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Note

Effect of water depth and substrate composition on growth of the aquatic weed rotala (*Rotala rotundifolia*)

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INTRODUCTION

Rotala [*Rotala rotundifolia* (Buch.-Ham. ex Roxb.) Koehne], also known as dwarf rotala and roundleaf toothcup, is a relatively recent invader of canals, ponds, and lakes in southern Florida. The first observation of rotala growing outside cultivation in Florida occurred in 1996, when the species was found in Coral Springs (Broward County) (Burks et al. 2003; Jacono and Vandiver 2007). Rotala has since spread to several aquatic systems throughout southern Florida and is particularly problematic in flood-control canals designed to rapidly move water and prevent flooding during tropical events and heavy rains. The only other observation of this species in the United States was recorded in 2001 in Tuscaloosa, AL, where it had invaded a pond on the campus of University of Alabama (Reese and Haynes 2002; Kral et al. 2013). The pond was subjected to a drawdown, which reportedly eradicated the population (Jacono and Vandiver 2007). The source of infestations in Alabama and Florida is unknown, but a quick search of the Internet reveals that rotala is readily available from aquarium and water garden nurseries. It seems likely that rotala was introduced to both states from cultivated populations; in fact, Kathleen Burks of the Florida Department of Protection suggested that aquarium dumps were likely responsible for rotala's introduction to North American waters because many infestations originate near residential areas (Milius 2003).

Rotala is a member of the Lythraceae or loosestrife family, whose namesake member is purple loosestrife (*Lythrum salicaria* L.), a federally listed noxious weed and notorious invader of wetlands and lake margins in New England (USDA 2013a). Other relatives in the United States include the native lowland rotala [*Rotala ramosior* (L.) Koehne] and the introduced Indian toothcup [*Rotala indica* (Willd.) Koehne]. As with rotala, both are classified as obligate wetland species. Lowland rotala is widely distributed throughout the United States but is classified as threatened, endangered, rare, or sensitive in several states, particularly in New England (USDA 2013b). Indian toothcup, which is widely available through the aquarium plant industry, has been vouchered in a single county in California and a few parishes in Louisiana (USDA 2013c).

Rotala is an amphibious herbaceous dicot that grows as a perennial in southern Florida. Populations maintained in outdoor culture at the University of Florida Center for Aquatic and Invasive Plants in Gainesville die back to the soil line during the winter but readily produce new shoots when temperatures increase during spring warm-up (L. A. Gettys, pers. obs.). The species is heterophyllous; emergent leaves are bright green, fleshy, and nearly round, whereas submersed leaves range from green to burgundy, are much thinner than emergent plant material, and are lanceolate in shape (Gettys and Della Torre 2014). Emergent stems are green to bright pink and can reach to 30 cm in height, although most field specimens are considerably shorter. Rotala uses multiple reproductive strategies to increase its spread; the species produces viable seeds from inflorescences of hot pink to fuchsia flowers (Jacono and Vandiver 2007) and single-node plant fragments are capable of forming adventitious roots (Ervin and White 2007). The emergent form of the species colonizes wet areas such as canal banks, whereas submersed plants grow in water as deep as 2 m (L. A. Gettys, pers. obs.). Although rotala can survive and become established in a wide range of water conditions, little is known regarding the influence of water depth and substrate type on its growth. Therefore, the goal of these experiments was to evaluate vegetative growth of rotala under various water depth and substrate composition regimes. This information may be useful to predict colonization potential under field conditions.

MATERIALS AND METHODS

Experiments were conducted and repeated at the University of Florida Fort Lauderdale Research and Education Center (FLREC) in Davie, FL. Three substrates were examined in these experiments: 100% coarse builders' sand, 100% topsoil,[1] and a mix of 50 : 50 v/v coarse builders' sand and topsoil, hereafter referred to as sand, topsoil, and mix, respectively. Substrate mixtures were thoroughly blended and amended with 2 g L^{-1} of a controlled-release

