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AUTECOLOGY OF INVASIVE SPECIES *Cyperus rotundus* L. IN FOREST EDGE OF POHEN MOUNTAIN, BATUKAHU NATURE RESERVE, BALI, INDONESIA

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ABSTRACT

Anthropogenic-origin forest disturbance has been known to increase the risk of invasion to native habitat. Invasive species caused problems for local ecosystems and their native species. The research on the dynamics and autecology of invasive species *Cyperus rotundus* was conducted on anthropogenic disturbed Pohen mountain forest in Bali, Indonesia. Results showed significant changes in microclimatic variables from forest edge to interior. *C. rotundus* in Pohen mountain forest can be found in a road edge and forest exterior where sunlight is abundant and decrease in a more shady sites and absent under thick forest canopies CCA ordination analysis showed that *C. rotundus* in Pohen mountain forest tends to co-occur together with *Imperata cylindrica* and *Bidens biternata.* To be able to control potentially troublesome exotic invasive species, firstly we have to understand what factors limit their growth and development. Therefore this study is has important value because the data which from result in studying invasive species autecology will act as baseline data that will be useful to generate management program including rehabilitation and restoration program.

Key words: species dynamics, autecology, Cyperus rotundus, Pohen mountain forest, Bali

INTRODUCTION

Nowadays mountain rain forests are becoming more and more threaten due to increase in human activity (Horn *et al*., 2001; Lavigne and Gunnel 2006), including forest on Pohen mountain in the Batukahu Nature Reserve area, Bali. The establishment of roads and pathways from the geothermal power plant activity creates an opening. The edge between this forest and the road opening is known to have different environmental condition such as higher level of sunlight and wind speed compare to interior of the forest (Chen *et al*., 1992). This condition is also known as the edge effect, which are characterized by microclimatic gradients and changes in vegetation composition from forest edge to interior (Forman 1995).

Abundant resources in the forest edge can contribute to the increase in number of species especially invasive ones. The opening of the forest creates a gap where direct sunlight reaches the floor and catalyses the germination of species that were dormant as soil seed banks such as those from Poaceae family (grasses) (Austin and Pausas, 2001; Aubert *et al*., 2003; Pena, 2003). Invasive species can cause problems for local ecosystems and their native species. Invasive species affecting the soil nitrogen availability in China (Bao *et al*., 2009), threaten the mangrove ecosystem in Bangladesh (Biswas, 2007), and influencing plant diversity in riparian ecosystem in Oregon (Fierke and Kauffman, 2006).

To be able to control other potentially troublesome exotic invasive species, firstly we have to understand what factors limiting their growth and development. However, the information regard to limiting environmental factors for other problematic alien invasive species is still inadequate (Kunwar, 2003), particularly in Indonesia. Thus, to remove invasive species, encourage to native, further studies and assessment of the invasive species will be required.

This research was conducted to study the autecology of nutgrass (*Cyperus rotundus* L.), one of the most invasive weeds in the world, in relation with another plant species in forest edge of Pohen Mountain forest. Autecology is the study for one species in relation to its environment which comprises other organism and abiotic factors (Jongman *et al*., 1987). In this study, we measured microclimatic gradient from forest edge to interior and identified vegetation patterns along that gradient. We also identified the association of *C. rotundus* with other plant species and identified the relationship between microclimatic variables with *C. rotundus* abundance. This study has important value because the data resulted in studying invasive species autecology will act as baseline data that will be useful to generate management program including rehabilitation and restoration program. One example is weed management to reduce the domination of exotic pioneer species and promotes the establishment of native species.

MATERIAL AND METHODS

The project was conducted in the Batukahu Nature Reserve, where most of it is situated in an area named Bedugul. Bedugul is located in a high plateau at the center of the Island of Bali, about 70 km North of Denpasar. The altitude varied from 1000 to the highest mountain is 2000 m asl. Bedugul is a part of two district; the Tabanan in the South and Buleleng district in the North. Generally according to Schmidt's and Fergusson's climate classification, Bedugul area is included in the A type of this climatic classification. It has rainfall average of 2000 mm/year, with 155.6 rainy days/per year average and temperature range from 11.5-24°C.

Sampling was done by establishing two line transects (line A and B) from forest edge up to interior. The distance between two transects was 100 m. In each transect we made 5 observation plots of 20×20 m at 0, 20, 40, 60 and 80 m distance from forest edge for trees inventorying. In total there were 10 plots. Trees (dbh≥10 cm) species were noted and number of individuals counted (Kent and Coker, 1992). We also used subplots of 2×2 m for understory invetorying.

