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資　料

琵琶湖における侵略的外来水生植物 ウスゲオオバナミズキンバイの葉は繁殖体となる

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Leaves as propagules of the invasive aquatic plant *Ludwigia grandiflora* subsp. *hexapetala* in Lake Biwa. Shinya Hieda* (*Graduate School of Environmental Science, The University of Shiga Prefecture*) and Naohiko Noma (*Department of Ecosystem Studies, School of Environmental Science, The University of Shiga Prefecture*)

Ludwigia grandiflora subsp. *hexapetala* (Onagraceae) is an invasive aquatic plant in Lake Biwa that can regenerate from stem fragments. We tested whether it can regenerate also from leaves from both emergent and floating stems on tap water. Both types of leaves generated buds and roots from the petiole base. Since the leaves float well, they can be dispersed by water currents. We recommend collecting not only stem fragments but also leaves during management efforts.

Keywords: invasive aquatic plant, Lake Biwa, vegetative reproduction, *Ludwigia grandiflora* subsp. *hexapetala*

要旨：琵琶湖における侵略的外来水生植物ウスゲオオバナミズキンバイは，茎断片からの再生が可能であることで知られている。本研究では葉に着目し，恒温実験機内で水道水に浮かべた状態で再生実験を行ったところ，抽水茎由来の葉と浮葉茎由来の葉の両方が，再生可能であること（葉柄の基部から開芽・発根できること）が明らかになった。葉は水に浮くため，繁殖体として水流散布されうる。駆除活動では，茎断片のみならず，葉の回収も行うべきである。

キーワード：侵略的外来水生植物，琵琶湖，栄養繁殖，ウスゲオオバナミズキンバイ

Introduction

Ludwigia grandiflora (Michx.) Greuter & Burdet sensu lato is an invasive emergent plant. It has two subspecies, *L. grandiflora* subsp. *grandiflora* and *L. grandiflora* subsp. *hexapetala* (Hook. & Arn.) G. L. Nesom & Kartesz (Nesom & Kartesz, 2000). Both subspecies have invaded Japan: *L. grandiflora* subsp. *grandiflora* has been recorded in Wakayama Prefecture (Naito & Hieda, 2014) and Hyogo Prefecture (Suyama et al., 2008), and *L. grandiflora* subsp. *hexapetala* has been recorded in Lake Biwa, the largest lake in Japan (in Shiga Prefecture) (Hieda et al., accepted) and Kagoshima Prefecture (Kadono, 2014; Kadono & Okamoto, 2018). After the *L. grandiflora* subsp. *hexapetala* was recorded in Lake Biwa, its vigorous spread was regarded as invasive. Shiga Prefecture initiated controls in 2013. Ministry of the Environment, Government of Japan registered *L. grandiflora* sensu lato as an Invasive Alien Species in 2014 (https://www.env.go.jp/nature/intro/2outline/files/siteisyu_list_e.pdf, Accessed August 3, 2018.).

In California, the range expansion of *L. grandiflora*

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sensu lato is derived mainly from vegetative reproduction (Okada et al., 2009). Similarly, we observed regeneration of *L. grandiflora* from stem fragments in Lake Biwa population (Hieda, 2018b). In addition, this species is dry-tolerant; plants removed during mechanical management can serve as propagules and regenerate (Hieda, 2018a). In Lake Biwa, the main management method is manual and mechanical removal. Because the plant is fragile, attention should be paid to fragmentation and dispersal during extermination efforts. For effective extermination, it is important to have information about the vegetative reproduction ability of each part of the plant. In this study, we cultivated the leaves of *L. grandiflora* subsp. *hexapetala* under aquatic conditions.