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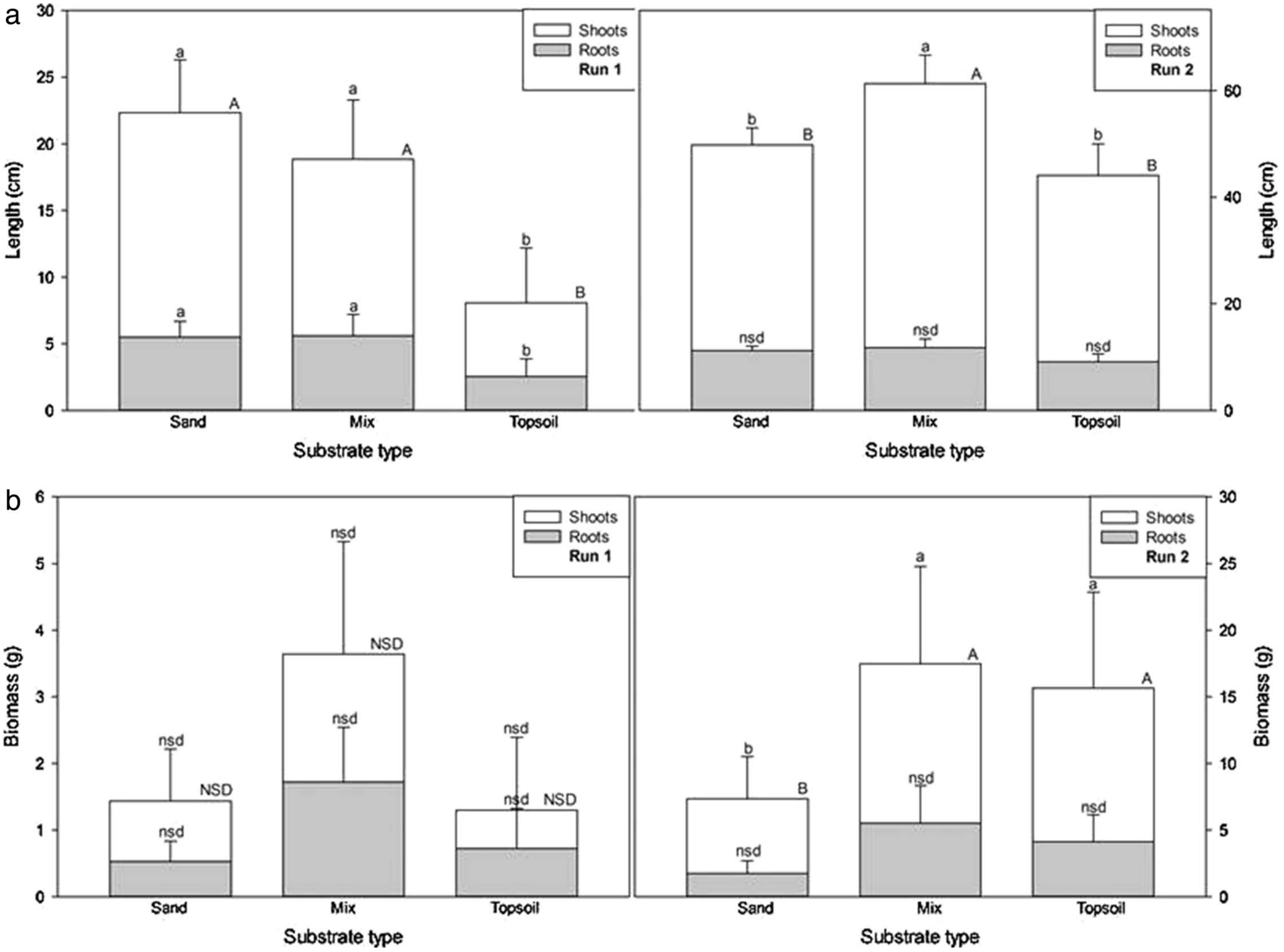

Figure 1. Effect of substrate composition on growth of rotala in run 1 and run 2. Bars represent the means of four replicates and error bars represent 1 standard error from the mean. Treatments coded with the same lowercase letter within each bar type are not significantly different at $P = 0.05$; uppercase letters indicate differences in cumulative summed values for shoot and roots. (a) Root, shoot, and total length (cm). (b) Root, shoot, and total biomass (g).

