimental field of the Department of Entomology, Gazipur Agricultural University, Gazipur (25°25′ N, 89°05′ E), Bangladesh. The region has a tropical climate with distinct dry, rainy, and short winter seasons. The average temperature ranged from 12.7°C to 36.0°C, with a relative humidity of 65.8% and an annual rainfall of 237.6 cm (Amin *et al*. 2015). Sweet corn seeds (variety BU Misti Vutta-1) were collected from the Department of Entomology, and soybean seeds (variety BU Soybean-2) from the Department of Agronomy, Gazipur Agricultural University. Both crops were sown on 2nd December 2024, with soybean intercropped between sweet corn rows. Experimental plots of 3 m × 3 m, with 1 m spacing between plots and blocks. Sweet corn plants were spaced 25 cm apart, with 60 cm between rows, and soybean seeds were arranged in alternating rows within the intercrop system. Routine intercultural practices, including irrigation, weeding, and thinning, were performed as required, with additional irrigation during tasseling and cob development. Fertilizer application was done following the Fertilizer Recommendation Guide (Ahmed *et al*. 2018).

Observation of sweet corn growth stages: Corn growth was divided into vegetative (V) and reproductive (R) phases. Vegetative stages included: V_E, when the coleoptile emerges through the soil; V_1, when the lowest leaf shows a visible collar; V_3, with three leaf collars and reliance on photosynthesis; V_7, with seven leaf collars and rapid vegetative growth; V_{10}, with ten leaf collars and a rapidly elongating stalk; and V_T, when the tassel's final branch is visible. Reproductive stages were: R_1, silk emergence from the husk; R_2, white, blister-shaped kernels; R_3, yellow kernels containing milky fluid; R_4, dough-like starch in kernels; R_5, dented kernels; and R_6, when all kernels reach maximum dry weight, indicating physiological maturity (Zhao *et al*. 2012).

Observation of arthropod prevalence: After seedling emergence, weekly field surveys were conducted to monitor arthropod populations. Species were identified using Taxonomic Keys and Google Camera and counted through direct visual observation. In each survey, ten plants were randomly selected per plot, and the abundance of insects and spiders on various vegetative and reproductive stages was recorded. The mean number of arthropods per plant was then calculated for each species.

Results and discussion

The pest complex in the sweet corn-soybean intercropping system included one major pest and several minor pests, with occurrence varying across crop growth stages (Table 1). *Spodoptera frugiperda* (Lepidoptera: Noctuidae) was identified as the major pest, as it infested the crop continuously from seedling (V_1-V_2) to reproductive stages (R_1-R_6), affecting leaves, tassels, and cobs. In contrast, minor pests showed stage-specific occurrence: grasshopper was present during vegetative to early reproductive stages (V_3-R_2); sap-sucking insects such as thrips, whitefly, and aphid were observed from V_3 to R_2; and cob-feeding pests including maize weevil, brown stink bug, and rice bug were recorded mainly during reproductive stages (R_3-R_6). The continuous occurrence of *S. frugiperda* across all growth stages is due to its polyphagy, high reproductive potential, and strong dispersal ability. In contrast, minor pests showed stage-specific patterns influenced by plant phenology and resource availability, with sap-suckers dominating vegetative stages and grain feeders appearing during cob development (Goergen *et al*. 2016, Prasanna *et al*. 2018).

Eight predator species were identified in sweet corn fields which are enlisted in Table 2, along with their taxonomy and occurrence across growth stages. Coleopteran predators, including *Coccinella septempunctata* (ladybird beetle) and *Staphylinus* spp. (rove beetle), were observed primarily on leaves and tassels, with rove beetles occurring throughout all growth stages (V_E-R_6). Arachnid predators such as *Lycosa* spp. (wolf spider) were present on leaves, tassels, and cobs, showing activity from vegetative to reproductive stages. Neuropterans like *Chrysoperla carnea* (green lacewing) were mainly recorded during V_3-R_2 stages. Odonates- such as *Anax junius* (darner dragonfly), *Ictinogomphus rapax* (clubtail dragonfly), *Agriocnemis* spp. (narrow-winged damselfly), and *Lestes* sp. (spread-winged damselfly) were consistently present across all growth stages, indicating their continuous predatory role from germination to maturity. The prevalence of these predators is strongly linked to the availability of prey

