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COLONIZATION AND MORPHOLOGICAL CHANGES OF A SEDGE RESTRICTING REGENERATION AFTER WIND DAMAGE IN A NATURAL FOREST

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ABSTRACT: Many old trees were blown down by typhoons in 1959 and 1961 in a natural coniferous forest deep in the mountains of Kiso District, Central Japan, and dense dwarf bamboo subsequently delayed the growth of tree seedlings. Forest engineers have tried to suppress dwarf bamboo to promote the regeneration of arboreal vegetation. However, after suppression of dwarf bamboo, an unknown grass unexpectedly colonized the area and replaced them. Afterward, almost no tree seedlings could be observed in the newly formed community, which seemed to worsen the extent of regeneration. It has been identified that the grass as *Carex oxyandra*, a native sedge species indigenous to Kiso District. Commonly, *Carex oxyandra* grows as short as about 10 cm like lawn grass, but it seems to have exceedingly enlarged the size in the community. Thus, investigation on the morphological variation of this sedge in Miure Experimental Forest within the Kiso National Forest was carried out. Leaf blade length, basal tiller length, and number of leaves per tiller were measured in upper and lower stands on three slopes in 2009. Results revealed that leaf blade length and basal tiller length in lower stands were approximately twice as large as those in upper stands on each slope, whereas the number of leaves per tiller was almost the same (8.8-9.4 leaves). Consequently, tussocks of this sedge became large in lower stands on a slope, which made the community overcrowded and damp, restricting tree regeneration.

Keywords: Natural Forest, Regeneration, Dwarf Bamboo, Carex oxyandra, Colonization

1. INTRODUCTION

After weather damage in natural forests far from human habitats, natural regeneration of trees is expected, instead of requiring artificial introduction of vegetation by revegetation. If vegetation damage occurs in a natural forest where germination and establishment of tree seedlings is difficult for a long period, technology promoting the growth of spontaneous seedlings is needed.

Recently, revegetation technologies have been developed and applied especially to cut slopes and landslide slopes adjacent to human habitats. This involves construction of foundations for retaining the soil and introducing vegetation. It is important to monitor succession of vegetation after its introduction, since plants will grow or decline, and the species composition is altered by surrounding species year after year. As an example, it was reported that the process of vegetational succession on landslide slopes on Mikura-jima Island, where native tree and herb species were initially planted using simple terracing [1], [2]. In contrast, regeneration technology in natural forests has scarcely been studied in Japan.

In a natural coniferous forest deep in the mountains of Kiso District, Central Japan (Fig. 1), large Japanese cypress (*Chamaecyparis obtusa*) trees aged up to about 300 years are known by a famous timber brand, 'Kiso-Hinoki'. The trees have been selectively cut for use as high-quality timber, and the trees have naturally regenerated for several hundreds of years. However, many old trees including Japanese cypress were blown down by typhoons in 1959 and 1961. Subsequently, dwarf bamboo (*Sasa* sp.), the dominant species on the forest floor, remained dense on the land surface [3], [4].

Forest engineers and researchers have tried to promote the regeneration of arboreal vegetation. They deduced that the seedlings had not successfully established, and suggested that the dwarf bamboo should be suppressed. The growth of Japanese cypress seedlings requires a very limited environment: it demands a shaded habitat with a relative luminous intensity from 2 to 5%, and moderately humid soil. However, the relative luminous intensity reaches only 1 to 2% under a dense community of dwarf bamboo. In addition, the cool pluvial climate in this district (an average annual temperature of 7°C and an annual precipitation of 3,500 mm at the meteorological station, which is at an elevation of 1,300 m [4]) has caused formation of a wet podzol layer in the soil, which is too humid and nutritionally poor for the seedlings. Thus, after the wind damage from the typhoons, the dense community of dwarf bamboo prevented the growth of tree seedlings in this district, especially in the higher elevation areas [3], [4].

