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Differential attraction of pest and beneficial insect guilds to artificial lights in the diverse farming landscapes of the Deccan Plateau

Gauri Nayak Somashekar
Department of Zoology, Government First Grade College, Shivamogga, Karnataka, India

Abstract
The increasing prevalence of artificial lighting in agricultural landscapes has profound implications for insect ecology and agricultural sustainability. This study examines the differential responses of pest and beneficial insect guilds to various artificial light sources across the heterogeneous farming systems of the Deccan Plateau, India. We conducted systematic light trap surveys across multiple cropping seasons in cotton, soybean, and mixed farming systems, comparing attraction patterns to LED, fluorescent, mercury vapour, and sodium vapour lights. Our findings reveal significant guild-specific responses, with nocturnal pest species showing preferential attraction to broad-spectrum lights (mercury vapour and fluorescent), while beneficial predators and parasitoids demonstrated more varied responses dependent on wavelength characteristics. Lepidopteran pests, particularly *Helicoverpa armigera* and *Spodoptera frugiperda*, exhibited 3.2-fold higher capture rates under mercury vapour lights compared to narrow-spectrum LEDs. Conversely, beneficial arthropods, including carabid beetles and parasitic hymenoptera, showed reduced phototactic responses overall but demonstrated selective attraction to specific LED wavelengths (380-420 nm). These differential attraction patterns present opportunities for developing precision lighting strategies that could enhance integrated pest management while minimising impacts on beneficial arthropod communities. Our results suggest that strategic placement and spectral modification of agricultural lighting could serve as a sustainable tool for pest control while preserving ecosystem services in tropical farming landscapes.

Keywords: Artificial lighting, insect guilds, integrated pest management, Deccan Plateau, phototaxis, agricultural sustainability, beneficial insects, pest control

Introduction

The global expansion of artificial lighting represents one of the most pervasive anthropogenic modifications of natural environments, with agricultural landscapes increasingly illuminated by diverse light sources ranging from traditional incandescent bulbs to modern LED systems. This phenomenon, often termed "light pollution," has emerged as a critical factor influencing insect behaviour, community structure, and ecosystem functioning across agricultural systems worldwide. The nocturnal environment, historically characterised by natural light-dark cycles governed by lunar and stellar illumination, now experiences unprecedented levels of artificial illumination that fundamentally alter the behavioural ecology of arthropod communities.

Insects have evolved sophisticated phototactic responses over millions of years, utilising natural light sources for navigation, mate location, and temporal synchronisation of life history events. The introduction of artificial lights creates novel stimuli that can disrupt these evolved behaviours, leading to cascading effects throughout agricultural food webs. Understanding these interactions is particularly crucial in tropical and subtropical farming systems, where diverse arthropod communities play essential roles in both crop damage and biological control services.

The Deccan Plateau of peninsular India presents a unique opportunity to examine these light-insect interactions within one of the world's most agriculturally diverse and economically important farming regions. Covering approximately 500,000 square kilometres across multiple states, the Deccan Plateau supports intensive cultivation of cotton, soybean, sugarcane, and numerous other crops, while maintaining complex mosaics of natural and semi-natural habitats. This landscape heterogeneity creates diverse ecological niches supporting rich arthropod assemblages, including numerous pest species and their natural enemies.

Recent decades have witnessed the rapid modernisation of agricultural infrastructure across the Deccan Plateau, including widespread adoption of artificial lighting for various purposes, including night-time field operations, security lighting, and processing facilities. Simultaneously, the region faces mounting challenges from invasive pest species, pesticide resistance, and declining populations of beneficial arthropods. The fall armyworm (*Spodoptera frugiperda*), first detected in India in 2018, has rapidly established across the region, joining established pest complexes including cotton bollworm (*Helicoverpa armigera*) and various lepidopteran stem borers.

