Contents

LMA responses of understory plants to artificial light at night

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ABSTRACT

PREMISE:

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RESULTS:

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KEY WORDS light pollution, leaf mass per area(LMA), leaf punch, Artificial light at night(ALAN),

INTRODUCTION

Artificial light at night(ALAN), consists of artificial light sources emission and the light reflected back from the sky(skyglow), had disturbed ecological processes since the start of 20th century (Bennie et al. 2016; Longcore and Rich 2004; Gaston et al. 2013). So far, artificial light at night extends both in intensity covered a large illuminance range from the degree hard to detect to almost daylight and in extent covered more and more World's terrestrial surfaces (Bennie et al. 2016; 2016). Oganisms as well as habitats could be effected directly near artificial light at night(ALAN) such as streetlight and indirectly by sky glow scattered from city ALAN at rural-urban continuum. Ignoring the effect of artificial light at night to multilevel ecological processes is self-deception, hence more and more research would be carried through about this important topic(Davies and Smyth 2018).

Artificial light at night calls effects among wild taxonomic groups both zoology and botany, from mammals, birds, reptiles and amphibians, fishes, invertebrates and plants etc(Rich and Longcore 2006). Typically, lighted towers and glow of city lights confuse migrating birds(Loss et al. 2014), and streetlight attracting sea turtle hatchlings which dead parched(Brei, Pérez-Barahona, and Strobl 2016). Recently study shows ALAN is an important bringer to drive insects population decline (Boyes et al. 2021; Owens et al. 2020). And to plants, biomass would increase responsing to ALAN and show different ratio between widely and less-widely naturalized alien plants(**Speißer2021?**). Generally, artificial light at night could cause ecological effects spanning trophic levels, and the impacts depends on the wavelengths(Bennie et al. 2018). However, no rigorous studies have examined effects of artificial light at night on plants in conditions close to their natural environment.

In previous study, it has been demonstrated that nitrogen contents per unit leaf area N_a increased with environmental nitrogen contents, while LMA shows different correlation decreasing with N supply (Jullien et al. 2009; An and Shangguan 2008). Wright (2019) shows nutrients clearly limit tropical forest plants, and especially the limitation of N and P in both lowland and montane forests. Hence, besides the direct effect from ALAN the nutrients condition of the plants should also jump into our sight. By the light compass theory (Baker and Sadovy 1978; Sotthibandhu and Baker 1979) that insects orient themselves by maintaining a constant angle to light rays, artificial light at night plays a role of sink attracting insects which replaces the role of the moon and stars to a great extent. Further more, it's been showed that about 30%–40% of insects die soon thereafter approaching street lamps for collision, overheating, dehydration, or predation (Minnaar et al. 2015; Owens and Lewis 2018). Then comes our research hypothesis that ALAN would decrease LMA of plants around it indirectly as a side-effect of gathering phototaxis insects which chagnes the nutrients condition by distance.

Although LMA driven by inherent genetic mechanisms(Asner et al. 2011), environmental stresses (temperature, water and light) also shapes LMA. Acually, plants could sense light through photorecpetors which allows the plant to respond to four parameters of their light environment: light spectral quality, light intensity, light direction, and light duration(Paik and Huq 2019; Rich and Longcore 2006). For individual species, LMA was proportional with species distributions along the insolation gradient, and was significantly higher in evergreen versus deciduous species(Ackerly et al. 2002; Onoda, Schieving, and Anten 2008; Niinemets, Kull, and Tenhunen 2004). Here, ALAN could be considered as a conduct of prolonging light duration to plants so plants LMA could increase with that.

To know the effets of artificial light at night on perfomance of understory species so as a simulation to the city street shrubs, we conducted a forest artificial light experiment. Two species were chosen in this experiment representing sun species and shade species respectively to test whether different responds would show between them. We predicted that artificial light at night would bring effect to understory both aboveground as direct light supplementary and undergound as indirect soil nutrients supplementary. And we also predicted that canopy-openness and its interaction with artificial light at night would show weaker impaction in this experiment.