All plants within each site were identified to species as possible. Identification was conducted at the Herbarium Bali Botanic Garden. Identification was done using flora books such as "the Flora of Java" (Backer and van den Brink, 1963) and "Mountain flora of Java" (van Steenis, 1972) and also confirming the results with a botanist. We also measure microclimate variables such as light intensity, wind speed, air temperature and relative humidity. The measurement was conducted in every plots with twice repetition. All these microclimatic variables were measured in the morning between 09.00-11.00 a.m.

We used linear mixed-effect model to show the relationship between the distance from forest edge with the measured microclimatic variables, and the relationship between *C. rotundus* abundance with the main microclimatic variables. We also conducted canonical correspondence analysis (CCA) ordination to see the influence of microclimatic factors on vegetation composition and association of *C. rotundus* with other plant species.

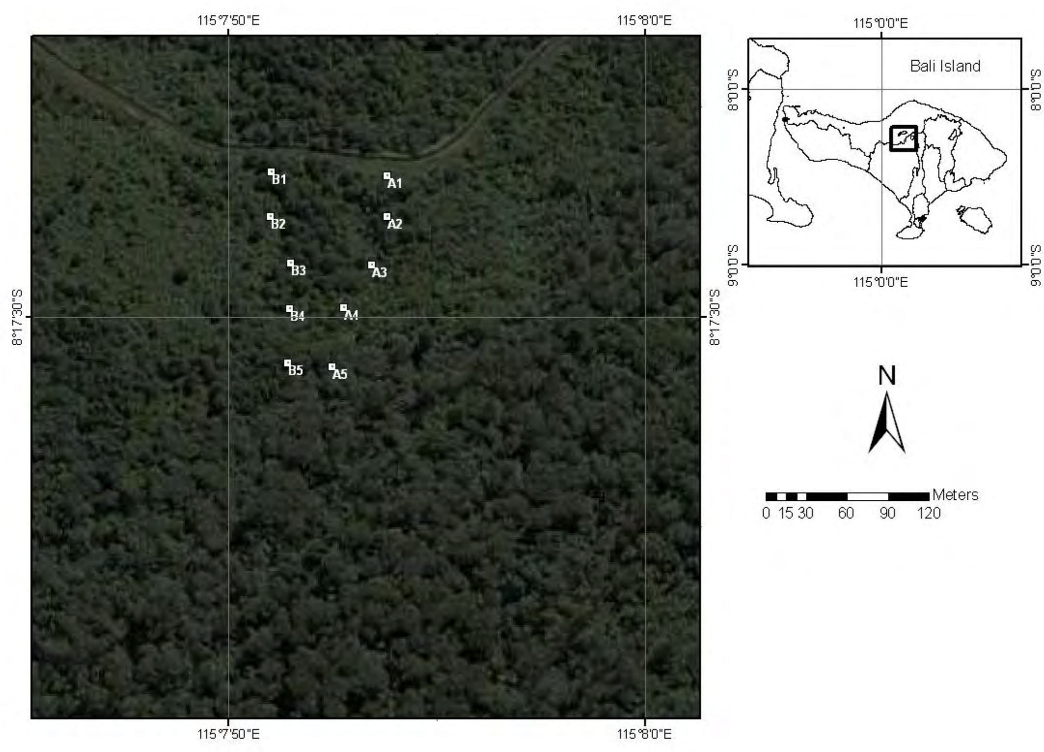

Figure 1. Research site location and sampling points on Pohen mountain forest as seen with Google Earth and Google Maps^{TM} 2011.

RESULTS AND DISCUSSSION

Nutgrass or *C. rotundus* is a very invasive weed. It has purple-brown, bisexual flowers. The fruits are achenes; purple nut sedge grows up to 2½ tall. The leaves are dark green, grass-like, with a prominent vein on the underside. It has red-brown spikelet with up to 40 individual flowers (Backer and van den Brink, 1963; van Steenis, 1972). *C. rotundus* is distributed throughout Atlantic Europe, western and eastern Mediterranean, Balkan Peninsula, Minor and Central Asia, tropical Arabia, Africa, North and Southern America, and Australia (Agro Atlas, 2010; Pagad, 2011). Physical or environmental easurement which correlated with invasive species distribution is has important value to understand the autecology of these species in order to control and manage them.

