ALLELOPATHIC POTENTIAL OF BROOM (*SAROTHAMNUS SCOPARIUS*) DOMINATING POST-FIRE STANDS IN SOUTHWEST JAPAN

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Summary. The Seto Inland Sea region of southwest Japan has a relatively dry climate where forest fires frequently break out at the slopes. Broom, *Sarothamnus scoparius*, has been introduced into the area and dominates post-fire stands 3-4 years after establishment. Few seedlings of other plants grow in the community. Greenhouse experiments were carried out to clarify its allelopathic and shading effects.

Aqueous extracts of broom shoots inhibited growth of the seedling of *Pinus densiflora* which is usually dominant in secondary succession in this region, and in some cases stimulated growth of the seedlings of broom and *Festuca arundinacea*. Neither *P. densiflora* nor *Lespedeza bicolor* could survive under dense broom canopies due to allelopathy and shade stress. The shade tolerance of broom seedlings was quite low and they could not survive under broom canopy.

INTRODUCTION

The broom, *Sarothamnus scoparius* (L.) Wimm. ex koch, is a rhizobium nodulated leguminous shrub which grows up to 4 meters in height and is indigenous in Europe, North Africa and Western Asia (2). Its stem possesses the photosynthetic activity with few small leaves that often defoliate. Symbiotic nitrogen fixation makes it a fast and well growing species in unproductive poor soil areas (14), but it only dominated at an early stage of plant succession (15). Therefore, broom is considered desirable species where the aim of vegetation management is to revegetate by native species in this region (6,16).

The broom was introduced into Japan during 1670's and has been widely planted as a horticulture shrub (4). Recently it has also been utilized as a nurse species for afforestation of post-fire stands (5). The forest fire often occurs in Seto Inland Sea region in air dried early spring (7,8). The broom is seeded or planted for the quick revegetation of the site to protect from soil erosion. The introduced broom becomes dominant soon afterward (13), but seedlings of component species of secondary succession in this region such as *Lespedeza cyrtobotrya*, *Pinus densiflora* (8) scarcely appear beneath and around this shrub.

Since Cowles (1) emphasized the role of allelopathy in plant succession, numerous studies have been done in this field in the United States. In Japan the role of allelopathic agents which are extracted from the dominant species in secondary succession was pointed out (11). There is a possibility that allelopathic agents are responsible for the introduced broom dominating sites in Seto Inland Sea region (3). However, allelopathic phenomena of broom plant has not been reported in the other regions of Japan. Therefore, if allelopathic agents take parts in the phenomena of Seto Inland Sea region, the specific conditions promoting effectiveness of this agents after egression from broom must exist.

The experiments reported here were performed to test the hypothesis that the specific conditions of Seto Inland Sea region promote the effect of allelopathic agents from the broom. Inhibitory effects of the extract from the broom on seedlings of *Lespedeza cyrtobotrya*, *Pinus densiflora* and the broom were tested under shaded and full-light conditions.

METHODS

The result of bioassays using the aqueous extracts from the broom indicated that its stem with leaf (SWL) inhibited remarkably the growth of lettuce seedlings both radicle and hypocotyl (Table 1). On the basis of this fact, the inhibitory effect of SWL was tested in this study.

Table 1. The growth inhibition of radicle and hypocotyl of lettuce plant by aqueous extracts of broom (redrawn from Nemoto *et al.* 1988)

	Radicle length (mm)	Hypocotyl length (mm)
Stem with leaf (SWL)	5.3 ± 1.0*	6.7 ± 1.6
Root	10.5 ± 2.3	8.8 ± 1.9
Control	21.4 ± 3.3	8.6 ± 1.9

* mean ± s.d.