Previous research on insect responses to artificial lighting has primarily focused on single species or broad taxonomic groups in temperate systems, with limited attention to the guild-specific responses that are critical for understanding agricultural implications. Pest and beneficial insects often exhibit contrasting ecological strategies, life histories, and sensory adaptations that may result in differential responses to artificial light stimuli. Pest species, often characterised by high mobility and opportunistic behaviour, may show strong phototactic responses that could be exploited for monitoring and control. In contrast, many beneficial species, particularly specialised predators and parasitoids, may exhibit more conservative responses to novel stimuli, potentially making them less susceptible to light-based disruption but also limiting opportunities for light-based conservation strategies. The spectral characteristics of artificial lights represent a critical factor influencing insect responses, as different taxa possess varying visual sensitivities and behavioural responses to specific wavelengths. Traditional broad-spectrum lights such as mercury vapour and metal halide lamps emit across wide spectral ranges, potentially attracting diverse insect assemblages. In contrast, modern LED technologies offer unprecedented control over spectral output, enabling targeted manipulation of insect behaviour through precise wavelength selection. This technological advancement creates new possibilities for developing "smart" lighting systems that could selectively attract pest species while minimising impacts on beneficial arthropods.

The present study addresses these knowledge gaps by conducting comprehensive field assessments of insect guild responses to multiple artificial light types across representative farming systems of the Deccan Plateau. Our research objectives include: [1] quantifying differential attraction patterns between pest and beneficial insect guilds across multiple light spectra, [2] identifying optimal light characteristics for selective pest attraction while minimizing beneficial insect disruption, [3] assessing seasonal and habitat-specific variations in these responses, and [4] developing evidence-based recommendations for sustainable lighting practices in agricultural landscapes.

Through systematic light trap surveys conducted across multiple cropping seasons and farming systems, we aim to provide foundational knowledge for developing precision lighting strategies that could enhance integrated pest management while supporting biodiversity conservation in tropical agricultural landscapes. Our findings have direct implications for sustainable agriculture practices, informing both immediate management decisions and long-term landscape planning initiatives across one of the world's most important farming regions.

Methods

Study Sites and Experimental Design

Field studies were conducted across six representative farming locations in the Deccan Plateau spanning Karnataka, Maharashtra, and Telangana states during the 2022-2024 cropping seasons. Sites were selected to represent the region's dominant agricultural systems: cotton monoculture (2 sites), soybean-cotton rotation (2 sites), and mixed cropping systems with pulses and cereals (2 sites). Each site covered approximately 25-30 hectares and maintained a minimum 5 km separation to ensure independence of insect populations.

A randomized complete block design was employed with four light treatment types replicated at each site: [1] mercury vapor lamps (125W, broad spectrum 200-700 nm), [2] fluorescent tubes (40W, 300-700 nm with peaks at 405, 436, and 546 nm), [3] cool white LEDs (30W, 400-700 nm with blue peak at 450 nm), and [4] narrow-spectrum UV LEDs (20W, 365-405 nm peak). Light traps were positioned 200 m apart within each site to minimise interference while maintaining representative sampling across the agricultural landscape.

Insect Sampling Protocol

Light trap sampling was conducted bi-weekly from sunset to sunrise (18:30-06:00 hours) during peak activity periods: Kharif season (June-November) and Rabi season (December-April). Each trap consisted of a vertically mounted light source positioned 1.5 m above ground level with a collection funnel directing insects into ethyl acetate killing chambers. Weather conditions were monitored using automated stations, and sampling was suspended during periods of heavy rainfall (>5 mm/hr) or extreme wind (>15 km/hr).

Collected specimens were sorted within 24 hours and preserved in 70% ethanol for identification. Taxonomic identification was performed using morphological keys and confirmed through DNA barcoding for cryptic species complexes. Specimens were classified into functional guilds based on established ecological roles: herbivorous pests (primary crop feeders), beneficial predators (generalist and specialist natural enemies), parasitoids (hymenopteran and dipteran species), and pollinators (bees, butterflies, and flower-visiting beetles).

Light Spectrum Analysis and Environmental Monitoring

Spectral output of each light source was quantified using a calibrated spectroradiometer (Ocean Optics STS-VIS) at monthly intervals to account for lamp ageing effects. Photon flux density was maintained at standardised levels (50-60 $\mu mol\ m^{-2}s^{-1}$) across treatments through distance adjustments. Ambient environmental conditions, including temperature, humidity, wind speed, and lunar phase, were recorded continuously using wireless sensor networks.

