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Original article

Invasion establishment and habitat suitability of *Chromolaena odorata* (L.) King and Robinson over time and space in the western Himalayan forests of India

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ABSTRACT

Habitat suitability assessment of the invasive species *Chromolaena odorata* (L.) King and Robinson from Himalayan forests reveals some interesting findings and conclusions. At different study sites, 29 of 72 species were exotic and invasive and comprised 21 genera and eight families. Indigenous species accounted for 59% of the total species and comprised 26 genera and 11 families. Perennials outnumbered the annuals in all study sites. *Chromolaena odorata* and *Lantana camara* L. were the only invasive species that were common to all sites with high importance value index values. The present work reveals that sites with high biotic pressure, maximum temperature variation, open forest canopy, and free from herbivory are the most suitable habitat for the growth of *C. odorata*. An elevated level of phosphorus, potassium, magnesium, soil organic matter, and nitrogen and acidic soil in all invaded sites are possible reasons for further invasion of *C. odorata*.

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Introduction

Chromolaena odorata (L.) King and Robinson (henceforth *C. odorata*), a species of the Asteraceae family—also known as "Christmas bush", "bitter bush", "Siam weed", "baby tea", "cariaquillo", "Santa María", and "fleurit Noël"—is a scrambling shrub (Howard, 1989; Liogier, 1997). It may reach 1 m or more as a free standing shrub and 4 m or more when climbing into trees or shrubs. Stems reach 2 cm in diameter (Figure 1). The plants are maintained by a system of abundant, yellow, fine lateral roots. Individual branches are long with relatively little branching. The seeds are a brown-gray to black achenes that are 4 mm long with a pale brown pappus 5–6 mm long (Howard, 1989; Liogier, 1997).

Chromolaena odorata is native plant from Florida to the West Indies and from Texas through Central America and through South America to Argentina (Howard, 1989; Liogier, 1997). It is found accidentally or is deliberately introduced. It is naturalized throughout much of the tropics such as in Guam and Hawaii (Pacific Island Ecosystems at Risk, 2001). It is reportedly one of the world's most invasive weeds, and is a serious weed in central and western Africa, India, Australia, the Pacific Islands, and Southeast Asia (McFadyen, 2003). This species has a wide tolerance to various climates and has invaded five continents (i.e. Asia, North and South America, and North and South Africa; Kriticos et al., 2005). It can become quickly established and smother plant crops, forestry, and native vegetation (McFadyen and Skarratt, 1996). It is unpalatable and noxious and may cause death if domesticated animals ingest it (Aterrado and Bachiller, 2002). *Chromolaena odorata* distribution areas are roughly divided into three types: (1) areas where *Chromolaena* is not yet reported; (2) areas where *Chromolaena* is introduced; and (3) areas where *Chromolaena* is native (Zachariades et al., 1999) (Figure 2). The geographical distribution of *C. odorata* is limited to regions within the latitudes of 30°N and 30°S and in areas with a rainfall of ≥ 200 cm and where air temperature ranges 20–37°C (Timbilla and Braimah, 2002).

The weed grows in areas that are near sea level to areas > 1000 m in elevation (Binggeli, 1999). It thrives in all types of well-drained soil and can grow on soils that are relatively low in fertility. Disturbance is required before a site can be colonized (Pacific Island Ecosystems at Risk, 2001). Once established, this weed competes aggressively with herbs, grass, and shrubs in open areas. In its

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Figure 1. A sketch of *Chromolaena odorata* (L.) King and Robinson. (Image courtesy of http://www.tramil.net/fototeca/imageDisplay.php?id_elem=169&lang=en; Reprinted with permission).

native range, it frequently grows on roadsides, riverbanks, vacant lots, abandoned farmland, and neglected pastures. According to Ohtsuka (1999) this weed can be found in a particular niche in the slash-and-burn agriculture cycle, and in Borneo this weed along with other perennial grasses and shrubs are invaded within 3 years of abandonment and are gradually replaced by trees. The species is shade intolerant and will not grow under a closed forest stand. It is also intolerant of frost (Binggeli, 1999) and is limited by drought (i.e. approximately $<$ 900 mm of mean annual precipitation).

