Kirinyuh (Chromolaena odorata): species distribution modeling and the potential use of fungal pathogens for its eradication

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Abstract. Chromolaena odorata is one of the weeds that is difficult to control and causes loss both economically and ecologically. This study aims to predict the distribution of C. odorata which affected by climate change and the potential of using fungal pathogens for its eradication efforts in Indonesia. The Biodiversity and Climate Change Virtual Laboratory application was used to create Habitat Suitability Index of C. odorata. Species data were obtained from the Global Biodiversity Information Facility and the variable environment parameters were obtained from the Worldclim current condition (1950-2000). Results show that Generalized Linear Model has values of 0.98. C. odorata most likely spreads to eastern parts of Indonesia. The model predicted it to be suitable to inhabit Bali-Lombok Islands (HSI ±0.8) as well as Lesser Sunda Islands, Flores (HSI ±0.76) and Sumba (HSI ±0.82), and also Papua which share similar HSI with Sumba. Four species of putative fungal pathogens were isolated from the diseased leaf tissue of C. odorata. One species of fungus that causes severe infection in the leaves of C. odorata was morphologically identified as Septoria sp. It considered as a biological control agent. Further studies are needed to confirm this association and their potential for biological control.

1. Introduction

Chromolaena odorata or better known as Kirinyuh or Siam Weed is one of the weeds that is difficult to control and causes many losses both economically and ecologically [1]. Its rapid regeneration with seeds and vegetative, makes manual weed control effort difficult. After the fires, C. odorata are able to regenerate vegetatively by trubulation and are able to transform open land and dominated the area [2]. This can cause ecologically negative impacts such as decrease in the amount of natural/native/local biodiversity as well as changes in ecosystem function [3]. This weed is indeed the most problematic in humid tropical countries. In Indonesia, there are different opinions about when the start of the spread of weeds in the country. However, it is calculated approximately to establish since the early 1900s in Lubuk Pakam North Sumatra [1,4].

Ecological tasks such as research on its ecological distribution to understand how species and communities respond to change are critical. Climate change can facilitate the invasion of new species to new areas [5]. Species Distribution Model (SDM) technique have the ability to assess the current distribution and predict its distribution based on climate shifts under different global change scenarios.
at species levels [6]. Therefore, SDM can identify areas at risk of further invasion by invasive alien species so that early prevention of action can be done with appropriate approaches.

Weed is commonly controlled with manual or mechanical means through slash and burn or mechanical ploughing [1,7]. Despite the report that ploughing to a certain depth will destroy the weed, manual or mechanical methods are considered less effective as the plant will resprout in a short time from underground plant remnants. Manual or mechanical methods will also require high labor input. Chemical control using several pre-emergence and post-emergence herbicides has become another prevalent method to control the weed. The use of herbicides gives better results regardless the need of repeated application within this method. Furthermore, undesirably the chemical control is costly, potential giving negative effects to the environment, and only suitable for large area.

The development of biological control in managing *C. odorata* is a promising method that is relatively cheap and environmentally safe. *C. odorata* can be a perfect target for biological control as the weed is perennial, widespread and abundant so that ensures constant food supplies for its natural enemies [7]. A number of insect pests such as aphids, weevils, and mites cause significant damages on *C. odorata* [8]. The presence of microorganism associated with disease symptoms on *C. odorata* has also been reported. Some fungal species infecting *C. odorata* including *Cionothrix praelonga*, *Septoria ekmaniana*, *Anhellia niger*, *Mycovellosiella perfoliata*, and *Phoma* sp. [9,10]. The pathogens can decrease the vigour and competitiveness ability of *C. odorata* [11].

The use of insect as biocontrol shows less successful compared with other biocontrol methods. However, the use of pathogen microorganism is still limited [7,8]. In Indonesia, biological control is considered has not been undertaken for this species [12]. Many biological control efforts for *C. odorata* are still at initial phase, and most of them failed. The implementation and effectiveness of biological control agents in controlling *C. odorata* has been initiated and demonstrated [9,13]. However, many factors such as compatibility with the climate, biological attributes of the agents, and new exploration of the agents were suggested to be considered for complete success in the biological control of *C. odorata*. The aims of this research were to identify areas at risk of further invasion of *C. odorata*. This research also will seek the potency of biological control as an appropriate control measure to obstruct rapid spread of *C. odorata*.