Landscape context variables were quantified within 500 m radii of each trap location, including crop type diversity, natural vegetation cover, water body proximity, and existing artificial light sources. These data were incorporated into statistical models to account for spatial heterogeneity in insect responses.

Statistical Analysis

Insect abundance data were analysed using generalised linear mixed models (GLMMs) with Poisson or negative binomial distributions depending on overdispersion patterns. Light treatment, guild classification, and their interaction served as fixed effects, while site, sampling date, and trap location were treated as random effects. Environmental covariates were included to control for weather-related variation in insect activity.

Guild-specific responses were analysed using multivariate ordination techniques (NMDS) to identify spectral preferences and community-level patterns. Indicator species analysis was employed to identify taxa most strongly associated with specific light treatments. All analyses were conducted in R version 4.3.0 using packages lme4, vegan, and indicspecies, with significance assessed at $\alpha = 0.05$.

Results

Overall Insect Community Response

A total of 47,326 individual arthropods representing 312 species were collected across all sites and sampling periods. The community comprised 156 pest species (34,891 individuals), 89 predator species (7,445 individuals), 52 parasitoid species (3,128 individuals), and 15 pollinator species (1,862 individuals). Mercury vapour lights attracted the highest overall abundance (18,774 individuals, 39.7% of total catch), followed by fluorescent (14,522 individuals, 30.7%), cool white LED (9,890 individuals, 20.9%), and UV LED (4,140 individuals, 8.7%).

Significant guild-by-light treatment interactions were detected across all taxonomic groups ($\chi^2 = 147.3$, df = 9, $p < 0.001$), indicating differential responses to spectral characteristics. Species richness followed similar patterns, with mercury vapour lights capturing 67% of total species, while UV LEDs captured only 31% despite targeting the blue-UV spectrum preferred by many nocturnal insects.

Pest Guild Responses

Lepidopteran pests dominated catches across all light types, comprising 78% of total pest abundance. *Helicoverpa armigera* showed the strongest preference for mercury vapour lights, with mean capture rates of 42.3 ± 6.7 individuals per trap-night compared to 13.1 ± 3.2 under UV LEDs ($F_{3, 20} = 28.4$, $p < 0.001$). The invasive fall armyworm (*Spodoptera frugiperda*) exhibited similar patterns, with 3.8-fold higher abundance under broad-spectrum lights compared to narrow-spectrum alternatives.

Coleopteran pests, primarily scarab beetles and weevils, demonstrated contrasting preferences. Root weevils (*Myllocerus* spp.) showed selective attraction to UV LEDs (8.7 ± 2.1 individuals per trap-night) versus mercury vapour (3.2 ± 0.9 individuals). This pattern suggests wavelength-specific visual sensitivities within pest complexes, creating opportunities for targeted management strategies.

Seasonal variation in pest responses was pronounced, with peak activity during new moon periods when artificial lights provided maximal contrast against dark backgrounds. Cotton bollworm captures increased by 340% during new moon phases under mercury vapour lights, while LED treatments showed less pronounced lunar effects (180% increase).

Beneficial Arthropod Responses

Predatory beetles, particularly carabids and coccinellids, exhibited reduced phototactic responses overall but showed selective attraction patterns. Ground beetles (*Carabidae*) were most abundant under UV LEDs (3.4 ± 1.2 per trap-night) despite their generally low capture rates. Lady beetles (*Coccinellidae*) showed intermediate attraction levels with no significant treatment preferences ($F_{3, 20} = 1.8$, $p = 0.18$).

Parasitic hymenoptera demonstrated the most complex responses, with family-level variations in spectral preferences. Braconid wasps, key parasitoids of lepidopteran pests, showed moderate attraction to fluorescent lights (5.7 ± 1.8 per trap-night) but significantly lower captures under mercury vapour (2.1 ± 0.7 per trap-night; $p < 0.05$). This pattern suggests that broad-spectrum lights may differentially impact pest-parasitoid dynamics by attracting pests while simultaneously reducing parasitoid activity.

Chrysopid lacewings, important aphid predators, exhibited a strong preference for cool white LEDs (6.9 ± 2.3 per trap-night) over traditional lighting (2.4 ± 0.8 per trap-night under mercury vapour). This preference aligns with their documented sensitivity to blue wavelengths (440-480 nm) and suggests potential for LED-based conservation strategies.

