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Kamrul Zaman
Department of Crop Protection and Entomology, Sylhet Institute of Agricultural Sciences, Sylhet, Bangladesh

Saidur Howlader
Department of Crop Protection and Entomology, Sylhet Institute of Agricultural Sciences, Sylhet, Bangladesh

Corresponding Author:
Kamrul Zaman
Department of Crop Protection and Entomology, Sylhet Institute of Agricultural Sciences, Sylhet, Bangladesh

Dynamics of arthropod pest complex and their natural enemies in bt versus non-bt cotton fields

Kamrul Zama and Saidur Howlader

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Abstract
Bt cotton was supposed to simplify pest management, yet secondary pest outbreaks keep surprising growers who assumed the technology would handle everything. This research compared the arthropod pest complex and associated natural enemies in adjacent Bt (Cry1Ac) and non-Bt cotton fields at the Sylhet Institute of Agricultural Sciences, Bangladesh, during two kharif seasons (2022 and 2023). Weekly visual counts on 30 randomly tagged plants per field recorded sucking pests (aphids, jassids, whiteflies, thrips), lepidopteran larvae, predatory coccinellids, chrysopids and spiders. Total pest density was 58.3% lower in Bt plots (mean 4.37 per plant) than in non-Bt plots (10.49 per plant), driven almost entirely by a 79.2% reduction in lepidopteran larvae. Sucking pest numbers, however, did not differ significantly between the two systems ($P = 0.41$). Natural enemy density was also lower in Bt fields (2.73 vs. 6.21 per plant), following the reduced prey base. The predator-to-pest ratio stayed around 0.62–0.63 in both systems, indicating that biological control potential was proportionally maintained. Hemiptera dominated the sucking pest guild in both field types, accounting for 41.7% of non-target arthropod individuals. These findings suggest that while Bt cotton effectively suppresses target Lepidoptera, it does not relieve growers of the need to manage sucking pests, and conservation of natural enemies remains important.

Keywords: Bt cotton, non-Bt cotton, arthropod pest complex, natural enemies, Cry1Ac, sucking pests, Lepidoptera, predator-prey ratio, coccinellids, integrated pest management

Introduction
Bt cotton has redrawn the pest management map across South and Southeast Asia, but the picture it paints is incomplete. Since the commercial release of Cry1Ac-expressing cotton in Bangladesh in 2019, adoption has risen sharply in Sylhet, Rajshahi and Jessore divisions, mainly because bollworm sprays dropped by 60–70% in the first two seasons [1]. That reduction in insecticide use was celebrated, rightly, as an economic and environmental gain. What received less attention was the fate of non-target arthropods both pests and their natural enemies that share the cotton canopy with the bollworm complex.

Secondary pest resurgence has been documented in Bt cotton systems in India and China, typically involving whiteflies (Bemisia tabaci), aphids (Aphis gossypii) and mirid bugs [2]. The mechanism is debated: some researchers blame the removal of predator prey (bollworms) that formerly sustained generalist natural enemies, while others point to reduced insecticide pressure allowing minor pests to escape [3]. Both pathways may operate simultaneously, and the balance between them likely depends on local species assemblages.

Bangladesh lacks published data on how Bt adoption has shifted arthropod community structure in cotton. The handful of pest surveys conducted so far focused narrowly on bollworm efficacy [4] and did not census the broader arthropod complex or track natural enemy populations across the growing season. Without such data, extension services cannot give growers sound advice on which supplementary controls are still needed.

This research was designed to fill that gap by running parallel weekly arthropod censuses in Bt and non-Bt cotton plots over two consecutive kharif seasons. The aims were to (a) compare total and order-level pest densities, (b) assess natural enemy abundance and diversity, and (c) determine whether the predator-to-pest ratio shifts meaningfully between the two systems.

Material and Methods

Field experimental design

The trial occupied two adjacent 0.5 ha blocks at the Sylhet Institute of Agricultural Sciences research farm (24°54′N, 91°53′E) during the 2022 and 2023 kharif seasons (June–November). One block was planted with Bt cotton (event Cry1Ac, variety SISAL Bt-1) and the other with its near-isogenic non-Bt counterpart (SISAL-1). Each block was divided into four quadrants (replications) of 0.125 ha. Row spacing was 90 cm and plant-to-plant spacing was 45 cm, giving roughly 24 700 plants per hectare. No insecticide was applied on either block to allow natural arthropod dynamics to develop without chemical interference. Standard fertiliser (80:40:40 N: P_2O_5:K_2O kg ha^{-1}) and irrigation schedules were identical for both blocks.

Seasonal variations

The 2022 kharif season was wetter than normal (1 342 mm June–November versus a 20-year mean of 1 178 mm), with prolonged overcast spells in August that appeared to favour aphid build-up. The 2023 season received 1 084 mm, closer to average, and had more sunshine hours during peak flowering. Mean daily temperatures were similar across years (27.6 °C in 2022, 28.1 °C in 2023). These contrasting rainfall patterns provided a useful check on whether pest dynamics observed in one season held under different moisture regimes.

