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Impact of Artificial Light Intensity on Nocturnal Insect Biodiversity in Different Environments from Multan

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ABSTRACT

Light intensity (adaptation), circadian periodicity and photoperiodism are highly associated with the behavioral responses of insects. Artificial light at night can interfere with the nocturnal behavior of insects and their growth and physiology. This study investigates the impact of artificial light on the diversity and community composition of noctuid moths in Multan, Pakistan, while considering the role of seasonal environmental factors and habitat. Moths were collected using light traps of different intensities installed in both crop and forest areas over a one-year period. Our results revealed a pronounced habitat-specific effect, with the maximum species diversity (H'=2.443), richness (4.152), and evenness (1.00) recorded from traps placed in crop areas. Conversely, the lowest diversity metrics were observed from traps in other locations, suggesting that light intensity interacts with habitat characteristics. A total of 16 noctuid species were identified, with community composition varying significantly between trap locations. The crop area harbored a more diverse assemblage, including species like Spodoptera exigua, Spodoptera litura, and Hadena trifoli while the forest area traps showed lower species richness. Seasonality was a critical factor, with peak moth populations observed in October and May. This period correlates with favorable environmental conditions and the presence of key host crops such as maize and wheat, which support noctuid populations. Conversely, minimal activity was recorded during the unfavorable conditions and host scarcity of December and January. The study concludes that while artificial light intensity is a factor in attracting and potentially disrupting nocturnal insects, its impact is strongly modulated by habitat type (crop vs. forest) and seasonal environmental conditions, particularly host plant availability. The findings highlight that crop areas, with their abundant food resources, can support higher moth diversity even under light trap pressure, underscoring the complex interplay of anthropogenic and natural factors in shaping nocturnal insect communities.

INTRODUCTION

Lepidoptera is the second largest order and a diverse group of the class Insecta and comprises butterflies and moths (Benton & Lehtinen, 1995). It included 16,0000 species out of which 95 % are nocturnal moths (Kristensen *et al*., 2007). Family Noctuidae includes 29 subfamilies, 42,407 species (Goldstein, 2017) and 1,089 genera (Zhang *et al*., 2011). Noctuid is dominant and economically important families of order Lepidoptera (Hampson, 1896). Larvae of Noctuidae are annual and major pest of many economically important crops like cotton, wheat, maize and rice. Immature referred as worms e.g. fall armyworms, ball worms, leaf worms, budworms, earworms and cutworms belong to this family (Urge *et al*., 2020). Adults are nocturnal insect and they use proboscis to suck juice from the fruits and flower (Klem & Zaspel, 2019).

Light trap provides a significant clue to check the diversity of night flying insects, e.g., nocturnal insects (Southwood & Henderson, 2000). It may be useful to evaluate the quantitative abundance of various groups of insect species of nocturnal insects (Szentkirályi, 2002). Nocturnal arthropods, mainly insects, are attracted by artificial light sources (Delvare *et al*., 1997). Light trap is most common and widely used method to check the abundance, distribution and seasonal flight period of insects (Combita-Heredia, 2020). Light sources which produce large amounts of UV radiations have reformed the light trap sampling (McGavin, 2007). Various light sources like gas lamps, mercury vapour lamps and fluorescent UV lights are utilized for sampling purpose. UV light trap is inexpensive and most widely used method. In Japan, yellow colored light traps were used extensively to suppress the rice stem borer, Chilo suppressalis Walker and the Trypory zaincertulas Walker moths that infest paddy fields (Ishikura, 2000). Mercury and black light traps collect more insects than incandescent light.

The recognition of insects has been mainly based on types of phenotypes and genital features. Phenotype of organisms can be limited in a number of ways because taxonomic keys are often limited to only one stage of life or gender of insects (Ball & Armstrong, 2006). A morphological identification was initiated only on one character i.e. wing position (Covell, 1984). There are also

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moths that keep their wings horizontal and flat. Species identification of moths that also varied in color pattern related to longer flying duration and more host plants (Franzen *et al.*, 2020). Genital structures are known among many insects characters very informative and more stable in taxonomic terms than antenna types, variation in color pattern and wing pattern (Mutanen, 2005). The external genitalia of Noctuid moths demonstrate the almost limitless and immense source of nonconformity compared to other morphological quality (Varga & Ronkay, 2013).

