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Age structure and dynamics of *Cercidiphyllum japonicum* sprouts based on growth ring analysis

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Abstract

We investigated the factors that encourage sprouting by *Cercidiphyllum japonicum*, as well as its ability to sprout after cutting, by analyzing the age structure, distribution, and growth of sprouts in one stool of this species. *C. japonicum* produced numerous sprouts in various age classes, ranging from 7 to 92 years old; the main stem was 226 years old. Sprouts that were relatively close in age (e.g., 30 or 80 years old) tended to form clusters. Based on an increase in the width of annual growth rings, we estimated that gap formation occurred about 30 years ago. This encouraged existing sprouts to grow more, and many sprouts were produced on the periphery of the stand to take advantage of the improved light conditions. After cutting, larger stems produced more simultaneous sprouts; therefore, sprout occurrence probably depends on the biomass of parent stems, although smaller stems were also able to produce some simultaneous sprouts. In the absence of physical damage, *C. japonicum* produced more sprouts as a function of increased age as a means of self-maintenance. *C. japonicum* sprouted simultaneously in response to external disturbances, such as gap formation and cutting, and it sprouted sequentially with increasing age. Therefore, although *C. japonicum* seedlings are rarely found in forests, *C. japonicum* can maintain its populations over long periods by sprouting, which compensates for sparse seedling regeneration.

Keywords: Age structure; Gap formation; Growth process; Light; Self-maintenance; Tree sprouting

1. Introduction

Cercidiphyllum japonicum Sieb. et Zucc. is a common tree species in riparian forests of Japan, and it maintains its populations over long periods of time by sprouting (Kubo et al., 2001a; Sakio et al., 2002).

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Since the sprouts of this species are often found in unstable areas, e.g., on steep slopes, small disturbances such as soil erosion probably provide a stimulus for sprouting (Kubo et al., 2001a). In addition, it is thought that *C. japonicum* sprouts to compensate for its sparse seedling regeneration (Kubo et al., 2001a), since its seedlings rarely regenerate more than those of coexisting tree species, including *Fraxinus platypoda* Oliv. and *Pterocarya rhoifolia* Sieb. et Zucc. (Kubo et al., 2000; Sakio et al., 2002).

The ability to encourage sprouting varies by species (Basnet, 1993; Bellingham et al., 1994; Zimmerman et al., 1994), stem size and age (Kamitani, 1986; Ito and Gyokusen, 1996), and the intensity of and interval between damage events (Malanson and Westman, 1985; Crow, 1988; Keeley, 1992). Generally, sprouting is very common in non-coniferous trees in coppice forests following overstory removal for human use (Negreros-Castillo and Hall, 2000; Rydberg, 2000; Luoga et al., 2004). On the other hand, in the absence of human activities, tree species that produce many sprouts are mostly found in areas that experience disturbances, such as heavy snowfall (Okitsu, 1991; Tanimoto, 1993), coastal winds (Ito, 1993; Ito and Gyokusen, 1996), and steep slopes (Sakai et al., 1995), where conditions are generally too severe for seedlings to regenerate. Therefore, sprouting likely compensates for sparse seedling regeneration (Hara, 1987; Ohkubo, 1992; Kruger et al., 1997). Even in stable forests, sprouting plays an important role in the maintenance of forest vegetation by repairing the forest canopy after gap formation (Koop, 1987; Ohkubo et al., 1988, 1996; Peters and Ohkubo, 1990).

Certain stimuli probably encourage *C. japonicum* to sprout, although this species can produce numerous sprouts even in the absence of direct physical damage. However, few studies have investigated sprouting by *C. japonicum* (Kubo et al., 2001a; Sakio et al., 2002), and little is known about the age structure and dynamics of sprouts or about the ability of this species to sprout after experiencing physical damage. Extended longevity by sprouting is essential to the species composition of a particular area (Malanson and Westman, 1985); therefore, it is important for conservation and/or management of riparian forests to understand the sprouting capability of *C. japonicum*. In this study, we investigated the age structure, distribution, and growth processes of *C. japonicum* sprouts, as well as its ability to sprout after cutting. Specifically, we discuss the factors that encourage sprouting by *C. japonicum*, and what traits characterize *C. japonicum* sprouts.

2. Study site and methods

Our study site was located along a small stream (Ooyamazawa) of the Nakatsugawa branch of the Arakawa River, in the Chichibu Mountains of central Japan (35°57′30″N, 138°45′32″E). This deciduous riparian forest is native forest that has no history of cutting (harvesting) or fire. The canopy in this area was over 30 m high and was dominated by *F. platypoda*, *P. rhoifolia*, and *C. japonicum* (Sakio, 1997). *F. platypoda*, which was the dominant tree, grew up to 40 m tall and 150 cm in diameter at breast height (DBH, approximately 130 cm above ground) and produced no sprouts; *P. rhoifolia*, which was the secondarily dominant pioneer species, grew up to 30 m tall and 100 cm in DBH and produced few or no sprouts. The age-class distribution of *F. platypoda* had a mode at the 200- to 220-year class, and the oldest tree was 254 years old (Sakio, 1997). *P. rhoifolia* grew in patches of even-aged trees (ca. 90 years old) based on measurements of core samples (Sakio et al., 2002). On the other hand, *C. japonicum* was the third most dominant species and grew up to 40 m tall and 150 cm in DBH, and almost all individuals of this species produced numerous sprouts. The topography in the forest included a site with muddy sediment upstream, which was formed by exposing the bottom of a V-shaped valley, and a V-shaped valley downstream, which was characterized by a steep slope of about 30°, a cliff, and a talus (Kubo et al., 2001b). There were many disturbances including erosion, and sedimentation of soil, sand, and gravel occurred frequently by stream flow in the area near the active channel. The maximum snow depth in this area was about 30 cm from January to March.

The *C. japonicum* stool that we investigated was located between the slope and the stream at the bottom of the V-shaped valley (Fig. 1), and included many sprouts that had originated from the root system or base of larger stems. All 29 sprouts were cut at about 50 cm from the base of the stem in the fall of 2001, and