2. Materials and Methods

2.1. Species distribution model analysis

The Biodiversity and Climate Change Virtual Laboratory (BCCVL) application (http://www.bccvl.org.au/) was used for the analysis of species distribution model (SDM) in this study [14,15]. Basically, SDM requires species matrix as response variable and environmental matrix as predictor. Species occurrence data that will form a species matrix is obtained from the Global Biodiversity and Information Facility database (GBIF/ http://www.gbif.org/). The GBIF database has about 5,389 geo-referenced for *C. odorata* records. The data then imported into BCCVL. The species data acts as response variable. The climate layers obtained from Worldclim current condition (1950–2000) also available in the BCCVL. Air temperature and rainfall variables are selected as shown in Table 1.

| No. | Symbol | Remarks |
|-----|--------|---------|
| 1   | B01    | Annual Mean Temperature |
| 2   | B02    | Mean Diurnal Range (Mean of monthly (max temp - min temp) |
| 3   | B03    | Isothermality (BIO2/BIO7) |
In the BCCVL, SDM analysis that we conducted was done using Generalized Linear Model (GLM) method that enable us to examine potential distribution of *C. odorata* under current and predicted climatic conditions. The prediction is visualized as the fitness of a grid cell on a scale from 0 to 1, where 0 refers to very low suitability and 1 refers to very high suitability. The principal output of a Species Distribution Model is a map that illustrates the predicted distribution of *C. odorata* based on the previously input baseline data. The predicted distribution implies the distribution of suitable habitat as defined by the environmental variables included in the model, and not the actual species occurrence [15]. Model strength was evaluated using the AUC (Area Under the Curve) of the ROC curve (Receiver-Operating Characteristics) [16]. The value for ROC is the area under the curve (AUC). AUC score is interpreted as follow: values above 0.9 is excellent, good 0.9 > AUC > 0.8, fair 0.8 > AUC > 0.7, poor 0.7 > AUC > 0.6 and fail 0.6 > AUC > 0.5 [6,17].

2.2. Biological control potential

Field surveys and laboratory studies of fungi associated with *Chromolaena odorata* were carried out at several sites located in Bandung Regency, West Java and the Laboratory of Plant Protection Biotechnology, Universitas Padjadjaran, Bandung, Indonesia. *C. odorata* plants grown particularly in bushland were surveyed and observed for the occurrence of plant diseases. Diseased *C. odorata* plant parts were opportunistically sampled, and the tissues were collected from the plants showing disease symptoms or signs. Plant materials were placed in paper bags and transported to the laboratory in an insulated container where they were stored in a refrigerator at 4°C until further examination.

Isolation from diseased plant parts were made by cutting pieces of diseased and healthy tissue and dipping them momentarily in 70% ethanol, followed by a solution of 1% sodium hypochlorite for 1 minute, washed 3 times in sterile distilled water, and placed in petri dishes containing half-strength Potato Dextrose Agar (½ PDA; Becton, Dickinson, Sparks, USA) with chloramphenicol (0.02%) added. The plates were maintained at room temperature and the cultures derived from the treated plates were sub-cultured onto fresh ½ PDA plates and maintained at 25°C. Pathogen identification was conducted both macroscopically and microscopically. Macroscopic observation was performed on...
samples of diseased plant material or fungal culture that had been isolated. Microscopic observation was done on the basis of spore types and other characteristic of the fungi [18].

3. Results and Discussion

3.1. Chromolaena odorata distribution model

Our data analysis results shows that with the current climate, it is predicted that C. odorata most likely to spread to eastern parts of Indonesia although some parts of Java especially in the south coast of East and Central Java, also predicted to be suitable for the species (Figure 1). To the eastern Indonesia, C. odorata predicted to be suitable to inhabit Bali and Lombok Islands (HSI ±0.8) as well as Lesser Sunda Islands. Most of Flores (HSI ±0.76) and all of Sumba Islands (HSI ±0.82) are suitable for C. odorata. Eastern Kalimantan (HSI ±0.72) as well as western Sulawesi (HSI ±0.72) and Papua are also predicted to be suitable for C. odorata (HSI ±0.84). Several of the climate variables respond to the prediction of C. odorata distribution such as isothermality, precipitation of driest quarter, annual precipitation, temperature seasonality, precipitation seasonality, and precipitation of warmest and coldest quarter and lastly, the most responsive was the mean temperature of the wettest quarter (Figure 3). In general, our model performance is of good results as AUC values (0.98) (Figure 4).