We used log transformation for the light intensity data. Our result suggested that light intensity was significantly decreased from forest edge to interior. We also found similar result from the temperature data. Wind speed was also significantly decreased along the forest edge. For the humidity data, we used the arcsine square-root transformation. In contrary, humidity was significantly increased along the forest edge to interior. Detailed results of microclimatic gradients from forest edge to interior can be seen in Figure 2.

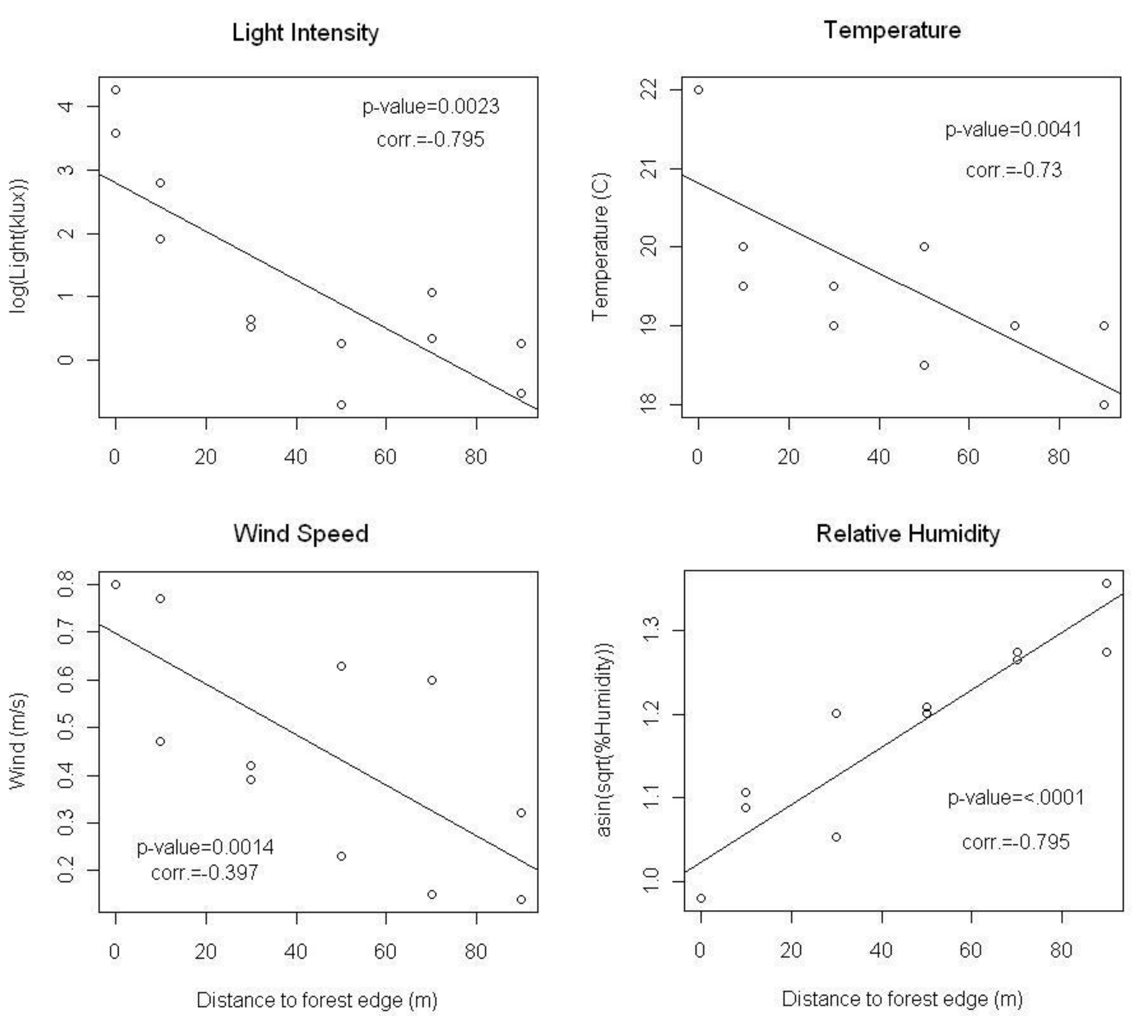

Figure 2. Microclimatic gradients along forest edge to interior in Pohen mountain forest.