Test with fragments of SWL. The fragments of SWL of both broom and *Lespedeza cyrtobotrya*, indigenous leguminosae in Far East including Seto Inland Sea region which was possessed of non-allelopathic effect, were used in this experiment. SWL of both species were dried at 70°C for 48 hours and broken into fragments, then, 10 g, 20 g, 30 g and 40 g of the fragments of broom SWL were mixed up with 40 g, 30 g, 20 g and 10 g of that of *L. cyrtobotrya* respectively. Total weight adjusted on 40 g among 4 series. Pots 15 cm in diameter, 10 cm in depth were filled with granitic gravel. The fragment mixture was mixed with the gravel of upper one-third of the pot. Seedlings of *Pinus densiflora*, *L. cyrtobotrya* and the broom were used for receptor plants. At 18 days after seeding, germinated seedlings of these species were transplanted into pots. Three seedlings were set in each pot and each treatment was done in three replicates. The pots were placed in a greenhouse where the room temperature was maintained at 25°C.

Test with aqueous extracts of SWL. The broom SWL kept in semi-dried cold room (5°C) was used. 2 L of distilled water was added to 100 g of broom SWL at about 45°C. After 1 h, the aqueous extract was filtered through a 1.2 mm sieve. *Lactuca scariola* L. var. sativa Bisch (lettuce), *Pinus densiflora* Sieb. et Zucc., *Pinus thunbergii* Parl., *Lespedeza bicolor* Turcz. var. japonica Nakai, *Miscanthus sinensis* Anderss, *Artemisia princeps* Pampan., *Trifolium pratense* L. (L.) Wimm. ex Koch, *Dactylis glomerata* L., *Festuca arundinacea* Schreb were used as receptor plants. The last three species were commonly introduced for recovery of post-fire stands (5). The seedlings of receptor plants or 20 days after emergence, except for lettuce, were transplanted in 1/5000 a Wagner pots filled with Masa. This material originated from the weathered granite and is the same parent material of soil as Seto Island Sea region. The lettuce were directly seeded. 500 ml of aqueous extract was added to each plot with three treatments. Seven plants were cultivated per pot with two replications. The pots were placed in a greenhouse where the temperature was maintained at 20°C.

Evaluation of complex effects of aqueous extract and shading. To evaluate the complex effects of aqueous extract and shading, *P. densiflora*, *L. bicolor* and *S. scoparius* were used for receptor plants. Thirty individuals for each of these species were seeded in 1/5000 a Wagner pots filled with the same soil as test 2 in 21 September 1988 and the pots were placed under dim condition (relative light intensity was reduced to 5.8% by cheese cloth cover) for about 150 days (13 February 1989). Up to two weeks after seeded, germination percentage of these species increased over 90%. 2.4 L of distilled water was added to 100 g of the broom SWL which is same one as test two at 45°C (high concentration of aqueous extracts). The EC value of this extracts was lower than 1 mS/cm. Then this extract was diluted to one half with distilled water (low concentration). 500 ml per pot of these two levels of extracts were employed every times. At the same time 500 ml of distilled water were added to control pots. The aqueous extracts were added five times (2, 6 Dec. 19, 23 and 30 Jan.) to receptor plants. This series of test was done with two replicates. Masa soil of this study was collected at Takahagi-City, Ibaraki Prefecture, and the broom was cultivated at the experimental farm of National Institute of Agro-Environmental Sciences. Seeds of *P. densiflora*, *P. thunbergii* and *L. bicolor* were presented from Forestry and Forest Products Research Institute. Seed of *M. sinensis* was presented from The Japan Association for Advancement of Phyto-Regulators. Other seeds were bought on the market. Seeds of leguminous species (*C. scoparius* and *L. bicolor*) were treated by sulfuric acid to break the dormancy before seeding.

RESULTS

Effects of broom SWL on the growth of seedlings of receptor plants. The seedlings of *P. densiflora* transplanted in the pots were extremely inhibited in the test with SWL fragments of the broom. Individuals withering above-ground part appeared soon afterward and all individuals in the pot that contained 40 g of the SWL died within 2 weeks after transplanting. The number of dead individual increased with increasing the amount of the fragments of broom (Fig. 1). At two months after transplanting, the growth of above-ground part did not show the definite tendency, while the biomass of subterranean part decreased with increasing the amount of SWL fragment.