Table 1. List of the major and minor pests prevailed in sweet corn field intercrop with soyabean

Pest	Taxonomic position	Prevalence (growth stage)
Major pest Fall armyworm	*Spodoptera frugiperda* (Lepidoptera: Noctuidae)	Seedling (V_1-V_2), Leaf (V_3-V_7), Tassel (R_1-R_2), Cob (R_3-R_6)
Minor pest		
Grasshopper	*Schistocerca americana* (Orthoptera: Acrididae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Maize weevil	*Sitophilus zeamais* (Coleoptera: Curculionidae)	Cob (R_5-R_6)
Corn silk fly	*Euscepes postfasciatus* (Coleoptera: Curculionidae)	Tassel (R_1-R_2), Cob (R_3-R_6)
Thrips	*Frankliniella spp.* (Thysanoptera: Thripidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Whitefly	*Bemisia tabaci* (Hemiptera: Aleyrodidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Aphid	*Aphis gossypii* (Hemiptera: Aphididae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Brown sting bug	*Halyomorpha halys* (Hemiptera: Pentatomidae)	Cob (R_3-R_6)
Rice bug	*Leptocorisa acuta* (Hemiptera: Alydidae)	Cob (R_3-R_6)

Development stages are Germination (V_E), Vegetative Stages (V_1–V_n), and Reproductive Stages (R_1–R_6). The reproductive stages include: R_1 (Silking), R_2 (Blister), R_3 (Milk), R_4 (Dough), R_5 (Dent), and R_6 (Maturity).

Table 2. List of the predators prevailed in sweet corn field intercrop with soyabean

Predators	Taxonomic position	Prevalence (growth stage)
Ladybird beetle	*Coccinella septempunctata* (Coleoptera: Coccinellidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Rove beetle	*Staphylinus spp.* (Coleoptera: Staphylinidae)	All stages (V_E-R_6)
Wolf spider	*Lycosa spp* (Arachnida: Lycosidae)	Leaf (V_3-V_7), Tassel (R_1-R_2), Cob (R_3-R_6)
Green lacewing	*Chrysoperla carnea* (Neuroptera: Chrysopidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Darner dragonfly	*Anax junius* (Odonata: Aeshnidae)	All stages (V_E-R_6)
Clubtail dragonfly	*Ictinogomphus rapax* (Odonata: Gomphidae)	All stages (V_E-R_6)
Narrow winged damselfly	*Agriocnemis spp* (Odonata: Coenagrionidae)	All stages (V_E-R_6)
Spread winged damselfly	*Lestes* sp. (Odonata: Lestidae)	All stages (V_E-R_6)

Development stages are Germination (V_E), Vegetative Stages (V_1–V_n), and Reproductive Stages (R_1–R_6). The reproductive stages include: R_1 (Silking), R_2 (Blister), R_3 (Milk), R_4 (Dough), R_5 (Dent), and R_6 (Maturity).

and habitat structure within the intercropping system. Generalist predators such as ladybird beetles and green lacewings feed on early-stage pests like aphids and thrips, explaining their activity during vegetative and early reproductive stages. Spiders and Odonates, which can capture both flying and ground-dwelling insects, maintain presence throughout the crop cycle, providing continuous biological control (Retallack 2019).

Table 3 summarizes the pollinators observed in sweet corn fields, including their taxonomy and occurrence across growth stages. Hymenopterans such as the honeybee (*Apis mellifera*) and carpenter bee (*Xylocopa violacea*), were recorded visiting tassels during silking and blister stages (R_1-R_2), facilitating pollen transfer. Lepidopterans, such as the sulphur butterfly (*Colias philodice*) and swallowtail butterfly (*Papilio polytes*), also visited tassels at the same reproductive stages. Among Dipterans, syrphid flies (*Helophilus* sp.) were observed on leaves during V_3-V_7 and tassels during R_1-R_2, contributing both to pollination and predation of soft-bodied insect pests. The occurrence of pollinators primarily during tasseling aligns with the peak availability of exposed pollen and nectar, which serve as key foraging resources. Hymenopterans are particularly effective due to their foraging behavior and flower fidelity, while butterflies provide supplementary pollen transfer. Syrphid flies, support both pollination and biological control, enhancing ecosystem services in the intercropping system. Such stage-specific activity is consistent with studies highlighting that pollinator visits in maize peak during silking to early blister stages when floral resources are abundant (Garibaldi *et al*. 2013).