MATERIALS AND METHODS

experimental setup

The field experiment was located within the Xishuangbanna Tropical Botanical Garden(XTBG),China in rubber tree forest(N21°54' E101°16') where we totally set 5 plots and selected 2 plots for this this after field investiation. LED (10w) is used to create an artificial light environment in all plots at night. The LED system includes 6 components. A metal box with an opening is used as a rainproof protector which is attached to a tree at around 1.2 m from the ground. A rechargeable lithium battery (12v/30Ah) and an electric timer controls the timing and duration of the LED light operation at night. An electric wire was used to connect battery and LED which was hanging from a tree branch with a lampshade at approximately 2 m from the ground. Then the LED would work automatically from 8 pm to 5 am every day. This experiment started from 2019 November, and samples were collected on 2021 November.

Species Selection

Considering the understory condition (enough mature individual numbers, distribution of individuals) and species specificity(it should be evergreen species, and not be the nitrogen fix plants like Leguminosae) of each plot, finally two species respectively in two plots were chosen for our study, *Colocasia gigantea (Blume) Hook. f.* representing shade species and *Melastoma candidum D. Don* for sun species.

Measurements

We measured the horizontal distance and geographic orientation of each individual away from the LED using tape measure representing the relative effects of ALAN. Canopy openness was selected to be on behalf of day light, which photographed by Nikon COOLPIX4500 with fish-eye lens(Nikon FC-e8) then measured using R package *LeafArea*(Katabuchi 2015). For leaf mass per area(LMA), we use leaf disc(10mmˆ2) punched from leaf avoiding vein and leaf margin instead of whole-leaf to calculate LMA value.

Data Analysis

To analyze the effects of ALAN, daylight's effect, and their interaction on both *Melastoma candidum D. Don* and *Colocasia gigantea (Blume) Hook. f.*, We fitted a Bayesian linear mixed-effets model for each species using 'rstan' package in R. Leaf mass per area(LMA) of each leaf of each individual was the response variable. Distance from the ALAN of each individual was transformed by log and reciprocal for both the accumulation of insects and the intensity of ALAN fade away from distance. We conducted individual as a random effect for each species on our model, for the non-independence of individuals of the same species. All statistical analyses were conducted in R version 4.1.2 (**RCoreTeam2021?**). ** how to cite R? **

RESULTS

For species *Colocasia gigantea (Blume) Hook. f.*, both the effcts of ALAN and daylight were significant, while species *Melastoma candidum D. Don* showed no significance. Artificial light at night drove the averaged individual LMA value decrease for species *Colocasia gigantea (Blume) Hook. f.* (mean: -0.1043) and for species *Melastoma candidum D. Don* (mean: -0.0422) although not significant. Both species showed no significance on the interaction of the effects of ALAN and daylight. (Table 1.)

DISCUSSION

Although it has been demonstrated that LMA increase with insolation[], our research shows the artificial light situation could make differences. Actually, artificial light at night exerts an influence on the physiological processes of understory by multi-approach both aboveground and undergound. For aboveground part, artificial light at night change the light environments of plants including light duration, light intensity and light spectral quality. For underground part, artificial light at night indirectly changed the soil nutrients conditions especially as an important nitrogen supplementary. So the response results of understory could vary according to the species specificity[] and artificial light resource[].

There was research showed that plants' biomass would increase under artificial light[], our study showed the change part of biomass could be channelled into mixed results. Further more, adequate tests of the influence of artificial light at night on understory will entail more experimental work under field conditions. Controlling experiment probably tend to underestimate the environmental heterogeneity and species interaction, because many irreplaceable features of field conditions, such as subtle nutrients change, herbivores and competitors are usually absent. Hence the general pattern how understory species responds to artificial light at night remains unknown. In future work, diverse artificial light resource in light spectral quality and light intensity is need to simulate multi-situation of artificial light. And if possible, long term field experiment combining with controlling experiment approaching to plants natural growth situation will figure out the generalized patterns.