CCA ordination suggested that CCA axis 1 explained 46% of the total variance, while CCA axis 2 explained 29.5%. Temperature and wind speed were the microclimate factors that mainly explained vegetation composition in the study site (Figure 3). Referring to Figure 2, plot A1 and B1 which were plots that near the road showed highest light intensity and temperature values. This value was decreasing as the plots moved to forest interior. In Figure 3, *C. rotundus* was located near light intensity and temperature arrows. Therefore *C. rotundus* seemed that might have some kind relationship with light availability and temperature as the main microclimatic factors that regulate its abundance and distribution. We further tested the correlation between *C. rotundus* abundance with the main microclimatic factors.

Figure 4 showed that *C. rotundus* abundance had a significant correlation with light availability, but not with temperature In terms of community composition, the ordination analysis using CCA identified that there was a clear separation of the plots below and upper the CCA axis 1 (Figure 3). Clear separation of the plots indicated that there is a difference in terms of species composition in these areas. The close points for plots below and upper CCA axis 1 indicated that species composition in these plots were quite similar to each other.

Figure 3 also showed that *C. rotundus* in the sampling location of Pohen mountain tends to present close together with *Imperata cylindrica* and *Bidens biternata*. Other group also apparent such as *Lantana camara* and *Glichenia linearis*, and group of trees and their seedling such as *Litsea* sp. and *Acronychia trifoliata*. There was also species that were tends to solitaire such as fern species *Athyrium asperum*, and for tree species it was *Homalanthus gigantheus* which is known as characterizing species for disturbed sites in Indonesia (Kebler, 2001).

The phenomenon that some species tends to co-occur together may be the result from biological interaction between them or perhaps indicating similarity in responding to disturbances and abiotic factor changes in their habitat (Dukat, 2006). Therefore, species co-occurrence observations may be seen as the first attempt to detect species interaction (i.e.facilitation and inhibition) and niche process that structuring the community (Walker and del Moral, 2003; Widyatmoko and Burgman, 2006). By taking the advantage of the results from exploring the few species that are strongly associated, the study into the role of species interaction throughout the community succession post-disturbances may become more effective (Myster and Pickett, 1992).

To be able to control other potentially troublesome exotic invasive species firstly we have to understand what factors limit their growth and development. For example *Lantana camara* is intolerant to frequent soil disturbance, and this rapidly spreading, fire resistant exotic species is also unpalatable and poisonous and has become weed elsewhere (FEPPC, 2005). Meanwhile soil moisture stress and competition with the adult plant was proposed as one of the possible factors regulating the population of *Eupatorium* spp. (Yadav and Tripathi, 1981).

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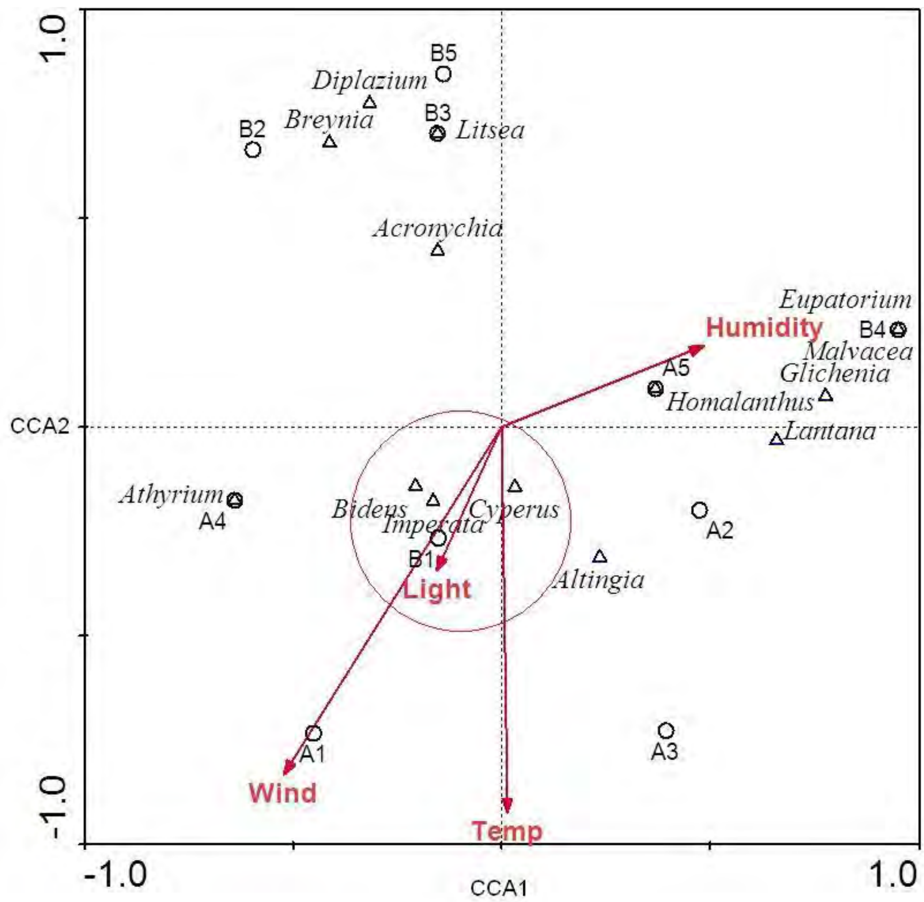