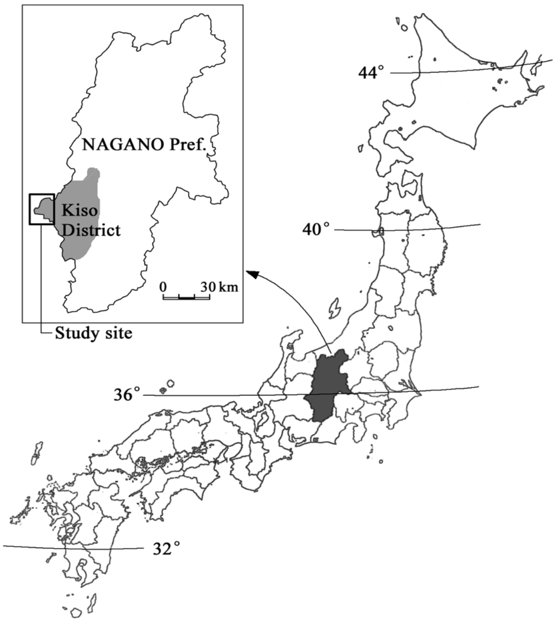

Fig. 1 Location of study site

Fig. 2 A case of colonizing *Carex oxyandra* (at forest compartment No. 2630) after withering of dwarf bamboo

In 1966, the Miure Experimental Forest of the Nagano Regional Forest Office was established to find a suitable regeneration method for forests in the wet podzolic zone, which appears in the peneplain area (at an elevation of about 1,200 to 1,500 m) on the southwest slope of Mt. Ontake in the Kiso District [4]. Many forest compartments (divided sections for forest managements or experiments) were established to examine various methods of regeneration involving the suppression of dwarf bamboo. In successful forest compartments, dwarf bamboo was suppressed by herbicide for several years, and the seeds of Japanese cypress germinated during this period and grew in moderate shade under the community of regenerating young dwarf bamboo.

However, in 2006, an unexpected phenomenon was observed in higher-elevation areas: an unknown grass began to colonize and replace the withered dwarf bamboo (Fig. 2). Afterward, few tree seedlings could be observed in the newly formed community, which seemed to reduce regeneration further.

Forest engineers at first suspected that the grass might be an invasive foreign species, but it has been identified as *Carex oxyandra*, a native sedge species indigenous to Kiso District. Commonly, *Carex oxyandra* grows as tussocks as short as about 10 cm like lawn grass, but it seems to have exceedingly enlarged the size in the community. *Carex oxyandra* is reported to remain at the forest floor as a low-preference foliage by sika deer [5], and to colonize bare ground after mining as a pioneer plant [6], but cases of colonizing in a forest or grassland where vegetation has already developed were previously unknown.

In the present study, the investigation of the morphological variation of *Carex oxyandra* in the Miure Experimental Forest within Kiso National Forest was carried out to identify the replacement dwarf bamboo by this sedge.

2. METHODS

The study site was located in Miure Experimental Forest, in the center of the mountain in Kiso District, at an elevation from 1,400 to 1,500 m.

In October 2009, we observed communities of *Carex oxyandra* on three slopes (forest compartments No. 2626, 2627 and 2630), and selected both upper and middle stands on each slope. Leaf blade length, basal tiller length (reddish-purple part near the base) and number of leaf blades per tiller were measured for five individuals per strand. The environmental conditions were as follows:

(a) Stands in No. 2626 were located at an elevation from 1,400 to 1,420 m, with a slope direction of 0° and an inclination of 27°. Dwarf bamboo were withered (dry culms remained), and the community of the sedge was observed on bare ground.

(b) Stands in No. 2627 were located at an elevation from 1,500 to 1,520 m, with a slope direction of 260° and an inclination of 30°. Communities were observed where dwarf bamboo dominated and where sedge dominated.

(c) Stands in No. 2630 were located at an elevation from 1,480 to 1,500 m, with a slope direction of 220° and an inclination of 20°. Dwarf bamboo was rarely observed, and the sedge constituted the largest community.