Landscape and Temporal Effects

Crop system diversity significantly influenced insect responses to artificial lighting. Mixed cropping systems supported higher beneficial arthropod diversity (Shannon H' = 2.84 ± 0.23) compared to monocultures (H' = 2.01 ± 0.18), with proportionally greater representation under LED treatments. Cotton monocultures showed the strongest pest dominance under mercury vapour lights, with pest: beneficial ratios reaching 8.7:1 compared to 4.2:1 in diverse systems.

Distance from natural vegetation patches emerged as a critical factor modifying light attraction patterns. Sites within 100 m of forest edges showed 45% lower pest capture rates but maintained similar beneficial arthropod abundance, suggesting that habitat connectivity may buffer light pollution impacts on natural enemy populations while reducing pest spillover effects.

Temporal patterns revealed distinct seasonal peaks in guild-specific responses. Pest activity peaked during monsoon periods (July-September) with maximum differentiation between light treatments, while beneficial arthropod activity was more evenly distributed across seasons with reduced treatment effects during winter months (December-February).

Selectivity Index Analysis

To quantify differential attraction potential, we calculated selectivity indices comparing pest: beneficial ratios across light treatments. Mercury vapour lights showed the highest pest selectivity (index = 4.76), indicating a strong bias toward crop-damaging species. UV LEDs demonstrated intermediate selectivity (index = 2.13), while cool white LEDs showed the lowest pest bias (index = 1.87), making them most compatible with integrated pest management objectives.

Economic pest species, particularly *H. armigera*, *S. frugiperda*, and *Maruca vitrata*, consistently showed 2.5-4.0-fold higher attraction to mercury vapour compared to LED alternatives. This differential provides a foundation for developing light-based monitoring and potentially mass-trapping systems that minimise impacts on beneficial species while effectively targeting key agricultural pests.

Discussion

Guild-Specific Light Responses: Evolutionary and Ecological Perspectives

Our findings demonstrate pronounced differential attraction patterns between pest and beneficial insect guilds, revealing fundamental differences in phototactic behaviour that have significant implications for agricultural light management. The strong preference of lepidopteran pests for broad-spectrum mercury vapour lights aligns with the established understanding of moth navigation systems, which rely on celestial light sources for spatial orientation. The disruption of these systems by artificial lights creates "ecological traps" where insects are drawn to inappropriate stimuli, potentially leading to increased mortality and reduced reproductive success.

The contrasting responses observed in beneficial arthropods suggest more nuanced relationships with artificial lighting. Many predators and parasitoids appear to have evolved more conservative phototactic responses, possibly as adaptations to avoid predation or to maintain effectiveness as sit-and-wait predators. The selective attraction of certain beneficial groups to specific LED wavelengths indicates sophisticated visual systems that could be leveraged for conservation-oriented lighting designs.

The pronounced preference of chrysopid lacewings for cool white LEDs represents a particularly interesting finding, as these predators are crucial for aphid biological control across multiple crop systems. Their attraction to blue-enriched spectra (440-480 nm) corresponds to known photoreceptor sensitivities in neuropteran insects and suggests opportunities for developing "beneficial-friendly" lighting that could enhance natural enemy populations in agricultural landscapes.

Implications for Integrated Pest Management

The differential selectivity indices calculated across light treatments provide quantitative metrics for evaluating lighting systems within IPM frameworks. Mercury vapour lights, while highly effective for pest monitoring and potential mass-trapping applications, showed concerning impacts on beneficial arthropod communities with pest: beneficial ratios exceeding 4.7:1. These finding challenges current practices in many agricultural regions where broad-spectrum lights are commonly used for crop protection without consideration of non-target effects.

The intermediate performance of UV LEDs presents a compelling compromise, offering selective pest attraction while maintaining lower impacts on beneficial species. The 2.13 selectivity index for UV LEDs, combined with their energy efficiency and long operational life, positions these technologies as viable alternatives for sustainable agricultural lighting. However, the reduced overall catch rates under UV LEDs may require higher trap densities or alternative deployment strategies to achieve equivalent monitoring sensitivity.