This research was done to establish the abundance of different species of the family Noctuidae that inflict damages on the economically significant crops. For proper management it is compulsory to identify insect pest upto species level and for the identification of morphological characters is very important. This study could also be useful to the formulation of effective management approaches to control noctuid pests.

LITERATURE REVIEW

Light traps are a good way of monitoring and controlling night insect pests since they trap both sexes of the insect pests. Light traps were the most common technique of moth species that utilizes their attraction to artificial light (Franzén & Johannesson, 2007). The seasonal variation of nocturnal insects in cropped and forest area is also determined using light traps. Numerous non-target insect pests and are killed using light traps (Ma *et al.*, 2009). It also offers a basic information of insect distribution, abundance and assists in determining the proper management tools at appropriate time (Singh *et al.*, 2012).

Light trap experiment was carried out in the Botanical Garden of the University Bayreuth, Germany. Light traps were effectively used for monitoring moth species. Mark recapture method was used to evaluate which species was more attracted toward light. Marked moths were recaptured at weak artificial light sources (2 × 15 W UV-light tubes). Almost 2,331 moths belonging to 167 species were captured at light traps and released at distance of 2-100m. Out of these 313 moths were returned toward light within 5 minutes. Percentage recapture were affected with temperature. Result showed that moth species attraction varied with distance of light traps and habitat preference toward light source (Truxa & Fiedler, 2012).

Two Ryrholm types of light traps were operated with different light source (250W mercury bulb 40W ultraviolet fluorescent tube) from March to October. Light traps attracted moths that were fall down though funnel into box. Traps were operated in open grassland area at the distance of 40m to avoid the influence of attraction. To check the traps performance their position was changed three times during night and data was collected throughout the night. Species abundance was clearly related with light source, temperature and humidity. The results showed that 49,472 individuals belonging to 372 species were collected. Trap with light source of 250W mercury lamp collected 29953 individuals and trap with 40W ultraviolet fluorescent tube collected 19519 specimens belonging to 299 species. Nocturnal species abundance was mainly depending upon temperature, humidity and trap type. Species abundance fluctuated according to environmental conditions (Jonason *et al.*, 2014).

Black light traps were installed in Nepal for monitoring maize insect pests. Efficiency of black light trap (10W and 350nm UV) was compared with traditional light trap (125W). Both traps were set in the field at National Maize Research Program between the months of February and October 2017. The data were collected after one week at dusk to down. The insects in the black light trap (BLT) were higher than in traditional light trap and Coleopteran was primarily trapped in BLT. Findings indicated that the efficiency of BLT was 3 times higher than conventional light traps (Bhandari *et al.*, 2017).

Traffic-regulated street light affects was observed on light traps to check nocturnal insect diversity. Street light reduced the level of artificial light at night. Nocturnal insect abundance was observed in one week without the effects of street light. In other week nocturnal insect abundance was observed on artificial light at night with the effects of street light on those traps. Street light could reduce the effects of artificial light intensity level by 35%. Mostly nocturnal insects were captured on artificial light. Findings indicated that street light dimming technology could be part of mitigating light adverse impacts of artificial lighting at night on nocturnal insects (Bolliger *et al.*, 2020)

Light traps were installed in exhibition garden during June and August 2017 in Korea. Insect diversity was compared at three urban sites and commercial areas with the gradient of artificial light at night. Road lights effect was checked out on light traps on both sites. Result showed that urban sites exhibited higher species density because of different light intensity due to road light effects. Species richness of nocturnal insects correlated with field light intensity at night (Hakbong *et al.*, 2021).

