Increasing Sustainability of Residential Areas Using Rain Gardens to Improve Pollutant Capture, Biodiversity and Ecosystem Resilience

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Abstract

- Rain gardens are an effective stormwater management solution for residential areas and urban green spaces..
- This research evaluated flooding and drought tolerance on native plant species and the P removal in monoculture and polyculture rain garden plantings.
- Plant tissue P was higher than either leachate or substrate, indicating the critical role plants play in P accumulation and removal.
- Polyculture plantings had the lowest leachate P, suggesting a polyculture planting may be more effective in preventing excess P from entering waterways from bioretention gardens.

Objective

- Evaluate five native plant species for tolerance to repeated short-term flooding.
- Evaluate three native plant species for P uptake and tolerance of bioretention conditions.
- Compare monoculture and polyculture planting combinations of same species.

Methods

Growth and Physiological Response Study

- Five native plant species were selected; Illicium floridanum (IF) (Florida anise), Morella cerifera (MC) (wax myrtle), Osmunda cinnamomea (OC) (cinnamon fern), Polystichum acrostichoides (PA) (Christmas fern) and Chasmanthium latifolium (CL) (river oats).

- Three native plant species were examined; Andropogen ternarius (AT) (splitbeard bluestem), Coreopsis verticillata (CV) (whorled coreopsis), and Ilex vomitoria (IV) (Schilling's Dwarf yaupon holly).

Compare monoculture and polyculture plantings.

- Four planting combinations included a monoculture of A. ternarius, C. verticillata, or I. vomitoria (three plants of same species per microcosm) or a polyculture of A. ternarius, C. verticillata, and I. vomitoria (one plant of each species per microcosm).

Results

Growth and Physiological Response Study

- With the exception of P. acrostichoides (Christmas Fern), all species evaluated tolerated intermittent flooding (Table 1).
- Regarding the five plant species evaluated, C. latifolium (river oats) tolerated flooding best, based on data collected and personal visual observations. The results were higher for flooded plants of this species in at least one measurement for each run, especially during summer.
- Measurements included: size index (SI), leaf area (LA), leaf chlorophyll content (LCC), shoot dry weight (SDW), leaf:stem DW ratio, and stomatal conductance (SC).

Growth and Physiological Study Results Summary

Type	Species	Run	SI [z]	LA	LCC	SDW	SC
Shrub	IF	SU 14	ND [y]	ND	ND	ND	NF
		FA 14	ND	ND	NF	ND	NF
	MC	SU 14	NF	ND	ND	ND	NF-
		FA 14	ND	ND	NF	ND	NF
Fern	OC	SP 15	ND	ND	ND	ND	ND
		SU 15	ND	ND	ND	ND	ND
	PA	SP 15	ND	ND	ND	ND	F
		SU 15	NF	ND	NF over time	ND	NF-
Grass	CL	SU 14	ND	F	ND	ND	F
		SP 15	ND	ND	NF	ND	ND
		SU 15	F	F	ND	F	ND

[z] SI = (height + widest width + perpendicular width)/3; [y] No significant difference is denoted by ND.

Figure 1. Summary of responses to 7-8 weeks of cyclic flooding for five species: Illicium floridanum (IF), Morella cerifera (MC), Osmunda cinnamomea (OC), Polystichum acrostichoides (PA), and Chasmanthium latifolium (CL).

Whole Plant Transpiration ($mol \cdot s^{-1}$)

		SU 14		FA 14		SP 15		SU15	
Type	Species	F	NF	F	NF	F	NF	F	NF
Shrub	IF	18.4a [z]	0.513b	0.097	0.201	-	-	-	-
	MC	0.242	0.527	0.131	0.186	-	-	-	-
Fern	OC	-	-	-	-	0.095	0.075	0.054	0.053
	PA	-	-	-	-	0.021	0.018	0.002a	0.018b
Grass	CL	0.141a	0.047b	-	-	0.022	0.025	0.237a	0.142b

[z] Letters indicate significant differences between treatments for each species within a run at $p < 0.05$.

Figure 2. Whole plant transpiration rates calculated using stomatal conductance ($mmolm{-2} \cdot s^{-1}$) and total plant leaf area (m^2) of Illicium floridanum (IF), Morella cerifera (MC), Osmunda cinnamomea (OC), Polystichum acrostichoides (PA), and Chasmanthium latifolium (CL) after 7–8 weeks of flooding.

Phosphorus (P) Retention Study

- All species tolerated repeated short-term flooding regardless of monoculture or polyculture.
- Final substrate P was higher in flooded (5.8 g/kg) than non-flooded (7.5 mg/kg).
- Leachate P was higher in flooded than non-flooded microcosms.
- Root tissue P (RTP) and shoot tissue P (STP) was highest in C. verticillata (Table 4).
- On a per plant basis, C. verticillata had 10.47 mg P, A. ternarius had 101.71 mg P, and I. vomitoria had 22.78 mg P in tissue.

Discussion

- O. cinnamomea was not affected by flooding during any run.
- Species negatively affected by flooding during at least one run include: C. verticillate, I. vomitoria, A. ternarius, M. Cerifera, I. floridanum and P. acrostichoides.
- Despite evidence of flooding stress, C. verticillate, I. vomitoria, M. cerifera, and A. ternarius tolerated the type of flooding (48 h) expected in rain gardens and are therefore recommended for use in rain gardens. The results for I. floridanum were less clear.
- C. latifolium and P. acrostichoides were benefited by flooding during at least one run.
- Supplemental irrigation is recommended for P. acrostichoides due to possible drought intolerance.
- O. cinnamomea and C. latifolium are excellent southeastern U.S.A. rain garden plants.

Conclusion

- Implementers must choose the parameter most important to their system's success (for example transpiration in systems with expected high volumes of water or P uptake in systems with high nutrient inputs).
- The Morash and Meder studies lay the groundwork for future rain garden plant studies and provide a method for simulating rain garden conditions with their use of microcosms in any region and with a range of plants species.
- This research built a strong case for the use of polyculture in rain garden systems and six diverse species proven to tolerate fluctuating wet/dry periods in the southeastern U.S.A.

Credits

- Morash, J. Flooding Tolerance of Six Native Landscape Plants for Use in Southeastern Rain Gardens. Master's Thesis, Auburn University, Auburn, AL, USA, 2016.
- Meder, A. Flooding Tolerance and P Uptake of Southeastern Native Plants in Bioretention Gardens. Master's Thesis, Auburn University, Auburn, AL, USA, 2013.

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