Table 3. List of the pollinator insects prevailed in sweet corn field intercrop with soyabean

Pollinator	Taxonomic Position	Prevalence (growth stage)
Honeybee	*Apis mellifera* (Hymenoptera: Apidae)	Tassel (R_1-R_2)
Carpenter bee	*Xylocopa violacea* (Hymenoptera: Apidae)	Tassel (R_1-R_2)
Sulphur butterfly	*Colias philodice.* (Lepidoptera: Pieridae)	Tassel (R_1-R_2)
Swallow tail butterfly	*Papilio polytes* (Lepidoptera: Papilionidae)	Tassel (R_1-R_2)
Syrphid fly	*Helophilus* sp. (Diptera: Syrphidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)

Development stages are Germination (V_E), Vegetative Stages (V_1–V_n), and Reproductive Stages (R_1–R_6). The reproductive stages include: R_1 (Silking), R_2 (Blister), R_3 (Milk), R_4 (Dough), R_5 (Dent), and R_6 (Maturity).

Table 4 lists casual visitors observed in sweet corn fields, including their taxonomy and presence across growth stages. Dipteran visitors included houseflies (*Musca domestica*), horseflies (*Tabanus* spp.), midge flies (*Cecidomyiidae* spp.), blowflies (*Calliphora* spp.), fruit flies (*Drosophila* spp.), and mosquitoes (*Culex* spp.), with some species occurring throughout all crop stages (V_E-R_6) and others limited to leaves and tassels (V_3-R_2). Hymenopteran ants (*Formicidae* spp.) were observed on leaves (V_3-V_7) and cobs (R_3-R_6). These casual visitors are primarily attracted by floral resources, nectar, or decomposing matter but do not contribute significantly to pest control or pollination in maize. Their presence reflects the general arthropod diversity in intercropping systems and can indirectly influence ecosystem dynamics through competition or incidental interactions with pests and natural enemies (Retallack, 2019).

The distribution of organisms in a sweet corn field are shown in Figure 1, with major pests (44%) being the most abundant, followed by predators (18%), minor pests (15%), pollinators (15%), and casual visitors (8%). Major pests like fall armyworm (*Spodoptera frugiperda*) cause the most damage, while minor pests such as grasshoppers have a lesser impact. Beneficial organisms, including predators like ladybird beetles (*Coccinella septempunctata*) and pollinators like honeybees (*Apis mellifera*), play important roles in pest control and yield improvement. Casual visitors such as horseflies (*Tabanus spp.*) have minimal influence. Beneficial organisms collectively constituted a substantial portion of the arthropod community. Predators such as ladybird beetles and wolf spiders contribute to natural pest suppression, while pollinators including honeybees and syrphid flies provide ecosystem services during tasseling. Such patterns align with evidence that cereal–legume intercropping significantly enhances beneficial arthropod abundance (predators, parasitoids, and pollinators) and concurrently reduces pest populations compared with monoculture systems (Gerezihar 2025).

The relative abundance of insect groups in the sweet corn–soybean intercropping system are illustrated in Figure 2. Lepidopterans were the most abundant group (20%), reflecting the higher presence of moths and butterflies, including the major pest *Spodoptera frugiperda*. Orthoptera (13%) and Coleoptera (12%) were also prominent, while sap-sucking insects such as Thysanoptera (12%) and Hemiptera (11%) contributed substantially to the pest complex. Beneficial predators were well represented, with Arachnida (10%) and Neuroptera (9%) providing natural pest control, whereas Diptera (6%), Odonata (4%), and Hymenoptera (3%) comprised smaller proportions of the community. The observed distribution highlights a complex insect assemblage with both pests and natural enemies, reflecting the structural and ecological benefits of intercropping. The dominance of lepidoptera, particularly fall armyworm, underscores the need for integrated management strategies targeting multiple growth stages. Simultaneously, the presence of predatory and pollinating taxa demonstrates the potential of natural biological control, which can reduce reliance on chemical insecticides and support sustainable pest management (Gerezihar 2025).

