Effects of *Imperata cylindrica* on Microbial Community

Subjects: Biology

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Imperata cylindrica (*I. cylindrica*) is native to Southeast Asia and East Africa and has become naturalized in humid tropics, subtropics and warmer temperate zones of the world. The species is one of the top ten worst weeds in the worlds and is listed among the world's top 100 worst invasive alien species. *I. cylindrica* was reported to affect the microbial flora in the soil of invaded areas and enhance the decomposition process of the plant residue

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1. Introduction

Imperata cylindrica (L.) Beauv., belonging to Poaceae, is a C_4 perennial rhizomatous grass species (**Figure 1**). This species has an extensive rhizome network. The rhizome development of *I. cylindrica* occurs 3–12 weeks after germination, beginning with downward growth. When the rhizome develops cataphylls, it grows horizontally, and the tip of the rhizome begins to turn upward between the fifth and sixth leaf stages. Then, a secondary shoot and rhizome arise from the apical bud and subapical bud of the first rhizome, respectively. The secondary rhizome produces the third shoot and rhizome, continuing the following shoot and rhizome formations [1][2][3][4][5]. It was reported that one plant produced 31 rhizomes in 10 months, with a total rhizome length of 12 m [6]. The shoots form loose to compact tufts. Several leaf sheaths are often tightly rolled together, forming a cylindrical culm. *I. cylindrica* is virtually stemless, except for the flowering stalks. The leaves are flat, slender (4–10 mm in wide) and linear–lanceolate (15–150 cm in length, depending on the growth condition), possessing serrated margins embedded with sharp silica crystals. Stomata are present on both surfaces of the leaves [7][8][9][10].

Figure 1. *Imperata cylindrica*. Photos were kindly provided by Dr. T. Tominaga.

I. cylindrica is native to Southeast Asia and East Africa and has become naturalized in humid tropics, subtropics and warmer temperate zones of the world [1][11][12][13][14]. The species is considered one of the top ten worst weeds in the world and is listed among the world's top 100 worst invasive alien species [1][12][13]. *I. cylindrica* thrives in the 10 southeastern states of the USA, the Mediterranean region, northern Africa to the Middle East, tropical and subtropical Asia, Australia and the Pacific Islands, covering more than 500 million hectares worldwide [3][12][13][15][16][17]. Very large monospecific stands of *I. cylindrica* of more than 10,000 hectares in size, known as mega grasslands, are often observed in Indonesia as a climax species [18][19]. Large monospecific stands are also observed in Africa from Egypt to Ethiopia [1]. The species grows between latitudes 45° N (e.g., Japan) and 45° S (New Zealand) and from sea level to more than 2000 m in elevation [20][21].

The characteristics of life history, such as high reproduction and growth rates, competitive ability and phenotypic plasticity, of the plants are important for the naturalization of invasive plants into non-native ranges [22][23][24][25]. *I. cylindrica* is also a prolific seed producer, although its flowering is variable, depending on the environmental conditions. The inflorescence of *I. cylindrica* is 10–20 cm in length, with approximately 400 spikelets, which are 3–6 cm in length and covered with short, white hairs [5][7][8]. (**Figure 1**). A single plant produces 500–3000 seeds, which are contained in the spikelets. The movement of the seeds was reported to generally span 15 m, traveled distances of as much as 24 km with the spikelets through wind dispersal [1][26][27]. The germination rate is 30–98%, depending on the conditions [8][28][29].

Vegetative reproduction maintains local stands of *I. cylindrica* and contributes to spread the plant in its vicinity. When rhizome pieces are dispersed by human activities and other disturbing factors, such as a hurricane, the establishment of new populations arises from rhizome pieces. The regeneration of *I. cylindrica* can occur within a small amount of rhizomes—as much as 0.1 g [30]. *I. cylindrica* rhizomes are also very fertile [31]. It was estimated that *I. cylindrica* produces 6 tons of rhizome biomass per hectare, with more than 4.5 million shoots and 10 metric tons of leaf biomass [32]. Terry et al. [33] also estimated a rhizome biomass of 40 tons per hectare. Over the course of 6 weeks, rhizomes were reported to develop 350 shoots, covering an area of 4 m^2 [34]. The extensive growth of *I. cylindrica* results dense mats of rhizomes in the soil, forming thick monospecific patches [32][33] (**Figure 1**).

I. cylindrica is an excellent competitor for nutrients. Its ability to absorb phosphorus, nitrogen and potassium is higher than that of native pine savanna plants, including *Pinus taeda* L. [35][36][37]. The species was reported to reduce the availability of water and nitrogen in surrounding soil, suppressing the establishment of juvenile *P. taeda* by 50% [38].

I. cylindrica has also been reported to increase wildfire occurrence and maximum wildfire temperatures [39][40]. High-temperature fire increases the mortality of native herbaceous and juvenile woody plant spices. Because *I. cylindrica* allocates a significant amount of biomass (over 60%) in below-ground rhizomes, it is able to regenerate quickly from its rhizomes after fires [37][39][41][42]. Therefore, frequent intense fires may result in the conversion of native ecosystems of herbaceous and juvenile woody plants into *I. cylindrica*-dominated grasslands.