The invasion of natural communities by these introduced species constitutes a major threat to biodiversity globally (Lodge 1993; Adair and Groves, 1998). Invasive plants adversely affect ecosystem structure and function in habitats throughout the world by reducing native species richness, altering water or fire regimes, changing soil nutrient status, and altering geomorphological processes (Macdonald et al., 1989; Cronk and Fuller, 1995; Rose, 1997). A major challenge for invasive plant research is developing the ability to predict the invasiveness of species and invisibility of habitats (Kareiva, 1996). Human activities have transported the plants worldwide, yet only approximately 10% of introduced species become established, and 10% of these become invasive (Groves, 1991).

For predicting invasiveness, several generalizations have been proposed such as the degree of similarity between the new climate and the native climate (Cronk and Fuller, 1995; Crawley et al., 1997) and invasiveness in other new habitats (Scott and Panetta, 1993; Reichard and Hamilton, 1997). Many studies have focused on identifying plant traits that confer invasiveness. Early work by Baker, (1974) identified the attributes of an ideal weed, including fast vegetative growth to flowering, production of large quantities of seed, vegetative propagation, and nonspecialized pollination system, and germination requirements. This approach is useful as a checklist of potential warning signs, although it is too broad to be of much predictive value (Noble, 1989). Some studies have been too broad in their scope by using too wide a range of habitats [e.g. worldwide (Binggeli, 1996) or North America (Reichard and Hamilton, 1997)] or by combining agricultural and environmental weeds (Newsome and Noble, 1986; Williamson and Fitter, 1996a). The lack of clear patterns has led to the suggestion that predicting invasiveness is impossible (Williamson and Fitter, 1996b).

Such studies have lacked environmental specificity (Newsome and Noble, 1986; Reichard and Hamilton, 1997). The most successful attempts to predict invasiveness based on species attributes have been confined to the genus *Pinus* (Rejmánek and Richardson, 1996; Grottkopp et al., 2002). An alternative hypothesis to explain the success of exotic species is that they are released from coevolved natural pests and predators in the new environment. Release from natural pests may increase plant fitness by several potential mechanisms: (1) a direct effect, the so-called "predator-release effect" (Newsome and Noble, 1986); (2) reallocation of resources from defense to growth (Crawley et al., 1997); or (3) as a result of selection of genotypes with increased allocation to growth and decreased allocation to defense [i.e. the evolution of increased competitive ability hypothesis (Blossey and Notzold, 1995)].

Landscape transformation by humans has been rapid, widespread, and extraordinarily thorough in many cases (Whitney, 1994). It is therefore no coincidence that anthropogenic disturbances resulting in habitat destruction and fragmentation are viewed as the leading threats to biodiversity, followed by the threat posed by invasive species (Wilcove et al., 1998). Fragmentation is characterized as "landscape level" disturbance and the disturbance is nearly unanimously acknowledged to influence invasive spread (Fox and Fox, 1986). Thus, habitat loss and fragmentation may facilitate the spread of invasive species. Other studies have shown that, in dry regions, increasing the water supply (whether by natural rainfall or by experimental additions) increases the invisibility of vegetation by a direct effect of the water supply or by improved access to mineral nutrients (Burgess et al., 1991; Dukes and Mooney, 1999).

In this study, we hypothesized that, after the Doon Valley became the capital of the state Uttarakhand, there has been a considerable change in economic possibilities available to local and outside people; hence to gain maximum benefit, there is a significant increase in the migration of people from within the state and outside the state. This increasing human population of the state has decreased land cover and forest size and has increased the number of people per forest area. Thus, increasing pressure on remaining forest areas may have led to changes such as forest canopy gaps, reduced understory biomass, and soil nutrient alteration, which further intensify the invasion of introduced species such as *C. odorata*, *Lantana camara* L., and *Parthenium hysterophorus* L. In particular, we try to disentangle the factors influencing the establishment of invasive exotic species in different altitudes and disturbance types. In this study, we attempted to assess the distribution, frequency, and abundance of *C. odorata* from different locations in the Doon Valley, based on different plant species' importance value index calculation (a simple yet powerful tool for assessing biodiversity). The scope of present study does not restrict itself to this alone but also throws light on the other dominant plant

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