Table 4. List of the casual visitor insects prevailed in sweet corn field intercropping with soyabean

Casual Visitor	Taxonomic Position	Prevalence (growth stage)
Housefly	*Musca domestica* (Diptera: Muscidae)	(V_E–R_6)
Horsefly	*Tabanus spp.* (Diptera: Tabanidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Midge fly	*Cecidomyiidae spp.* (Diptera: Cecidomyiidae)	Leaf (V_3-V_7), Tassel (R_1-R_2)
Blowfly	*Calliphora spp.* (Diptera: Calliphoridae)	(V_E–R_6)
Ant	*Formicidae spp* (Hymenoptera: Formicidae)	Leaf (V_3-V_7), Cob (R_3-R_6)
Fruit fly	*Drosophila spp.* (Diptera: Drosophilidae)	(V_E–R_6)
Mosquito	*Culex spp.* (Diptera: Culicidae)	(V_E–R_6)

Development stages are Germination (V_E), Vegetative Stages (V_1–V_n), and Reproductive Stages (R_1–R_6). The reproductive stages include: R_1 (Silking), R_2 (Blister), R_3 (Milk), R_4 (Dough), R_5 (Dent), and R_6 (Maturity).

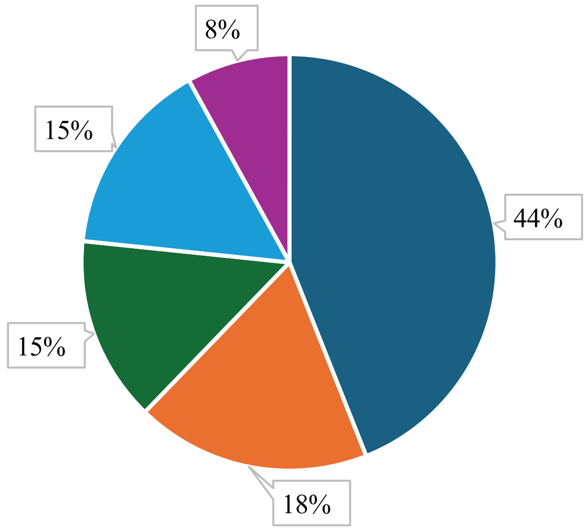

Figure 1. Abundance (%) of major pest, minor pest, predators, pollinators and casual visitor insect found in sweet corn field intercrop with soybean.

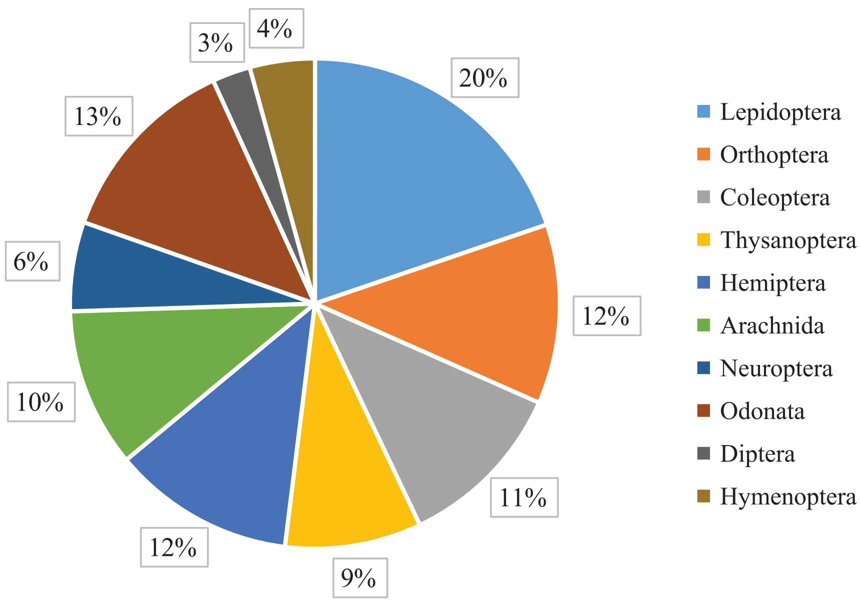

Figure 2. Abundance (%) of insects belonging to different taxonomic orders found in sweet corn field intercrop with soyabean.