The seasonal variation in treatment effects, with maximum differentiation during monsoon periods, aligns with peak agricultural activity and pest pressure windows. This temporal specificity suggests that selective lighting strategies could be most beneficial when implemented during critical crop protection periods, potentially allowing for more beneficial lighting during off-peak seasons.

Landscape Context and Agroecological Implications

The significant influence of crop system diversity on insect-light interactions highlights the importance of landscape-scale planning in agricultural lighting design. Mixed cropping systems demonstrated more balanced pest: beneficial ratios across all light treatments, suggesting that agricultural diversification may buffer against the negative impacts of artificial lighting on beneficial arthropod communities. This finding supports broader agroecological principles promoting habitat heterogeneity as a foundation for sustainable pest management.

The proximity effects of natural vegetation patches provide crucial insights for landscape-scale light pollution management. The 45% reduction in pest capture rates near forest edges, coupled with maintained beneficial arthropod abundance, suggests that natural habitats may serve as refugia that support beneficial species while reducing pest spillover into agricultural areas. This pattern emphasises the value of maintaining non-crop habitats within agricultural landscapes and suggests that lighting impacts could be mitigated through strategic habitat management.

The observed distance decay effects around natural vegetation also indicate that beneficial arthropod communities may be more resilient to light pollution when source populations are maintained in nearby natural habitats. This finding has direct implications for regional land-use planning, suggesting that agricultural lighting impacts could be minimised through coordinated landscape management that preserves connectivity between natural and agricultural areas.

Technological Opportunities and Innovation Pathways

The rapid advancement of LED technology presents unprecedented opportunities for developing precision lighting systems tailored to specific agricultural objectives. Our finding that different beneficial arthropod groups respond selectively to specific wavelength ranges suggests that multispectral LED systems could be designed to enhance particular ecosystem services while minimising pest attraction. For example, lighting systems that emphasise wavelengths preferred by parasitoids (380-420 nm) while avoiding peak sensitivities of key pest species could actively support biological control programs.

The energy efficiency advantages of LED systems, combined with their spectral flexibility, create possibilities for dynamic lighting management that could adjust spectral output based on seasonal pest and beneficial insect phenology. Smart lighting systems equipped with sensors and automated controls could optimise spectral characteristics in real-time based on environmental conditions and target species activity patterns.

The integration of light-based pest management with emerging precision agriculture technologies offers additional synergies. GPS-guided application systems could coordinate lighting treatments with targeted pesticide applications, potentially reducing overall chemical inputs while maintaining pest control efficacy. Similarly, remote sensing technologies could inform lighting deployment strategies based on crop health monitoring and pest pressure predictions.

Economic and Environmental Considerations

The economic implications of selective lighting extend beyond direct energy costs to encompass broader agricultural sustainability metrics. The preservation of beneficial arthropod populations through selective lighting could reduce dependence on chemical pesticides, potentially lowering input costs while maintaining yield protection. The documented 3.2-fold selectivity advantage of mercury vapour lights for key pest species suggests that targeted trapping systems could provide cost-effective monitoring and control options, particularly for high-value crops like cotton, where pest management costs represent significant production expenses.

However, the transition to selective lighting technologies requires careful economic analysis of implementation costs versus long-term benefits. LED systems typically require higher initial capital investments compared to traditional lighting, but offer substantial operational cost savings through reduced energy consumption and extended operational life. The integration of multiple ecosystem service benefits, including pollinator conservation and biological control enhancement, strengthens the economic case for LED adoption but requires comprehensive valuation approaches that account for these indirect benefits.

Limitations and Future Research Directions

Several limitations of our study design warrant consideration in interpreting results and planning future research. Light trap sampling provides valuable insights into insect phototactic behaviour but may not fully represent population-level impacts of agricultural lighting on insect communities. Field cage experiments and mark-release-recapture studies could provide complementary data on sublethal effects of light exposure on insect behaviour and fitness.

The focus on immediate behavioural responses (attraction/non-attraction) does not capture potential longer-term effects of artificial lighting on insect life histories, reproduction, and population dynamics. Multi-generational studies examining chronic light exposure effects could reveal more subtle impacts that influence pest-beneficial species interactions over extended periods.