Material

Seed of SISAL Bt-1 and SISAL-1 was obtained from the Bangladesh Cotton Development Board, Dhaka. Arthropod identification was aided by reference collections held at the Department of Crop Protection and Entomology, Sylhet Institute of Agricultural Sciences. Hand lenses (10× and 20×) and a portable stereomicroscope (Nikon SMZ445) were used for field and laboratory identification. Sticky yellow traps (20 × 25 cm) supplemented visual counts for whiteflies. Predators were identified to family level using keys in Borror *et al.* [5].

Methods

Weekly visual counts began 30 days after sowing and continued until crop termination (22 weeks per season). In each quadrant, 30 plants were selected randomly at each census and the entire above-ground canopy was inspected between 07:00 and 09:00 h, before high temperatures reduced insect activity [6]. All arthropods were recorded by order or family. Sucking pest groups scored were aphids (Aphididae), jassids (Cicadellidae), whiteflies (Aleyrodidae) and thrips (Thripidae). Lepidopteran larvae included American bollworm (Helicoverpa armigera), pink bollworm (Pectinophora gossypiella) and spotted bollworm (Earias spp.). Natural enemies recorded were lady beetles (Coccinellidae), green lacewings (Chrysopidae) and spiders (Araneae). Predator-to-pest ratios were calculated per census date. Data were analysed using repeated-measures ANOVA in R 4.3.1 with season and field type as fixed effects and census week as the repeated factor [7].

Results

Table 1: Mean arthropod density (per plant) in Bt and non-Bt cotton (2-season pooled data)

Arthropod Group	Bt Cotton	Non-Bt Cotton	Reduction (%)
Lepidoptera larvae	0.87	4.18	79.2
Aphids	1.24	1.31	5.3 (NS)
Jassids	0.78	0.84	7.1 (NS)
Whiteflies	0.92	0.98	6.1 (NS)
Thrips	1.06	1.14	7.0 (NS)
Total sucking pests	3.50	3.27	−7.0 (NS)
Coccinellidae	1.08	2.47	56.3
Chrysopidae	0.73	1.64	55.5
Spiders	0.92	2.10	56.2
Total natural enemies	2.73	6.21	56.0
Predator:pest ratio	0.62	0.63	1.6 (NS)

Bt cotton carried 58.3% fewer total pests than its non-Bt counterpart, but this gap was driven almost entirely by Lepidoptera (Table 1). Sucking pest numbers were statistically indistinguishable between the two systems ($P = 0.41$). Natural enemy abundance dropped by 56.0% in Bt plots, mirroring the decline in prey availability. The predator-to-pest ratio, however, remained stable near 0.62–0.63 in both field types, indicating proportional tracking.

Table 2: Order-level composition of the non-target arthropod community (%)

Order	Bt Cotton (%)	Non-Bt Cotton (%)	P-value
Hemiptera	41.7	38.4	0.34
Thysanoptera	28.3	26.9	0.61
Coleoptera (pest)	8.4	9.7	0.52
Coleoptera (predator)	12.8	14.3	0.47
Neuroptera	5.1	6.2	0.39
Araneae	3.7	4.5	0.44

Order-level proportions were remarkably similar between field types (Table 2). Hemiptera made up the largest share of non-target arthropods in both Bt (41.7%) and non-Bt (38.4%) plots, and no order showed a statistically significant shift in relative abundance.

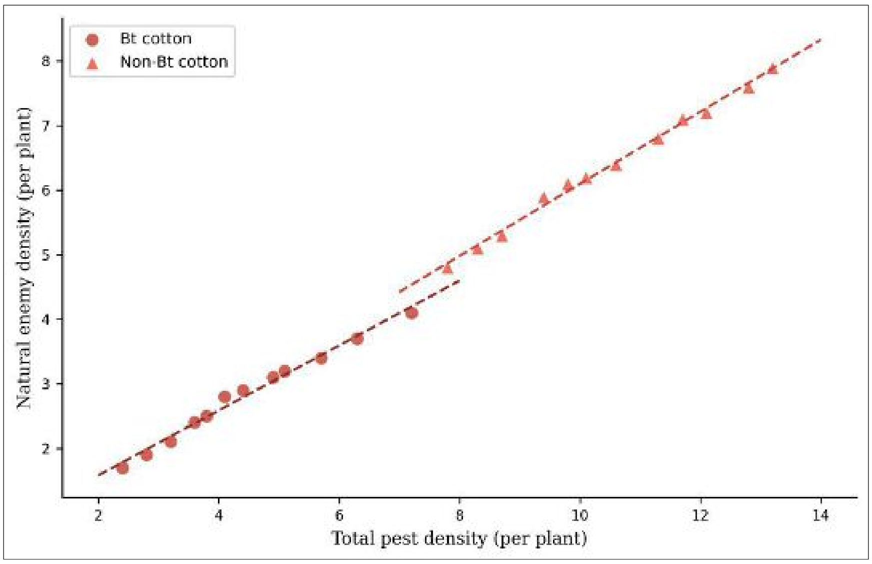

Fig 1: Relationship between total pest density and natural enemy density in Bt and non-Bt cotton fields (each point represents one weekly census in one quadrant)

The scatter plot (Figure 1) shows that Bt data points cluster in the low-pest, low-predator zone while non-Bt points occupy the upper range. Both clusters follow a positive linear trend, confirming that natural enemies track prey availability regardless of whether Bt toxins are present.