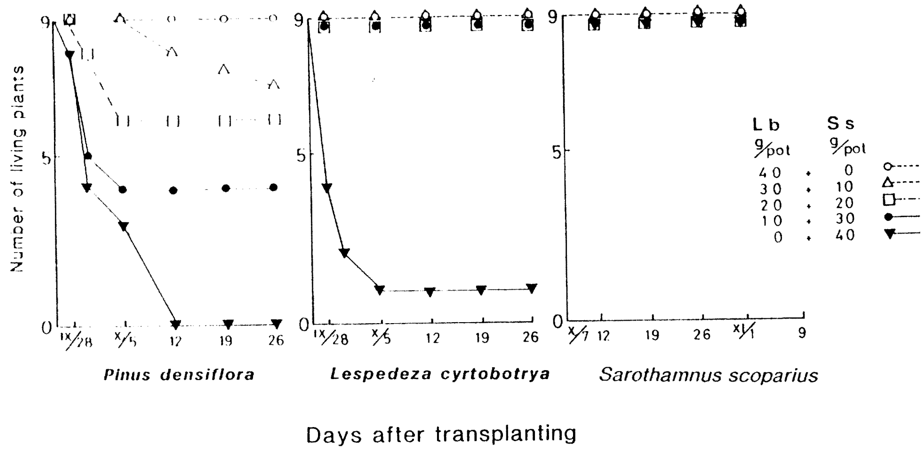

Figure 1. Survivorship curve of the seedlings of *P. densiflora*, *L. cyrtobotrya* and *S. scoparius* which were cultivated the pots containing the SLW fragments both broom and *L. bicolor*.

Soon after transplanting, the growth of *L. cyrtobotrya* was depressed where a lot of SWL treated, and only one individual survived in the pot that had 40 g of SWL added (the largest amount of application). However, 3 weeks after transplanting the growth vigor had recovered in 20 g pot. The dry matter production of both above-ground and subterranean became the largest level in the 20 g pot 2 months after treatment.

Broom did not die in all treatments. In 20 g plot total dry weight of broom plant 2 months after treatment had also became the largest value, and subterranean weights in 0 g and 10 g pot were apparently smaller than that in the other treatments. The effects of SWL fragment on the seedling growth of above mentioned three species were quite varied. Then 10 species were employed for receptor plants to classify the effects of the aqueous extracts of broom SWL on the seedling growth. The sensitivity of seedlings of 10 species employed were divided into three categories, 1 : the biomass decreased with increasing the amount of extracts, 2 : individual biomass at one time application pot is over that at control, and 3 : individual biomass at control pot is the smallest level in the whole. At first *P. thunbergii*, *T. pratense* and *L. scariola* were sensitive to the broom extracts and were involved in the first category. Secondary *P. densiflora*, *L. bicolor* and *M. sinensis* were involved in the other category. By contrast, species involved in the third category such as broom, *F. arundinacea*, *D. glomerata* and *A. vulgris* were rather promoted by the application of this extract. The sensitive species to broom extracts showed a tendency to become inhibited in their root development. As a result their T/R ratio of individuals in the extract treated pots were higher than that in the control. By contrast, the T/R ratio of broom decreased with increasing the frequency of extract application.

Complex effects of broom extract and shading. *P. densiflora* and *L. bicolor*, which are early colonizers after forest fire, and introduced broom are sun demanded plant. Therefore their seedling growth under dense shrub of broom may possibly be inhibited by shade stress.

When the broom extract was added to seedlings of *P. densiflora, L. bicolor* and broom, which were cultivated 2 months under shade condition (RLI=5.8%), withered individuals arised in both species. The greatest number of dead individuals was broom seedlings. Then the seedlings of *P. densiflora* followed. This tendency differed much from that showing the above-mentioned test one.