Two light traps were installed at different location of Orchard and paddy field at night over two years in 2 sites in Japan. Data was collected in between July and September 2015. Conventional light source emitted ultraviolet radiation which was more attractive for nocturnal insects than LED. Experiment was carried out by comparing the fluorescents mercury vapor (MV) lamp and white LED. The attraction of lepidopterans and coleopterans to white LED was about 85-90 percent less than the MV lamp. Result showed that spectral turning of LEDs affect the population density of different orders and light color has a significant effect on nocturnal insect behavior (Kamei *et al.*, 2021).

MATERIALS AND METHODS

Experimental Site

The field experiment was carried out in crop and forest region at Multan, Punjab, Pakistan to collect Noctuid moth. Wheat, rice, maize, cotton, mangoes and oranges are some agricultural crops cultivated on the land in the

Multan. The rest of the non-cultivated lands are forest-like habitats. In this region, the climate is sub-tropical, and the temperature fluctuates between 8 to 12 oC and 38 to 50 oC, respectively.

Installation of Traps

Data were collected during September 2021 to May, 2022. Sixteen yellow colored light traps of 100W were installed at different site of forest and crop area of Multan. Three light traps were installed in crop area and two were installed in forest area. All the night traps were operated during sundown and sunrise. Light traps were suspended 1.5m above the ground level. Data were collected on daily basis.

Collection and Preservation

The specimens of adult Noctuid moths were collected manually from the light traps. These samples were killed in potassium cyanide killing jar after killing sampling was shifted into taxonomic lab for further study. Furthermore, these specimens were submerged in butter paper in petri dishes for 2-3 hours to soften legs, wings,

Table 1. Diversity of noctuid in all traps from Multan

Order name	Species name	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17
Lepidoptera	Spodoptera litura	—	√	√	√	√	—	√	√	√	√	—	√	—	—	√	—	√
	Spodoptera exigua	√	√	√	—	√	√	—	√	—	√	√	√	√	—	√	√	√
	Mythimna separata	√	√	√	√	√	√	√	√	—	√	—	√	√	—	√	—	√
	Agrotis ypsilon	—	—	√	—	—	√	—	√	√	—	√	—	√	√	—	√	√
	Hadena stigmosa	—	√	—	—	—	√	√	—	√	—	√	√	—	√	—	√	√
	Hadena trifoli	√	√	√	√	√	√	√	√	—	—	√	—	√	√	√	√	—
	Helicoverpa zea	—	√	—	—	—	—	√	—	√	—	—	√	—	√	—	—	√
	Heliothis peltigera	—	√	√	—	—	—	√	√	—	√	—	√	√	√	—	—	—
	Pyrrhia umbra	—	—	√	—	—	—	—	√	—	√	—	—	√	—	√	—	√
	Aletia album	—	√	√	√	—	—	√	√	√	√	—	√	—	√	—	—	√
	Helicoverpa armigera	√	—	√	—	—	√	—	√	—	√	√	—	√	—	√	√	—
	Hadena jahangiri	—	—	√	—	—	—	—	√	—	√	√	—	√	—	—	√	—
	Chrysodeixis furihatai	—	—	√	—	—	—	—	√	—	√	√	—	√	—	√	√	—
	Lacanobia oleracea	—	√	√	√	—	—	√	√	—	√	—	√	√	√	—	—	—
	Plutella xylostella	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Spodoptera frugiperda	—	√	—	—	—	—	√	—	√	√	—	√	—	—	√	—	√

antennae and abdomen. Then, each moth was pinned by using entomological pins. Specimens were spread by card strips; both wings separate from each other and left it for drying for 2 to 3 days. These samples were dried and placed in airtight box made of wood to preserve the specimens together with tag. The specimens were preserved by keeping them in phenyl tablets and cupex powder to avoid ants, mites and other predators. Each tag has complete information like collector name, date, trap number and species number.

Table 2: Diversity, richness and evenness of species of moth of family Noctuidae trapped by light traps at various localities of district Multan.