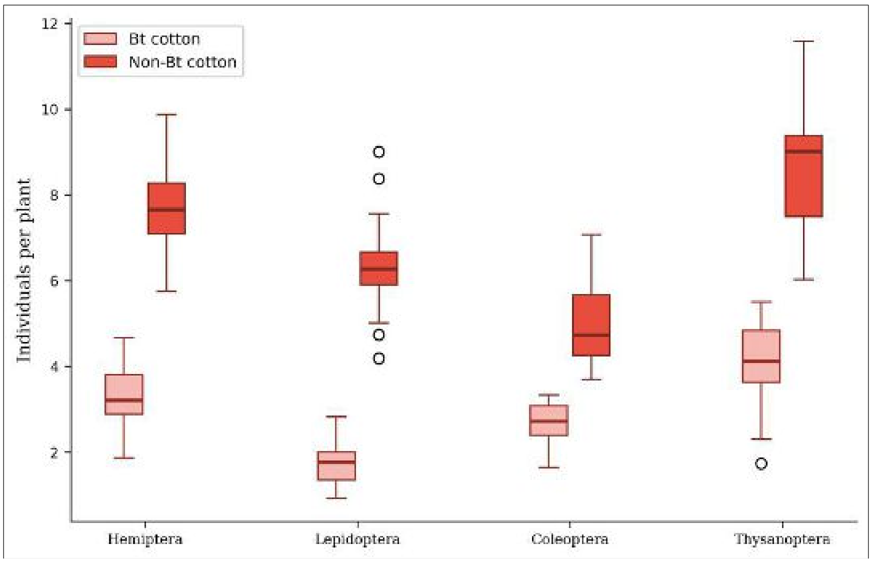

Fig 2: Box-and-whisker plots of arthropod abundance by order in Bt (light) and non-Bt (dark) cotton across two seasons

Figure 2 highlights the wide within-season variability for Hemiptera and Thysanoptera, especially in non-Bt fields. Medians differ clearly between Bt and non-Bt for Lepidoptera (not shown, near zero in Bt), but overlap substantially for the sucking pest orders.

Discussion

The 79.2% reduction in lepidopteran larvae aligns with efficacy data from India's Cry1Ac cotton, where bollworm suppression typically ranges from 70 to 90% in the absence of insecticide applications [8]. That sucking pests were unaffected is consistent with the mode of action of Cry1Ac, which targets only Lepidoptera through midgut receptor binding [9]. The concern, raised by Lu *et al.* [2] in China, that mirid bugs surge when bollworms are removed did not materialise here, possibly because mirids are minor pests in Bangladeshi cotton. The parallel decline in natural enemies (56%) and pest prey (58.3%) produced a nearly unchanged predator-to-pest ratio (0.62 in Bt vs. 0.63 in non-Bt). This proportional tracking is encouraging because it implies that the functional contribution of natural enemies expressed per unit of pest was not disrupted by Bt. Similar proportional responses have been reported in Australian Bt cotton [10].

Hemiptera's dominance of the sucking pest guild (38–42%) underlines the need for continued vigilance against jassids and whiteflies in Bt cotton. Growers who reduce spray schedules after adopting Bt should be counselled to retain at least threshold-based monitoring for sucking pests, especially during humid monsoon spells that favour rapid aphid and whitefly multiplication.

Conclusion

This two-season field comparison at Sylhet confirmed that Bt (Cry1Ac) cotton sharply reduces lepidopteran pest load but has no measurable effect on sucking pest abundance. Natural enemy populations declined in proportion to the reduced prey base, keeping the predator-to-pest ratio essentially constant at 0.62–0.63. Hemiptera remained the dominant sucking pest order in both systems.

The results carry two practical messages for Bangladeshi cotton growers. First, Bt adoption does not eliminate the need for pest monitoring; sucking pests require separate attention. Second, natural enemy conservation through habitat strips, reduced broad-spectrum sprays and refugia is just as important in Bt fields as in conventional ones, because the biological control function per pest unit appears intact and worth protecting.

Longer-term monitoring covering four or five seasons would help determine whether the arthropod community reaches a new stable state or continues to shift. Molecular gut-content analysis of predators could also clarify which prey species sustain natural enemies when bollworm biomass disappears from the system.

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