In each stand, arboreal vegetation (comprised of Japanese cypress and some broad-leaved deciduous trees) was sparse, and plants with sizes common for *Carex oxyandra* were observed in the area near the ridge above the upper stand. The difference in elevation between upper and middle stands on each slope was approximately 10 m.

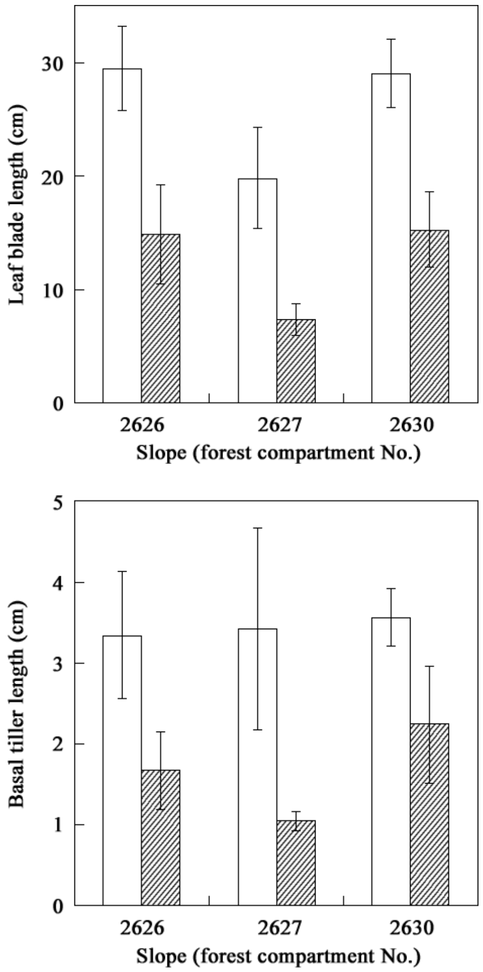

Fig. 3 The leaf blade length and basal tiller length of *Carex oxyandra* in each stand. Solid columns (left) and hatched columns (right) show the middle stand and the upper stand on the slope, respectively. The bar on the top of each column indicates ±1 SD.

3. RESULTS

Fig. 3 shows the leaf blade length and basal tiller length in each stand. The average leaf blade length was 7 to 15 cm in upper stands, whereas it was 20 to 30 cm in middle stands. The maximum length was 36.0 cm (in the middle stand of No. 2626 slope). Analysis of variance detected a significant difference based on location on a slope (F-test, $p<0.01$). A significant difference based on specific slope was also detected (F-test, $p<0.05$), since the lengths were smaller on No. 2627 slope than the others.

Average basal tiller length was 1.0 to 2.2 cm in upper stands, whereas it was 3.3 to 3.6 cm in middle stands (Fig. 4). The maximum length was 5.2 cm (in the middle stand of No. 2627 slope). Analysis of variance detected a significant difference based on location on a slope (F-test, $p<0.01$). However, no significant differences based on specific slopes were detected (F-test).

In contrast, the number of leaf blades per tiller proved relatively stable among stands; the average was 8.2 to 9.0 in upper stands, and 8.8 to 9.4 in middle stands. No significant differences were detected based on either location on a slope or on specific slopes (F-test). In Fig. 4, we present images of actual samples of the sedge on the same slope (No. 2630) that were obviously different from each other: the number of leaves per tiller did not seem to differ, but the leaf blade length and basal tiller length in the middle stand were twice as large as in the upper stand.

Fig. 4 Herbarium specimens of *Carex oxyandra* collected on the slope No. 2630 (left: middle stand; right: upper stand). The black scales in the figure are 16 cm.

4. DISCUSSION

At the study site, the native sedge *Carex oxyandra* proved to change the above-ground morphology drastically. Between communities close to each other on the same slope, leaf blade length and basal tiller length in middle stands were twice as large as in upper stands (Figs. 3 and 4). In addition, the number of leaf blades per tiller was relatively stable independent of the location on a slope, meaning the sedge community was dense in the middle stands.

