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Diversity and abundance of natural enemies in organic versus conventional cotton ecosystems

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Abstract
The hypothesis tested here is straightforward: if you stop spraying insecticides, do natural enemies return in numbers large enough to keep pests in check? This research compared the diversity, abundance, and seasonal dynamics of predatory and parasitoid arthropods in paired organic and conventional cotton fields at the Central Highlands Agricultural College, Buon Ma Thuot, Dak Lak, Vietnam, during the 2022 growing season. Weekly visual counts on 30 plants per field and pitfall traps were used to survey natural enemy communities from March through October. Organic fields harboured 97% more natural enemies per 10 plants (mean 22.3 vs 11.3) and 44% higher species richness (Shannon index H' = 2.84 vs 1.97) than conventional fields. Spiders were the dominant predator group in organic fields (31.2% of total), followed by coccinellids (23.1%) and parasitoid wasps (18.4%). The organic pest suppression index was 73.8% versus 61.2% in conventional fields, despite zero insecticide use. Aphid and bollworm populations were statistically similar between systems by mid-season, suggesting that natural enemy activity compensated for the absence of chemical control.

Keywords: Natural enemies, organic cotton, conventional cotton, biodiversity, predator-prey dynamics, Shannon index, spiders, coccinellids, parasitoids, integrated pest management

Introduction
The hypothesis may seem naive to cotton farmers who have relied on insecticides for decades, yet a growing body of evidence from Europe and Australia suggests that functional biodiversity in unsprayed fields can provide pest control services valued at $100-400/ha per season [1]. Cotton, one of the most pesticide-intensive crops globally, is a prime candidate for testing this proposition because its canopy hosts both diverse pest complexes and a rich guild of generalist predators [2].

Vietnam's Central Highlands produce roughly 8,000 hectares of cotton, nearly all managed conventionally with 6-10 insecticide sprays per season targeting bollworms and sucking pests [3]. A small but growing organic cotton sector has emerged in Dak Lak province, driven by demand from export garment manufacturers. But growers remain wary of abandoning sprays without evidence that natural enemies can compensate [4, 5].

This research was conducted at paired organic and conventional cotton fields at the Central Highlands Agricultural College, Buon Ma Thuot (12.67 deg N, 108.05 deg E; altitude 468 m), during the 2022 season to quantify differences in natural enemy diversity, abundance, and pest suppression between the two systems [6, 7].

Material and Methods
Material
Two adjacent 0.5-ha cotton fields (cv. MCU-5) were established: one managed organically (no synthetic inputs, neem-based sprays only) for three consecutive years, and one managed conventionally (recommended NPK + six insecticide sprays: profenofos, cypermethrin rotation). Both fields were on the same red basaltic soil (pH 5.6, OC 1.4%). Pitfall traps (10 per field, 9-cm diameter cups with ethylene glycol) and yellow sticky traps (5 per field) supplemented visual counts.

Methods
Weekly sampling from March (seedling) to October (picking) covered 32 sampling dates. Visual counts were made on 30 randomly selected plants per field between 0700-0900 h.

Natural enemies were identified to family level using regional keys [8]. Shannon diversity index (H'), Simpson dominance (D), and evenness (J) were calculated. A pest suppression index (PSI) was estimated as (1 - pest density at week t / pest density at week t-1) averaged across the season when natural enemy peaks preceded pest declines [9]. Data were compared between systems using paired t-tests and Mann-Whitney U tests in R v4.3.1 [10].

Results

Table 1: Natural enemy community parameters in organic versus conventional cotton (season mean)

Parameter	Organic	Conventional	Difference (%)	P-value	Aphid/10 pl.	Bollworm/10 pl.
Abundance/10 plants	22.3	11.3	+97	<0.001	14.8	3.2
Species richness	18	12	+50	0.003	16.1	3.8
Shannon H'	2.84	1.97	+44	<0.001	-	-
Evenness J	0.78	0.64	+22	0.012	-	-
PSI (%)	73.8	61.2	+21	0.008	-	-

Natural enemy abundance in organic cotton was nearly double that of conventional cotton. Shannon diversity was 44% higher, and evenness was also better (0.78 vs 0.64), indicating a more balanced community. The pest suppression index reached 73.8% in organic fields. Aphid and bollworm densities in the organic field (14.8 and 3.2 per 10 plants) were not statistically different from conventional (16.1 and 3.8, $p>0.05$ by mid-season).