It appears that in the future, C. odorata will become problematic as well in the eastern part of Indonesia. Although this weed has been invading Sumatra and Java which have wetter climate, C. odorata seems to be shifting its preference. As shown by the species response curve for annual precipitation, C. odorata occurrence reached maximum suitable index at precipitation around 700 to less than 2000 mm/yr. However, this is merely a prediction using the climate data. Perhaps there are other factors that need to be considered as well that are not included in our model. Factors such as topographic and soil, dispersal mechanism, dispersal agent, anthropogenic involvement in dispersing it by means of migration and forest destruction as well as their eradication efforts. Considering this weed can cause value lost to both ecologically and economically, hence social factors are also perhaps needed to be included. Chromolaena odorata is unable (intolerant) to grow under shade of forest or tree stand. Therefore the high rate of anthropogenic disturbance such as forest destruction could also increasing the risk of invasion of C. odorata [19].

Figure 1. Prediction map of invasive alien species Chromolaena odorata distribution in Indonesia using Generalized Linear Model (GLM) within the BCCVL application (AUC = 0.98)
Figure 2. Mean Habitat Suitability Index for *Chromolaena odorata*

Figure 3. Species response curve of *C. odorata* toward environmental factors that were used in this study. X axis refers to the environmental factors and Y axis refers to occurrence index of the species. See table 1 for meaning of B01 – B19
3.2. Biological control potential

Initial research and observation showed that many C. odorata plants suffered from foliar disease with initial symptoms of necrosis and chlorosis (Figure 5). These disease symptoms were resulting from biotic and abiotic agents. Fungal foliar disease with leaf spots was the most frequent symptom and occurred on C. odorata in all sites. Meanwhile, a leaf spot that developed into foliar blight symptom was considered to be the most prevalent fungal disease and occurred severely with disease intensity reached up to more than 80% in a few of C. odorata plants.

Biological control is an alternative control that can be done without having negative influence on the environment and its surroundings [20]. In contrast to classical biological control i.e increasing the antagonistic capacity of organisms as competitors, parasites, or producing antibiotics against plant pathogens, plant (weeds) biocontrol is an attempt to utilize pathogens to reduce losses caused by the weeds [21]. Many types of fungi attack certain types of weeds and some are reported practically control the weeds, for example Acacia glauca controlled by the fungus Cephalosporium zonatum and Chondrilla juncea controlled by the rust fungus Puccinia chondrillana [21]. Plant pathogenic fungi can potentially be a good biocontrol agent to control weeds because the infection can cause severe damage to these weeds [22]. The fungal pathogen group is the most potential weed biocontrol agent because it is the most common found plant pathogen and has high destructive capability [23]. In the case of C. odorata, the weed is attacked by a number of insects and pathogens that some are considered as potential biocontrol agents and need to be explored. Several species of fungi from the Mycosphaerellaceae family have been reported to cause damage to C. odorata, namely Pseudocercospora eupatorii, Passalora perfoliati, and Septoria ekmaniana [10]. The fungi of the Mycosphaerellaceae family are stated to be a host of the specific fungi. With the serious damage that can be caused and the nature of the host specific pathogens, these species are mentioned as potential species to be used as bio-control agents for C. odorata [9,10].

Fungi were isolated from leaf lesions of naturally infected C. odorata plants in laboratory conditions. Four fungal isolates were isolated but not all cultures have been specifically identified. All cultures can be considered as fungal pathogens since they were isolated from the diseased leaf tissue. One species of fungus that causes severe disease symptom as mentioned above on C. odorata leaves was morphologically identified as Septoria sp. This species can be useful for a biological control agent. Previous research reported that Septoria ekmaniana is a promising candidate for biological control of C. odorata [9,10]. Further studies concerning disease intensity, pathogen identification, and pathogenicity test are still needed to confirm the fungal status associated with C. odorata. Meanwhile,
the studies on the criteria and the host range of biocontrol agents will verify whether the isolated fungal species would be of any potential for further utilization in biological control of this weed.

![Image of disease symptoms on C. odorata leaves and flowers](image)

**Figure 5.** Disease symptoms on *C. odorata* leaves and flowers

### 4. Conclusion

With climate change to consider, *C. odorata* most likely to spread to eastern parts of Indonesia. The high incidence and disease intensity of *C. odorata* in this initial study suggests the potential for the development of fungal pathogens as biocontrol agents to control *C. odorata*. Several species of fungi were associated with *C. odorata* and several of them have been isolated and identified. However, this research is still ongoing to obtain accurate and comprehensive information regarding the incidence and type of disease, characteristics of the pathogen, and disease ecology of *C. odorata* plants.
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