Figure 3. CCA ordination of vegetation and microclimatic factors at the study site in Pohen mountain forest in relation to the first two CCA axes.

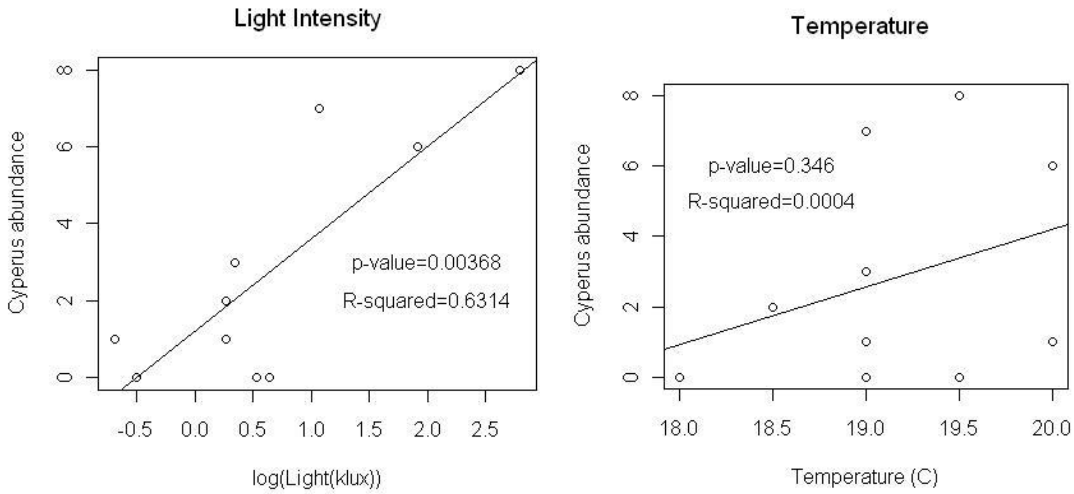

Figure 4. Relationship between light intensity and temperature with C. rotundus abundance in the study site.

C. rotundus commonly been known to populate sandy places, humid rivers bank and cotton and rice fields. In natural conditions, it develops on loamy and damp solonetzic soils, especially on alluvial "cultural" layer of irrigated crops. It develops better on friable, well aerated sandy and argillaceous unsalted soils. It is depressed on heavy and salted soils (Soerjani *et al*., 1987).

C. rotundus also known as light-loving plant where it is found that in light places it forms over-ground shoots 6 times larger and the number and length of rhizomes increase by 1.5 times compare with shady ones. It is dispersed to new territories with main watering, in the lesser degree with manure, bird excrements, by wind and wheels of agricultural instruments and transport (Radosevich *et al*., 2007)

In order to promote establishment of native species, control of weeds including *C. rotundus* is needed to be done. Management control of *C. rotundus* can be done manually by removing the tuber by making shallow tillage, this tillage activity must be done at frequent interval. Physical control can be done by making a barrier using plastic polyethylene mulch. Weed suppression can also be done by use of allelopathic plant such as those from Brassicaceae family (Bangarwa, 2008). Application of Luken succession management theory (Luken, 1990) in terms of controlling *C. rotundus* can also be done by changing its resource availability. This study has also shown and confirm previous finding that *C. rotundus* is a light demanding species. Hence the use of shade from tree canopy is an important action to suppress *C. rotundus* and kick start the vegetation succession sequence and site recovery.

CONCLUSION

This study has increased our knowledge about the autecology of *Cyperus rotundus*. *C. rotundus* known as light-loving plant and in Pohen mountain forest it was found in a road edge and forest exterior where sunlight is abundant and decrease in a more shady sites. *C. rotundus* tends to present close together with *Imperata cylindrica* and *Bidens biternata*. This study has important value because the data resulted from studying invasive species autecology will act as baseline data that will be useful to generate management program including rehabilitation and restoration program. One example is weed management to reduce the domination of exotic invasive species and promotes the establishment of native species.

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