fertilizer[2] before filling containers. Each experimental unit consisted of a single azalea pot with drainage holes (18 cm diam by 12 cm tall filled to 10 cm deep; filled volume *ca.* 2.6 L) planted with 10 unrooted 10-cm-long apical cuttings of rotala, which were obtained from a source population onsite at the FLREC. All experimental units were placed in a single concrete mesocosm (3 m by 6 m) filled with well water (pH *ca.* 8.5) maintained at a depth of *ca.* 46 cm. Four water depths were examined in these experiments. Subirrigation treatments were set so that water was maintained *ca.* 5 cm below the substrate surface, with all substrate moisture obtained by water wicking up through the drainage holes and into the substrate. The remaining depth treatments were designed to simulate shallow-, medium-, and deep-water field conditions, with water maintained at 2.5, 15, and 30 cm, respectively, above the substrate surface. Concrete blocks were used to maintain correct water levels for subirrigation, 2.5-cm, and 15-cm-depth treatments, whereas treatments calling for a water depth of 30 cm were placed directly on the bottom of the mesocosm. Four replicates were prepared for each substrate/depth combination in this 3 (substrate) by 4 (depth) factorial and experimental units were placed in a randomized block design within the mesocosm. Two independent runs were prepared for these experiments, with run 1 commencing in April 2012 and run 2 starting in May 2012. Plants were cultured for 8 wk, at which time length of the longest shoot and the longest root in each container was recorded. A destructive harvest was then used to separate aboveground material and belowground roots at the substrate surface. Plant tissue was washed clean of substrate and other debris and dried in a forced-air oven at 90 C until a constant weight was achieved. Raw length and dry biomass data were subjected to ANOVA and LSD separation of means[3] to evaluate main (substrate, depth) and interactive (substrate by depth) effects at $P = 0.05$.