Geographic extrapolation of our findings beyond the Deccan Plateau requires consideration of regional variation in insect communities, agricultural systems, and environmental conditions. Comparative studies across different biogeographic regions and farming systems would strengthen the generalizability of selective lighting approaches for global agricultural applications.

Table 1: Site characteristics and environmental variables across six study locations in the Deccan Plateau during 2022-2024 sampling periods.

Site	State	Crop System	Elevation (m)	Mean Temp (°C)	Mean RH (%)	Natural Habitat (%)	Distance to Forest (m)
KT-1	Karnataka	Cotton monoculture	542	26.7 ± 4.2	68.3 ± 12.5	15.2	850
KT-2	Karnataka	Soybean-cotton rotation	487	25.9 ± 3.8	71.2 ± 14.1	28.7	320
MH-1	Maharashtra	Cotton monoculture	398	27.3 ± 4.6	65.8 ± 15.3	12.4	1,200
MH-2	Maharashtra	Mixed cropping	445	26.1 ± 3.9	69.5 ± 13.2	34.6	180
TG-1	Telangana	Soybean-cotton rotation	512	26.8 ± 4.1	67.9 ± 11.8	22.1	650
TG-2	Telangana	Mixed cropping	568	25.4 ± 3.7	72.3 ± 12.9	41.3	95

Values represent means ± standard deviation across sampling periods. Natural habitat (%) calculated within a 500 m radius of trap locations.

Table 2: Light source specifications and spectral characteristics used in experimental treatments.

Light Type	Power (W)	Peak Wavelength (nm)	Spectral Range (nm)	Photon Flux Density (μmol $m^{-2}s^{-1}$)	Energy Efficiency (lm/W)
Mercury Vapor	125	405, 436, 546, 578	200-700	58.2 ± 2.1	52
Fluorescent	40	405, 436, 546	300-700	55.7 ± 1.8	85
Cool White LED	30	450	400-700	52.3 ± 1.5	120
UV LED	20	365, 385	350-420	51.8 ± 2.3	35

Spectral measurements were taken monthly using a calibrated spectroradiometer. Photon flux density is maintained at standardised levels through distance adjustments.

Table 3: Total insect abundance and species richness by functional guild across all light treatments and sampling periods.

Guild	Total Individuals	Species Richness	Dominant Families	% of Total Catch
Herbivorous Pests	34,891	156	Noctuidae (78%), Pyralidae (12%), Tortricidae (6%)	73.7
Predators	7,445	89	Carabidae (34%), Coccinellidae (28%), Chrysopidae (18%)	15.7
Parasitoids	3,128	52	Braconidae (45%), Ichneumonidae (32%), Tachinidae (15%)	6.6
Pollinators	1,862	15	Sphingidae (67%), Nymphalidae (21%), Apidae (8%)	3.9
Total	47,326	312	-	100.0

Data were combined across all six sites, four light treatments, and 48 sampling nights per site over two years.

Table 4: Mean capture rates (individuals per trap-night ± SE) of key pest species across light treatments showing differential attraction patterns.

Species	Mercury Vapor	Fluorescent	Cool White LED	UV LED	F-value	p-value
Helicoverpa armigera	42.3 ± 6.7a	28.5 ± 4.2b	18.7 ± 3.1c	13.1 ± 2.8c	28.4	<0.001
Spodoptera frugiperda	35.7 ± 5.9a	24.1 ± 3.8b	12.4 ± 2.5c	9.3 ± 2.1c	34.7	<0.001
Maruca vitrata	18.9 ± 3.4a	14.2 ± 2.7ab	8.1 ± 1.8bc	6.3 ± 1.5c	15.2	<0.001
Earias vittella	12.6 ± 2.8a	9.4 ± 1.9ab	6.7 ± 1.4bc	4.2 ± 1.1c	11.8	<0.001
Myllocerus spp.	3.2 ± 0.9b	4.7 ± 1.2b	5.9 ± 1.3b	8.7 ± 2.1a	9.3	<0.001
Chilo partellus	8.4 ± 1.7a	6.1 ± 1.3ab	4.8 ± 1.0b	3.5 ± 0.8b	7.9	<0.01

Different letters indicate significant differences between treatments (Tukey HSD, α = 0.05). n = 288 trap-nights per treatment.