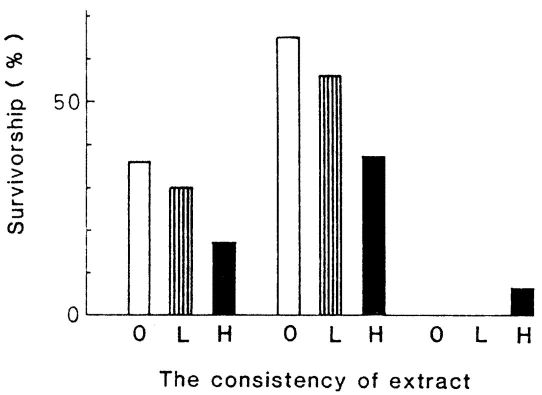

Figure 2. The relation between the survival rate of receptor plants and consistency of broom extracts under shade condition after 5 times application of these extracts 0 : control, L : low concentration, H : high concentration

Figure 2 shows the relationship between the consistency of extract and survival rate after 5 times application of these extract. The survival rate of *P. densiflora* and *L. bicolor* applied with the thicker extract was lower than that applied with the thinner extract. While the survival rate of broom showed reversed tendency. Seedlings of *P. densiflora* were cultivated under full-light condition and then broom extract was added in pots the same way as mentioned above. In this case one seedling died in thick extract application pot.

DISCUSSION

In Seto Inland Sea region artificial broom shrubs planted at post fire stands where the parent rock is granite inhibit the growth of regenerated coppices and seedlings originated from soil seed bank (9). Allelopathic agent after egression from broom plant was pointed out to take part in a factor of this inhibitory action.

Specific difference of the sensitivity to allelopathic agent. Results of the experiment using aqueous extracts of various kind of organs of broom plant indicated that SWL apparently inhibited the radicle growth of lettuce (10). So broom SWL was entirely employed in this study.

The sensitivity of receptor plant to the fragment of broom SWL differed with species : *P. densiflora* and *L. cyrtobotrya* were relatively sensitive, while *S. scoparius* and *Artemisia princeps* were non-sensitive. However, the growth of broom sensitive species above-mentioned were not influenced by the SWL of *L. bicolor*, which is a abundant shrub at young post-fire stand.

In the field condition allelopathic agent contained in broom SWL is leached by rain and accumulate in soil under broom canopy. Therefore, method using aqueous extracts of broom SWL may reflect more the field condition than the addition method with SWL fragment. The result of the test with aqueous extracts of broom indicates that the response of receptor plants differed with species in growth. One is promoted and the other is suppressed. Therefore, it may well be that allelopathic agents take part in interspecific relation of plant community in post-fire stands.

Complex effects of allelopathic agent and shading by broom dominated. Broom canopy completely covered the ground surface when artificial broom shrub at post-fire stands developed into prosperous stage (13). Early colonizers of sun demanded plants must be exposed under such light condition. In general, the root growth is suppressed and the T/R ratio is increased under shade condition. The allelopathic agent of broom suppressed particularly the subterranean organs of sensitive receptor plants. So root of the broom sensitive *P. densiflora* and *L. bicolor* as sun demanded plants are complexly damaged by both effects in the soil under broom canopy and withered individuals will frequently occur. The same phenomenon was observed in the seedlings of *Cryptomeria japonica* in nurseries maintained under shade condition. The number of witherd individuals of *C. japonica* increased with increasing the amount of fertilizer (12). By contrast, seedlings of *P. densiflora* cultivated under unshaded condition were scarcely influenced by the effect of allelopathic agent of broom.

Allelopathic agent of broom SWL accelerates seedling growth of broom. Under dense broom canopy, however, there are very few individuals except for the existence of first year seedlings. This fact indicates that broom seedling is extremly weak in shade condition and does not survive under dense broom canopy. Shade tolerance of broom is less than those of *P. densiflora* and *L. bicolor* as sun demanded plants. But the proper amount of allelopathic substance of broom SWL may raise the survival rate of its seedling under shading condition (Fig. 2). The floristic composition and vegetation succession in Seto Island Sea region may well be partially modified by allelopathies of introduced broom.

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