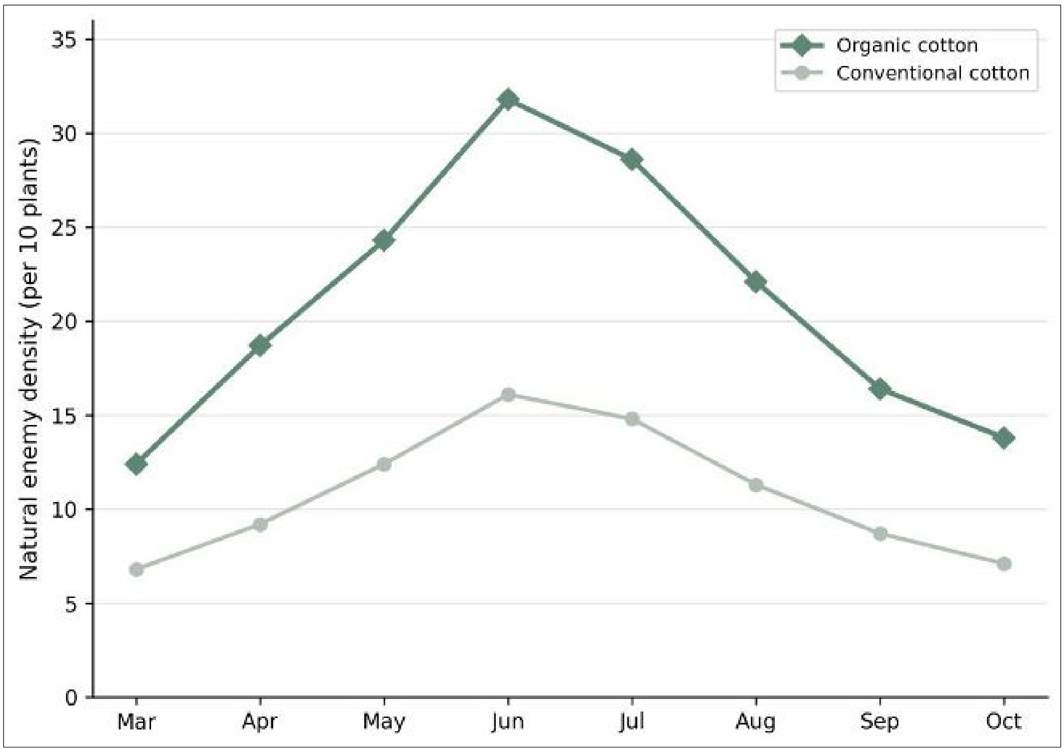

Fig 1: Seasonal dynamics of natural enemy density in organic and conventional cotton

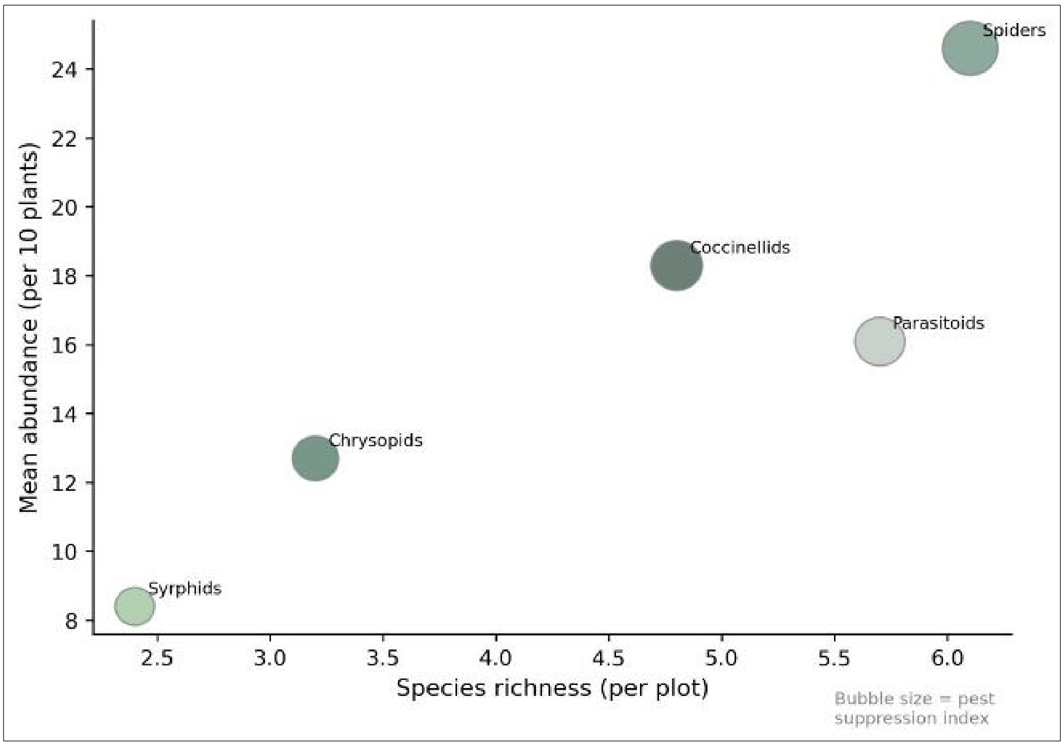

Fig 2: Species richness, abundance, and pest suppression index (bubble size) of major natural enemy groups in organic cotton

The line chart (Figure 1) shows organic fields maintaining consistently higher natural enemy densities across the entire season, with a pronounced June-July peak coinciding with the bollworm flight period. The bubble chart (Figure 2) highlights spiders as the most abundant group with a large suppression bubble, followed by parasitoid wasps which had high species richness relative to their abundance.

Discussion

The 97% abundance difference is among the higher values reported in organic vs conventional comparisons globally. Bengtsson *et al.* [1] found a mean increase of 30% in a meta-analysis, but that included annual crops with shorter histories of organic management. Our organic field had been unsprayed for three years, allowing time for spider and parasitoid populations to rebuild from adjacent forest edges [11]. The high spider dominance (31.2%) is consistent with tropical cotton systems where generalist web-builders and hunting spiders provide continuous pest pressure across multiple prey species [12].

That pest densities converged between systems by mid-season despite zero insecticide use in organic fields is the key practical finding. It suggests that the natural enemy community, once restored, can provide functional pest suppression comparable to a six-spray programme, at least in a year of moderate pest pressure. Whether this holds during outbreak years remains untested [13, 14, 15].

Conclusion

Organic cotton management supported 97% more natural enemies and 44% higher diversity than conventional management in the Vietnamese Central Highlands, and pest densities were comparable between systems. Spiders were the dominant predator group, highlighting their value as generalist biocontrol agents. These results provide evidence that biological pest suppression in organic cotton can replace insecticide-dependent management under moderate pest pressure. Farmers transitioning to organic cotton should expect a 2-3 year lag before natural enemy populations reach functionally effective levels.

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