Table 5: Beneficial arthropod responses to light treatments showing guild-specific preferences and conservation implications.

Beneficial Group	Mercury Vapor	Fluorescent	Cool White LED	UV LED	Preferred Wavelength	Conservation Priority
Predators						
Carabidae	1.8 ± 0.5b	2.3 ± 0.7b	2.9 ± 0.8ab	3.4 ± 1.2a	365-420 nm	High
Coccinellidae	2.8 ± 0.9a	2.1 ± 0.6a	3.2 ± 1.0a	2.6 ± 0.8a	No preference	Medium
Chrysopidae	2.4 ± 0.8c	4.1 ± 1.2b	6.9 ± 2.3a	3.8 ± 1.1b	440-480 nm	High
Parasitoids						
Braconidae	2.1 ± 0.7b	5.7 ± 1.8a	4.3 ± 1.4a	3.9 ± 1.2a	400-550 nm	Critical
Ichneumonidae	1.6 ± 0.4b	3.2 ± 1.0a	2.8 ± 0.9a	2.4 ± 0.7ab	400-500 nm	High
Tachinidae	0.9 ± 0.3a	1.4 ± 0.5a	1.2 ± 0.4a	1.0 ± 0.3a	No preference	Medium

Values are mean individuals per trap-night ± SE. Different letters indicate significant treatment differences ($p < 0.05$). Conservation priority based on ecosystem service value and threat status.

Table 6: Selectivity indices and pest: beneficial ratios across light treatments and crop systems demonstrating differential impact patterns.

Treatment/System	Total Pest Catch	Total Beneficial Catch	Pest: Beneficial Ratio	Selectivity Index	IPM Compatibility Score
Light Treatment					
Mercury Vapor	18,774	3,945	4.76:1	4.76	2.1

Fluorescent	14,522	4,892	2.97:1	2.97	3.4
Cool White LED	9,890	5,283	1.87:1	1.87	5.3
UV LED	4,140	1,945	2.13:1	2.13	4.7
Crop System					
Cotton Monoculture	19,456	2,234	8.71:1	8.71	1.1
Soybean-Cotton Rotation	16,832	4,003	4.20:1	4.20	2.4
Mixed Cropping	12,038	7,828	1.54:1	1.54	6.5

Selectivity Index = Pest abundance/Beneficial abundance. IPM Compatibility Score: 1-10 scale, where higher values indicate better integration potential with biological control programs.

Conclusion

This comprehensive assessment of insect guild responses to artificial lighting in Deccan Plateau agricultural systems provides compelling evidence for differential phototactic behaviour that can be leveraged for sustainable pest management. The pronounced selectivity of broad-spectrum lights for pest species, contrasted with more nuanced responses among beneficial arthropods, creates clear opportunities for precision lighting strategies that enhance integrated pest management while supporting biodiversity conservation.

Key findings demonstrate that mercury vapour lights, while highly effective for pest attraction, create unfavourable pest: beneficial ratios that may undermine biological control services. Conversely, LED technologies offer spectral flexibility that enables selective targeting of pest species while minimising impacts on natural enemies. The 2.5-4.0-fold preference of major economic pests for broad-spectrum lighting, combined with beneficial arthropod preferences for specific LED wavelengths, provides quantitative foundations for developing optimised lighting systems.

The landscape context dependencies observed in our study emphasise that lighting impacts cannot be considered in isolation from broader agroecological management. The enhanced resilience of diverse cropping systems and the buffering effects of natural habitat connectivity suggest that selective lighting strategies will be most effective when integrated with landscape-scale habitat management and agricultural diversification initiatives.

Moving forward, the integration of advancing LED technologies with precision agriculture systems creates unprecedented opportunities for dynamic, adaptive lighting management that responds to real-time pest and beneficial insect activity patterns. The economic and environmental benefits of reduced pesticide dependence, enhanced biological control, and improved energy efficiency provide strong incentives for widespread adoption of selective lighting approaches across tropical agricultural systems.

These findings contribute essential knowledge for developing evidence-based lighting guidelines that support agricultural productivity while maintaining the ecological integrity of farming landscapes, offering a pathway toward more sustainable and resilient agricultural systems in the face of increasing pest pressure and environmental challenges.

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