For *Carex oxyandra*, the upper and middle stands in each slope were not considered to be genetically remote, since the distance between them was relatively close. The morphological changes in this sedge were presumably the result of adaptation to growth environments, such as soil moisture and air temperature. For example, water stress and high temperature are reported to influence leaf morphology in some grasses [7] and trees [8]. If excessive soil moisture favors large tillers and leaf blades of *Carex oxyandra*, the above-ground environment would also become wetter, which impedes the establishment of Japanese cypress seedlings. Therefore, a method to suppress this sedge is needed for the regeneration of Japanese cypress at the study site.

Finally, we try to explain why *Carex oxyandra* replaced dwarf bamboo. There are two means of expansion, vegetative reproduction (clonal growth) and seed dispersal. From the viewpoint of vegetative reproduction, tillering from the base is one means, since this sedge produces many tillers.

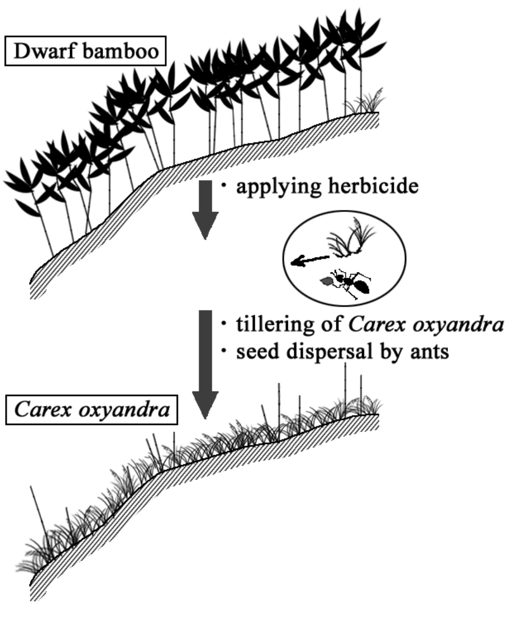

Fig. 5 Schematic depiction of the presumed process of *Carex oxyandra* colonization after withering of dwarf bamboo

However, the sedge is able to expand only incrementally outward merely by clonal growth. From the other viewpoint of seed dispersal, it has been reported that *Carex oxyandra* seeds are dispersed by ants: an elaiosome is attached to the seed surface, and ants take the seeds to their nest and bite off only the elaiosome [9]. Consequently, we suggest a process for colonizing by *Carex oxyandra* in Fig. 5. How long the dominance of the sedge lasts or whether dwarf bamboo can recover in the sedge-dominated community are worth investigating in terms of the regeneration of the forest.

5. CONCLUSION

In the present study, the morphological variation of a native sedge, *Carex oxyandra*, was investigated in the Miure Experimental Forest within Kiso National Forest where many old trees had been blown down by typhoons.

The sedge proved to change the above-ground morphology drastically: between communities close to each other on the same slope, leaf blade length and basal tiller length in middle stands were twice as large as in upper stands, and the number of leaf blades per tiller was relatively stable independent of the location on a slope. This fact means the sedge community was dense in the middle stands. If excessive soil moisture favors large sizes of *Carex oxyandra*, the above-ground environment would also become wetter.

The reason why *Carex oxyandra* replaced dwarf bamboo would be explained by two means of expansion, (a) vegetative reproduction (tillering, i.e., clonal growth) and (b) seed dispersal. By the former means, the sedge is able to expand incrementally inch by inch. By the latter means, *Carex oxyandra* seeds can be dispersed over a long distance by ants.

Our results suggest that the colonized larger-sized *Carex oxyandra* and wetter habitat impede the establishment of Japanese cypress seedlings, and therefore a method to suppress this sedge is needed for the regeneration of Japanese cypress at the study site.

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