In conclusion, our study showed the LMA of some understory species would decrease with artificial light at night. The effects of artificial light at night consists of aboveground part directly as light resource and undergound part indirectly as soil nutrients. Still, more studies are needed to reveal the comprehensive effcts, from plant physiology to plant community. Nevertheless, the negative effct of artificial light at night on understory species indicates that increments of artificial light at night might bring about a physiological suppression to those understory plants.

ACKONWLEGEMENTS

AUTHOR CONTRIBUTIONS

MK and CZ conceived the study; CZ collected data and performed the analysis with MK together; all authors contributed to revisions.

DATA AVAILABILITY STATEMENT

SUPPORTING INFORMATION

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Fig. 1. The distribution of individuals around the ALAN and the illustration of the experiment setup. (a). The locations of the artificial-light-at-night plots and relative locations of each individual, each triangle represents one individual and the size of it represents the averaged LMA value. (b) and (c). Photographs of the experiment during the day and night.

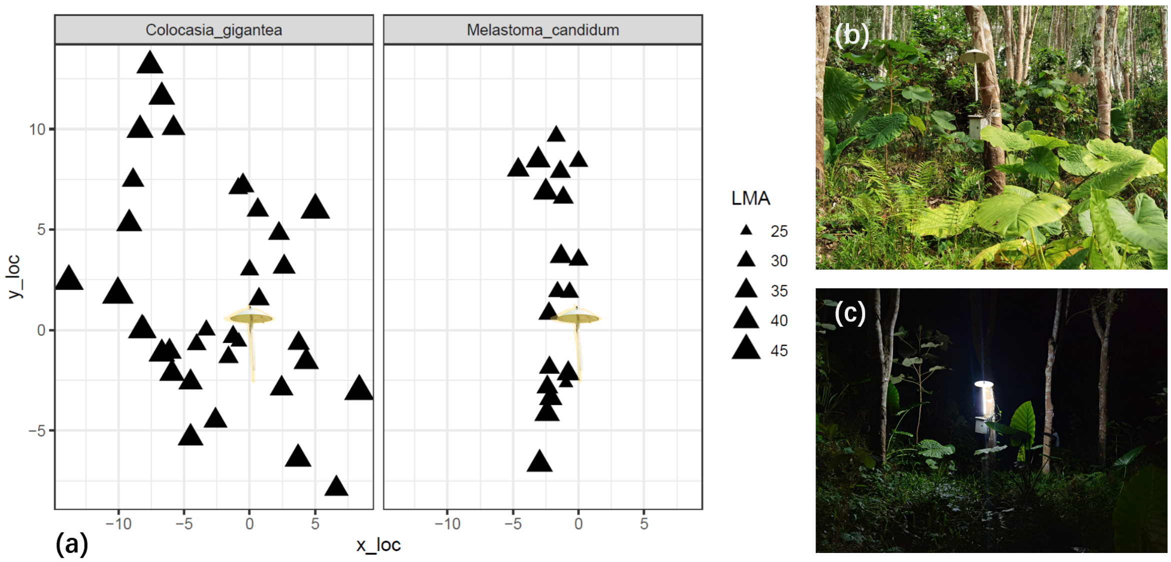

Table 1: Coefficients table

X	Parameters	mean_value	quantile_interval
Melastoma_candidum			
1	ALAN's effect	-0.0422	[-0.1129, 0.0276]
2	Daylight's effect	-0.0006	[-0.0761, 0.0744]
3	interaction	-0.0308	[-0.0836, 0.0216]
Colocasia_gigantea			
4	ALAN's effect	-0.1043	**[-0.1458, -0.0621]**
5	Daylight's effect	0.0495	**[0.0051, 0.0938]**
6	interaction	-0.0120	[-0.0428, 0.0195]

Table. 1.
Results of Bayesian general linear mixed-effect models testing the effects of artificial light at night, daylight and interaction on experimental species. Significant effects ($p < 0.05$) are in bold.