Localities	Shanon diversity(H)	Margalef's index (R)	Evenness index (E)
Trap 1	1.55	2.056	0.9421
Trap 2	2.183	3.189	0.8065
Trap 3	2.443	4.152	0.8889
Trap 4	1.677	2.276	0.8916
Trap 5	1.609	2.485	1.00
Trap 6	1.322	3.621	0.871
Trap 7	2.121	2.163	0.881
Trap 8	2.301	2.145	0.671
Trap 9	1.401	2.104	0.801
Trap 10	1.051	2.017	0.608
Trap 11	2.5	3.28	0.899
Trap 12	2.141	1.23	0.953
Trap 13	2.5	2.901	0.882
Trap 14	1.59	3.871	0.818
Trap 15	2.301	4.127	0.982
Trap 16	2.521	3.109	0.831

Identification

Species-level identification was performed through microscopic examination. Specimens were determined by consulting relevant taxonomic literature and comparing key morphological features, including antennal type and segmentation, overall body morphology, wing venation and pigmentation patterns.

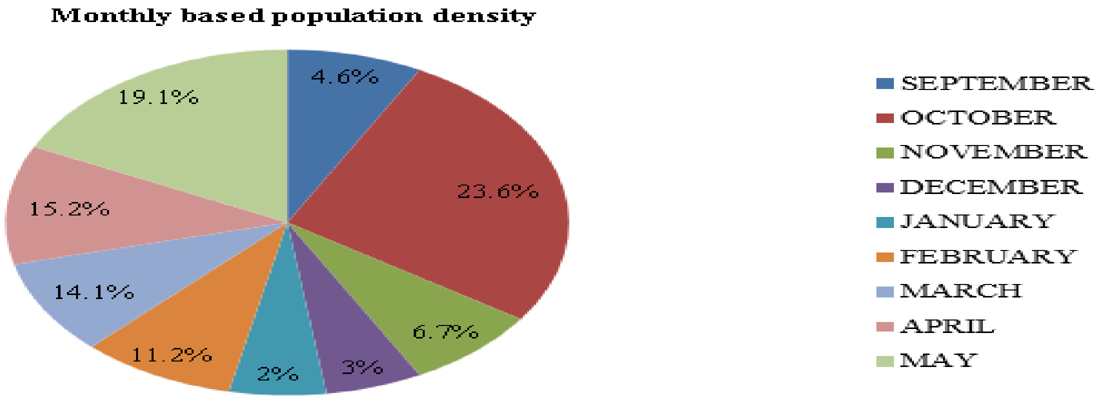

Figure 1: Monthly recorded population density of Noctuid moths

Statistical Analysis

The data were organized on a Microsoft Excel sheet to compute the mean and standard error. To assess the nocturnal insect biodiversity within the study area, this research quantified various diversity metrics for the insect communities in each habitat. These metrics included the Shannon-Wiener Index, species evenness, and the Margalef richness index. The Statistix 8.1 software was used to calculate the analysis of variance (ANOVA).

RESULTS AND DISCUSSIONS

Overall diversity of Noctuid Moths

Based on the collection of 51,49 individuals representing 16 noctuid species, the following table was constructed