The phenotypic plasticity of *I. cylindrica* is high, and the species has adapted to a wide range of environmental conditions, such as various soil types, pH values (4.4 to 8.0), organic matter (0.9 to 5%) and nutrients (P; 6 to190 kg/ha, K; 46 to 734 kg/ha) [43]. It thrives in tropical, subtropical and warm temperate areas, where annual rainfall is 750–5000 mm [7]. Its characteristics in terms of floral traits (such as spikelets, anthers and glumes) and leaf traits (such as length and width) vary within the species [27][44][45]. The species can be separated into five major varieties based on growth and morphological characteristics, as well as geographic origin: *I. cylindrica* var. *europa* (2*n* = 40), *major* (2*n* = 20), *Africana* (2*n* = 60), *latifolia* (not available) and *condensate* (not available). The genetic diversity of *I. cylindrica* in 676 samples from seven southern US states was determined using amplified fragment length polymorphisms, with two genetic lineages identified [46]. Random amplified polymorphic DNA analysis conducted in Florida showed that the species was highly outcrossed [8]. Hybridization may have facilitated the expansion of the species.

The interactions of these invasive plants with natural enemies, such as herbivores and pathogens, are critical for their naturalization. [23][24][47]. Multiple insect predators and fungal pathogens have been identified in *I. cylindrica* stands. However, none of them caused the extensive damage to the population of *I. cylindrica* [21]. In addition, methanol extracts of shoots, roots and inflorescences of *I. cylindrica* showed antifungal activity against the plant pathogen *Macrophomina phaseolina* (Tassi) Goid. [48].

The chemical interactions of the invasive plants with native plants are also crucial [24][49][50]. Several observations suggest that some invasive plants are allelopathic and that their allelochemicals are toxic to native plant species in the invasive ranges [51][52]. Therefore, allelopathy may among the factors allowing the invasive plants to establish their habitats and naturalize within the invasive ranges [52]. Allelopathy is the chemical interaction between a donor plant and receiver plants through the specific secondary metabolites defined as allelochemicals [53]. Available data from a number of observations under field and laboratory conditions suggest that *I. cylindrica* is also allelopathic*,* and possible evidence for the compounds involved in this allelopathy has been accumulated.

2. Effects of *I. cylindrica* on Microbial Community

Several investigations under field and greenhouse conditions have showed that *I. cylindrica* altered the microbial community in the rhizosphere soil and affected the growth of several plant species, including crop plants. The decomposition process of an *I. cylindrica* residue was reported to be significantly faster than that of a local native grass species, *Andropogon glomeratus* (Walt.) Britton, Sterns & Poggenb. *I. cylindrica* was reported to affect the microbial flora in the soil of invaded areas and enhance the decomposition process of the plant residue [54]. The enhanced decomposition process of the plant residue may enable increasing nutrient cycling and availability. Although there are many possible explanations for the alteration of the microbial community in the soil, certain compounds of *I. cylindrica* may be involved in this alteration.

The abundance of mycorrhizal colonization and biomass of fine feeder roots of *Pinus taeda* L. was significantly suppressed in *I. cylindrica*-infested plantations compared with plantations not infested by *I. cylindrica*. The diversity of understory vegetation in pine plantations was also reduced by the presence of *I. cylindrica* [55]. The invasion of *I.*

cylindrica into a *Pinus palustris* Mill. community caused significant loss of native plant species and reduced the distinctiveness of the native flora [56]. Arbuscular mycorrhizal colonization of *Mesicago denticulata* Greene and *Trifolium resupinatum* L. was decreased in *I. cylindrica*-infested fields compared with non-infested fields [57]. The mycorrhizal colonization of some weed species was also suppressed by the presence of *I. cylindrica* [58]. In addition, the rhizobium nodulation, nitrogen fixation and root growth of *Melilotus parviflora* Desf. were suppressed when *M. parviflora* was grown together with *I. cylindrica*. The populations of some fungi, such as *Aspergillus spp*., also differed between *I. cylindrica*-infested soil and non-infested soil [59]. When *I. cylindrica* was grown with *Zea mays* L. or *Sorghum bicolor* (L.) Moench for 8 weeks, the biomass of *I. cylindrica* was not affected by the presence of *Z. mays* and *S. bicolor.* However, the biomass of *Z. mays* and *S. bicolor* was significantly reduced by the presence of *I. cylindrica* even under the conditions that eliminated possible nutrient competition [60]. These observations suggest that *I. cylindrica* may suppress the mycorrhizal colonization and rhizobium nodulation in native plant species, leading to the growth inhibition of these plant species. Although some authors found no direct evidence of allelopathy, they suggested the involvement of *I. cylindrica* allelopathy in the suppression of mycorrhizal colonization and rhizobium nodulation [54][58][59][60].

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