Conclusion

The study revealed that sweet corn–soybean intercropping supports a diverse arthropod community. Major pests accounted for 44% of the total arthropod population, with fall armyworm dominating across all growth stages from seedling to maturity. Minor pests contributed 15%, appearing mainly during specific stages, such as grasshoppers (V_3-R_2) and cob-feeding bugs (R_3-R_6). Predators made up 18% of the community, with ladybird beetles, wolf spiders, and odonates providing continuous pest suppression. Pollinators represented 15%, primarily active during tasseling (R_1-R_2), including honeybees, carpenter bees, butterflies, and syrphid flies. Casual visitors accounted for 8% and had minimal impact on pest dynamics. Intercropping maintained a balanced arthropod community, where beneficial predators and pollinators helped regulate pests and support ecosystem services. The observed abundance and functional composition highlight the potential of intercropping to reduce pest pressure and enhance sustainable sweet corn production through natural biological control.

Acknowledgement

This study was funded by the National Science and Technology (NST) Fellowship under the Ministry of Science and Technology, Government of Bangladesh. The authors sincerely appreciate this support.

References

Ahmed M, Rahman M, Hossain M and Karim S. 2018. Fertilizer recommendation guide-2018. Bangladesh Agricultural Research Council (BARC).

Amin MR, Miah MRU, Afroz M and Moon TT. 2023. BU Misti Vutta 1. Leaflet (In Bengali). Department of Entomology, GAU, Gazipur, Bangladesh.

Amin MR, Namni S, Miah MRU, Miah MG, Zakaria M, Suh SJ and Kwon YJ. 2015. Insect inventories in a mango- based agroforestry area in Bangladesh: foraging behavior and performance of pollinators on fruit set. Entomological Research. 45: 217-224.

Aziz MA, Rahman AKMM, Chakma R, Ahmed M and Ahsan AFMS. 2011. Performance of BARI hybrid maize varieties in the hilly areas of Bangladesh. Journal of Experimental Biosciences. 2: 25-28.

BBS (Bangladesh Bureau of Statistics). 2024. Yearbook of Agricultural Statistics of Bangladesh 2024. Statistics and Informatics Division, Ministry of Planning, Dhaka, Bangladesh.

FAO Food and Agriculture Organization. 2024. Global corn production and trade statistics for the 2023-24 marketing year.

Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, Cunningham SA, et al. 2013. Wild pollinators enhance fruit set of crops regardless of honey bee abundance. Science. 339: 1608–1611.

Gerezihar MA. 2025. Evaluating the effect of intercropping on arthropod abundance, weed suppression and crop performance. SLU, Department of Biosystems and Technology. A2E: Alnarp.

Goergen G, Kumar PL, Sankung SB, Togola A and Tamo M. 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* in West and Central Africa. PLoS One. 11: e0165632.

Huber C, Zettl F, Hartung J and Lindenlauf MM. 2022. The impact of maize-bean intercropping on insect biodiversity. Basic and Applied Ecology. 61: 1-9.

Karl JR. 2012. The maximum height of the maize subspecies: data. Maize. 86:1-11.

Moon TT, Miah MRU, Islam MT, Afroz M and Amin MR. 2023. Fall armyworm infestation on the performance of sweet corn varieties. Ecology Journal. 5: 91-97.

Moon TT, Miah MRU, Islam MT, Afroz M and Amin MR. 2024. Foraging insects on sweet corn plants at Gazipur in Bangladesh. Journal of Entomological Research. 48: 408-412.

Prasanna BM, Huesing JE, Eddy R and Peschke VM. 2018. Fall armyworm in Africa: A guide for integrated pest management. CIMMYT, Mexico.

Retallack MJ. 2019. The potential functional diversity offered by native insectary plants to support populations of predatory arthropods in Australian vineyards. PhD Thesis, University of Adelaide.

Roy CK, Hossain MS, Karim MA and Amin MR. 2024. Diversity of insects in insecticide treated sweet corn ecosystem. Ecology Journal. Vol. 213-218.

Sahoo SC & Mohanty M. 2020. Performance of sweet corn under different fertility levels-A review. International Journal of Current Microbiology and Applied Sciences. 9: 3325-3331.

Zhao X, Tong C, Pang X, Wang Z, Guo Y, Du F and Wu R. 2012. Functional mapping of ontogeny in flowering plants. Briefings in Bioinformatics. 13: 317-328.