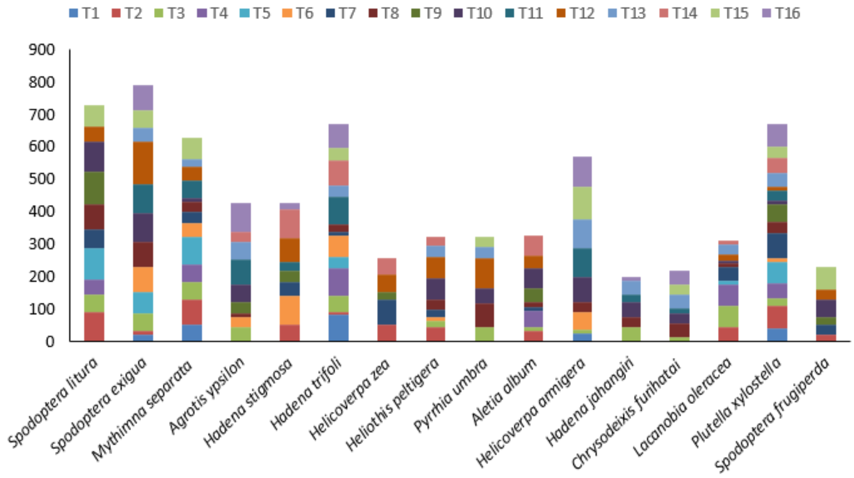

Figure 2: Variation of species in Light traps

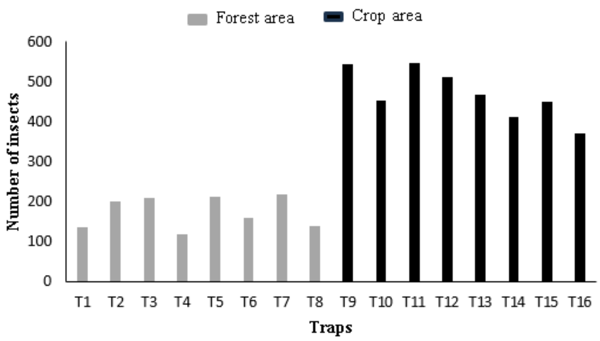

Figure 3: Diversity of moth's population in forest and crop area

to detail species distribution. It documents the presence or absence of each species across the 16 trap sites. This effectively illustrates the heterogeneity of species assemblages among the different light traps. The data reveals distinct patterns of habitat utilization, with some species appearing in nearly all traps and others showing a narrow distribution. These presence/absence patterns form the basis for the subsequent analysis of diversity structure.

Diversity Indices of Noctuid Moths

The maximum species diversity (2.443), richness (4.152) and evenness (1.00) were recorded from 3, and 5 traps that were installed in crop area. The minimum trap diversity (1.051), richness (1.23) and evenness (0.608) were recorded from trap 10, 12 and 10 (Table 2). Temperature, relative humidity and light intensity affect the population density of Nocturnal insects both in forest and field area. Traps were installed in crop area and forest area having high population of Nocturnal insects due to presence of host and favorable environmental conditions.

Seasonal distribution of Noctuid Moths in different habitat types

The maximum population was observed in October and May due favorable environmental conditions and presence of crops like maize and wheat, which are the host of noctuid moths and minimum population was observed in December and January due to unfavorable environmental condition and absence of host (Figure 1).

Noctuid Moths Variation in Light Traps

The composition of Noctuid moth species showed variation across light traps 1 to 16.

Specimens collected belonged to species including S. exigua, M. separata, and A. ypsilon. Additional species identified were H. stigmosa, H. trifoli, H. zea, and H. peltigera. The survey also recorded P. umbra, A. album, H. armigera, and H. jahangiri. Further species present in the traps included C. furihatai, L. oleracea, and P. xylostella. The invasive pest S. frugiperda was also represented among the trap catches. Analysis of the collection data revealed distinct patterns in species abundance. The species S. exigua was the most prevalent, occurring in high numbers across all traps. The next most frequently captured species, ranking second in abundance, was S. litura. H. trifoli was identified as the third most abundant species in the trap samples (Figure 2).

Population Abundance in Forest and Crop Area

Maximum population of noctuid moths was collected in crop area due to diversity of host and favorable environmental conditions as compare to forest area (Figure 3). Highest population (543 moths) of noctuid moth were found in trap 9 in crop area and lowest population (370 moths) was found in trap 16. However, in forest area the maximum population of noctuid moths was 137 moths in trap 1 while minimum population 219 moths were observed in trap 7.