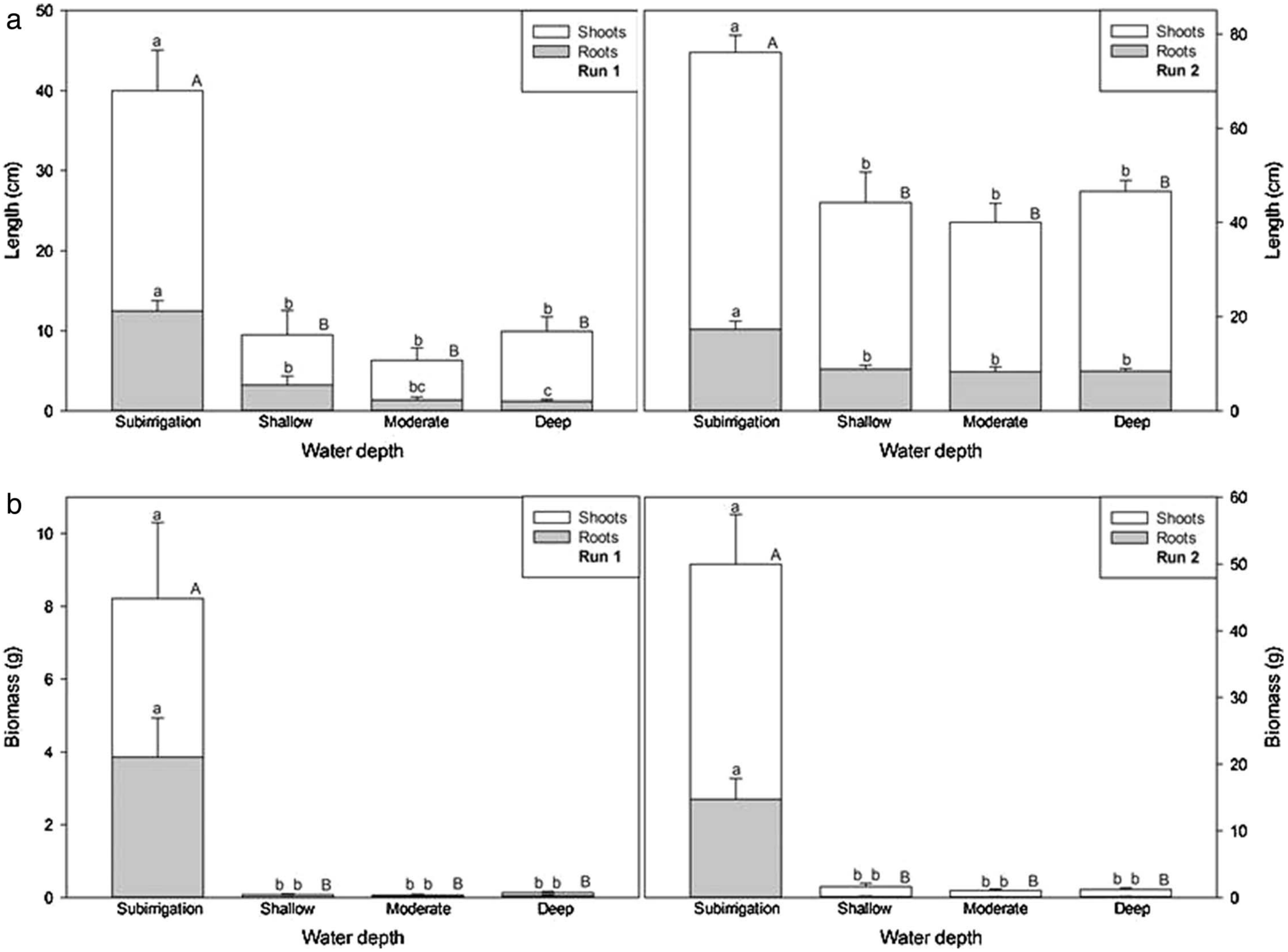

Figure 2. Effect of water depth on growth of rotala in run 1 and run 2. Bars represent the means of four replicates and error bars represent 1 standard error from the mean. Treatments coded with the same lowercase letter within each bar type are not significantly different at $P = 0.05$; uppercase letters indicate differences in cumulative summed values for shoot and roots. (a) Root, shoot, and total length (cm). (b) Root, shoot, and total biomass (g).

RESULTS AND DISCUSSION

Run 1 was started on a hot, sunny day and cuttings experienced stress because of these harsh environmental conditions. In contrast, run 2 was started on a cloudy, overcast day, which greatly reduced plant stress in comparison with run 1. As a result, overall plant growth was significantly greater in run 2 than in run 1, so run 1 and run 2 were analyzed separately. No significant interaction between substrate and depth was detected in either run. Substrate had an effect on some parameters, but these were inconsistent between runs and not particularly robust (Figure 1). For example, longest shoots and roots were produced by plants grown in sand or mix in run 1, but shoot, root, and total biomass were not affected. Shoots were longest in plants grown in mix and highest shoot and total biomass were accumulated by plants grown in mix or topsoil in run 2, but substrate composition had no effect on root length or root biomass. These results suggest that substrate composition may influence growth and colonization of rotala, but the impact is likely to be minimal. In contrast, water depth had a profound effect on all biometric parameters measured in both runs (Figure 2). Longest shoot and root lengths and greatest shoot, root, and total biomass were greatest when rotala was grown under subirrigation conditions in both runs.

These experiments revealed that rotala is most productive when grown under subirrigated (wet soil) conditions. Biometric growth characters were greatest when the surface of the sediment was not submersed. In most cases, there were no differences in growth among submersed treatments (i.e., plants cultured with 2.5 cm of water over the sediment surface were the same as those cultured with 15 or 30 cm of water over the sediment surface). Although sediment composition had an effect on some parameters, those results were contradictory and often differed between runs.

In contrast, the effect of depth was robust and consistent between the runs and is likely a major factor that influences colonization.

These findings could have important implications for the management of rotala. Many populations of this species initially become established under submersed conditions and do not produce emergent growth for an extended period of time. For example, a 6-foot-deep pond on site at the FLREC hosted a submersed population of rotala for at least 5 yr before plants topped out and produced emergent growth (L. A. Gettys, pers. obs.). This seems counterintuitive because these experiments clearly show that rotala grows more robustly under moist soil conditions than in a submersed environment. However, it is likely that the heterophylly exhibited by this species results in frequent misidentification. For example, most Florida resource managers readily recognize the emergent form of rotala, which is characterized by round, bright green, fleshy leaves, but the vast majority of aquatic weed samples brought to the FLREC for identification have proven to be submersed rotala, which has a very different phenotype from emergent rotala (i.e., thin, lanceolate, dull green to reddish leaves) (L. A. Gettys, pers. obs.). As a result, it likely that submersed populations of rotala go unidentified—and untreated—during initial establishment and are only recognized as rotala when they reach the surface of the water and produce emergent growth. This lag period between initial establishment and the development of explosive emergent growth could be exploited by managers and should be targeted for management efforts. Although there is little information regarding herbicidal control of rotala, it may be possible to eliminate nascent submersed populations with applications of 2,4-D, triclopyr, diquat, or fluridone (Puri and Haller 2010, Della Torre et al., unpub. data). Early identification and treatment of submersed populations of rotala would certainly eliminate seed-facilitated expansion of rotala as flowers and seeds are only produced on emergent growth. In addition, early control measures could prevent formation of the extremely dense infestations that interfere with water flow and navigation.

SOURCES OF MATERIALS

[1]Earthgro Topsoil, Hyponex Corporation, Marysville, OH.

[2]Osmocote Plus 15–9–12, The Scotts Company LLC, Marysville, OH.

[3]SAS Version 9.1, SAS Institute, Cary, NC.

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