Materials and methods

On 28-October 2013, we collected emergent and floating stems from *L. garndiflora* subsp. *hexapetala* along the shore of Akanoi Bay in southern Lake Biwa, Japan. We placed the collected wet plants in plastic bags, and stored in a refrigerator (Sanyo model SR-42 SK [G][A]) at about 4℃ in the dark until the start of the experiment. About 1 month later, on November 30, we detached the leaves including both leaf blade and petiole from the emergent stems (17 leaves) and floating stems (15 leaves). We floated the all leaves from emergent and floating stems in separate plastic cups (n=1 each) (KP 860 MB[B]; bottom diameter, 10 cm; top diameter, 13 cm; height, 9.5 cm) filled with tap water (water depth, 7 cm) and cultivated them for 18 days in an incubator (NK System TG 180CCFL 5L[D][C]) at 25℃ under 24h fluorescent light condition (average ± SD): 47.8 ± 2.9 microeinsteins sec^{-1} m^2 (measured by QSL-100 BOX[D]).

Results and discussion

By 18th day, 6 of the 17 leaves from emergent stems and 3 of the 15 leaves from floating stems had budded and rooted from the base of the petiole (Fig. 1). On the regenerated leaves, the mother leaf part had withered. Although the leaves from the emergent stem originally adapted to aerial conditions in nature, they could produce new roots and leaves and adapt aquatic conditions. *Ludwigia grandiflora* subsp. *hexapetala* is a phenotypically plastic species; it can grow in various environments in Japan (Hieda et al., unpublished data). In this study, since the leaves from both emergent and floating

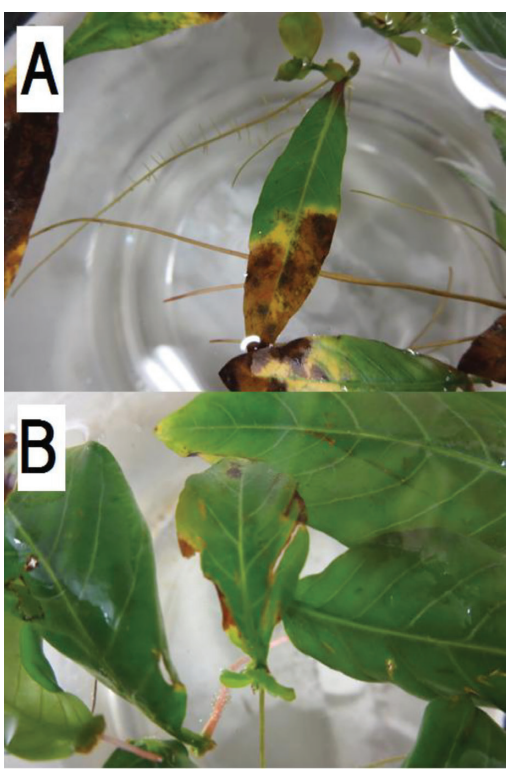

Fig. 1. Regeneration of *Ludwigia grandiflora* subsp. *hexapetala* from the base of the petiole. (A) Leaves from emergent stems; (B) leaves from floating stems. Photographs by S. Hieda (sixteen days from the start of the experiment).

stems could bud and root, the phenotypic plasticity likely contributed to regenerate. In addition, the both types of leaves could float, suggesting that they could be dispersed by water currents.

In this paper, we showed, through laboratory experiments, that the potential of vegetative reproduction from leaves of *L. grandiflora* subsp. *hexapetala.* The leaves from both emergent and floating stems can be propagules (vegetative fragments) in natural conditions; we therefore recommend collecting not only stem fragments but also leaves during management efforts.

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Sources of materials

[A] Sanyo SR-42 SK (G), Sanyo Electric Co., Ltd., 2-1-61 Shiromi, Chuou-ku, Osaka City, Osaka 540-6226, Japan.

[B] KP 860 MB, Kohnoike Plastic. Co., Ltd., 3-1-38 Nishi Kohnoikecho, Higashi Osaka City, Osaka 578-0976, Japan.

[C] NK System TG 180CCFL 5L (D), Nippon Medical & Chemical Instruments Co., Ltd., 3-9, Tamatsukuri Motomachi, Tennoji-ku, Osaka 543-0014, Japan.

[D] QSL-100 BOX, Biospherical Instruments Inc., 5340 Riley Street, San Diego, CA 92110, USA.

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