Discussion

Scientists have also employed light traps to survey community composition, monitor useful insects (Nasir, 2025; Nabli *et al*., 1999), and suppress population of insect pests (Pawson *et al*., 2009; Goretti *et al*., 2011). Diptera, Coleoptera, and Lepidoptera are the most frequent orders of insects that are attracted and trapped in the light traps (Wakefield *et al*., 2016). There are several significant differences between light-trapping equipment and ALAN (Artificial Light at Night): Experimental light traps tend to produce more short wavelengths, lack glass shields (which block UV), and are also located close to the ground (Degen *et al*., 2016). Nevertheless, experiments, which modify the intensity and spectral composition of light traps, can still provide some information on the possible impacts of artificial light on positively phototactic insects. The foraging bats do not keep moths off the artificial light (Acharya & Fenton, 1999). Artificial lighting can also interfere with the movement of insects among patches of the habitat, attract them to the water bodies or distract them into traffic depending on where it is placed (Frank, 2006). Insects that are not killed instantly might get stuck in a light sink, and they cannot forage (Van Langevelde, *et al*., 2017).

The summery of this study shows that 16 species of family Noctuidae were H. armigera, M. separata, S. litura, S. exigua, H. jahangiri, C. furihatai, A. ypsilon, H. trifoli, L. oleracea, P. umbra, H. peligera, A. misogona, H. stigmosa, P. xylostella and A. album belonging to different genera were collected in light traps from cropped and compared to forest area from District Multan. Similarly, Zahoor *et al.* (2003) observed that more species of the family Noctuidae were trapped in crop and forested habitats. This observation is also in agreement with a previous study which had indicated a greater abundance of Noctuidae and Pyralidae species, respectively, in agri-horticultural ecosystems than in forested habitats (Adiroubane & Kuppammal, 2010). It is important to note that a greater range of noctuid moths was gathered than those moths that were in the family Pyralidae. Such findings are in line with earlier studies in which species of Noctuidae exhibited greater diversity in comparison to those of the Pyralidae family (Aslam, 2009).

The highest population of noctuid moths was recorded in traps planted in diverse cropping habitats of maize, wheat, rice and vegetables. The above studies explained that abundance of insects depended on complexity of the landscape and diversity of the hosts. The maximum abundance of collected species was recorded in the crop areas due to presence of host and favorable environmental conditions and minimum population was recorded in forest area due to unfavorable environmental conditions. The natural enemies ensured low population abundance of pests in semi natural habitats (Bianchi *et al*., 2006). The artificial lighting of the forest regions with conspicuous ecological effects on the nocturnal moths resulting in reduced population of the moths (Frank *et al*., 2006). In present study maximum insects were captured in October and May as compare to other months of year. Above results were similar to previous research conducted by (Yela & Holyoak, 1997) in which the richness and abundance of insects were more in May, June, September and October with respect to other months of year.

We found that attractiveness of noctuid moths to the source of light was influenced by the presence of a host and good environmental conditions. The large disproportion was documented in moths that were taken at varying heights. Earlier research found out that the efficiency of light traps catch depends on the light color (Mabrouk & Mahbob, 2015). In the current studies, maximum noctuid moths were found in light traps fitted with yellow light. The same findings were recorded in earlier works that established that yellow light trap is the most attracting and catches a large sample size (Sridhar & Kumaran, 2018). One of the species that was relatively higher in crop areas compared to forested areas was S. litura. This trend agrees with the past studies which have emphasized S. litura as a powerful species in agricultural setups (Zahoor *et al*., 2003). The findings of the study highlight the fact that nocturnal insects are more diverse, rich in species, and have a high evenness in crop cultivated areas than in forested areas. This effect can be explained by the existence of rich vegetation and a variety of habitats (Cook & Graham, 1996).

CONCLUSION

This study confirmed the effectiveness of light traps for monitoring noctuid moths. Such traps provide a valuable tool for capturing these insects in agricultural settings. The findings offer a systematic basis for developing timely pest control tactics. This approach supports localized pest management efforts to specific areas. Accurate taxonomic identification of insects is fundamental to effective pest management. Correct identification allows for the control of diverse pests with limited resources. This knowledge is particularly significant for protecting economically important cash crops. Understanding insect behavior and diversity is key to building robust control programs. By studying these intricacies, researchers can better address agricultural pest challenges. This work ultimately contributes to the development of sustainable pest management strategies.

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