The Use of Marine Aquaculture Solid Waste For Nursery Production of the Salt Marsh Plants *Spartina alterniflora* and *Juncus roemerianus*

Heather M. Joesting  
*University of Southern Mississippi, heather.joesting@armstrong.edu*

Reginald B. Blaylock  
*University of Southern Mississippi*

Patrick Biber  
*University of Southern Mississippi*

Andrew Ray  
*University of Southern Mississippi*

Follow this and additional works at: [https://aquila.usm.edu/fac_pubs](https://aquila.usm.edu/fac_pubs)

Part of the [Aquaculture and Fisheries Commons](https://aquila.usm.edu/fac_pubs)

**Recommended Citation**  
Available at: [https://aquila.usm.edu/fac_pubs/17220](https://aquila.usm.edu/fac_pubs/17220)

This Article is brought to you for free and open access by The Aquila Digital Community. It has been accepted for inclusion in Faculty Publications by an authorized administrator of The Aquila Digital Community. For more information, please contact [Joshua.Cromwell@usm.edu](mailto:Joshua.Cromwell@usm.edu).
The use of marine aquaculture solid waste for nursery production of the salt marsh plants *Spartina alterniflora* and *Juncus roemerianus*

H.M. Joesting *, R. Blaylock, P. Biber, A. Ray

Department of Coastal Sciences, Gulf Coast Research Laboratory, University of Southern Mississippi, 703 East Beach Drive, Ocean Springs, MS 35964, USA

**A R T I C L E   I N F O**

**Article history:**
Received 6 August 2015
Received in revised form 6 January 2016
Accepted 9 January 2016
Available online 23 January 2016

**Keywords:**
Marine aquaculture
Salt marsh plants
Solid waste
Phytoremediation

**A B S T R A C T**

Recent technological advances in marine shrimp and finfish aquaculture alleviate many of the environmental risks associated with traditional aquaculture, but challenges remain in cost-effective waste management. Liquid effluent from freshwater aquaculture systems has been shown to be effective in agricultural crop production (i.e., aquaponics), but few studies have explored the potential for reuse of marine aquaculture effluent, particularly the solid fraction. The purpose of this study was to investigate the use of marine aquaculture solid waste as a nutrient source for the nursery production of two salt-tolerant plants commonly used in coastal salt marsh restoration, *Spartina alterniflora* (smooth cordgrass) and *Juncus roemerianus* (black needlerush). Specifically, measurements of plant biomass and tissue nitrogen and phosphorus allocation were compared between plants fertilized with dried shrimp biofloc solids and unfertilized controls, as well as between plants fertilized with dried fish solids and unfertilized controls. In both experiments, *S. alterniflora* plants fertilized with marine aquaculture solids showed few significant differences from unfertilized controls, whereas fertilized *J. roemerianus* plants had significantly greater biomass and absorbed and incorporated more nutrients in plant tissue compared to unfertilized controls. These results suggest that *J. roemerianus* may be a suitable plant species for the remediation of marine aquaculture solid waste.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. **Introduction**

Traditional pond and open-ocean aquaculture can have negative environmental impacts on aquatic ecosystems, including habitat alteration, nutrient and chemical pollution of nearby waters, transmission of diseases and parasites to wild populations, and accidental release of exotic species (Diana, 2012; Hamilton, 2013; Klinger and Naylor, 2012; Marba et al., 2006; Ruiz et al., 2010). While a robust industry can accommodate a variety of production models, recent strategies have focused on developing production-intensive recirculating culture systems that alleviate many of these risks (Klinger and Naylor, 2012).

Recent research has concentrated on identifying alternative uses for aquaculture waste effluent from recirculating culture systems to avoid the economic and environmental costs associated with disposal. Aquaculture waste streams typically contain ammonia, nitrate, and phosphorus (Hargreaves, 1998), which are essential for plant growth, suggesting that aquaculture effluent may be a viable nutrient source for plant production. The use of freshwater liquid aquaculture waste for crop production has been shown to increase plant biomass, and freshwater aquaponic systems are used to lessen the environmental risks of food production (Castro et al., 2006; Ghaly et al., 2005; Turcios and Papenbrock, 2014). However, little research has investigated the fertilization potential of waste effluent from marine aquaculture systems.

Several studies suggest that marine waste effluent can be successfully used to irrigate salt-tolerant crop species (Dufault and Korkmaz, 2000; Dufault et al., 2001; McIntosh and Fitzsimmons, 2003) and plants with potential as forage and oil seed crops (Brown and Glenn, 1999). Although there is potential for marine aquaponics to conserve water and salt in recirculating culture systems, there remain economic and environmental challenges in disposal of the solid portion of the effluent. Furthermore, there are limitations to marine aquaponics associated with either a relatively low demand for the crop and/or the negative effects of salinity (Boxman et al., 2015). However, the increased interest in restoring salt marsh habitats and their ecosystem services has created a demand for crops of native salt marsh plants (Needelman et al., 2012). Therefore, the aim of the present study was to investigate the use of waste...
solids removed from both a minimal-exchange, intensive shrimp aquaculture system and a marine finfish recirculating aquaculture system (RAS) as nutrient sources for the nursery production of two salt-tolerant marsh plants commonly used in coastal restoration projects, *Spartina alterniflora* and *Juncus roemerianus*.

2. Material and methods

To determine the fertilization potential of marine aquaculture solids, plant biomass and nutrient allocation were examined under greenhouse conditions for two plant species commonly used in salt marsh restoration on the Atlantic and Gulf of Mexico coasts, *S. alterniflora* Loisel (smooth cordgrass) and *J. roemerianus* Scheele (black needlerush). *S. alterniflora* is the dominant species in Atlantic salt marshes and typically occurs as a monoculture bordering open water subject to daily tidal fluctuations. *S. alterniflora* is a C₄ grass with predominant spring-fall growth and winter senescence after flowering in the fall (Gabriel and de la Cruz, 1974; Eleuterius and Caldwell, 1984). Productivity and shoot/leaf growth are highest in the spring and summer, with an increase in standing stock biomass throughout the growing season (Squier and Good, 1974). Growth slows or stops as temperatures cool into the winter, and decomposition of standing shoots occurs into the following growing season. *J. roemerianus* is the dominant species in Gulf Coast salt marshes and occupies habitats upland of *S. alterniflora* where tidal inundation is more irregular. *J. roemerianus* is a C₃ rush with evergreen leaves that grows year-round. Peak productivity is in the summer after spring flowering (Eleuterius, 1975; Eleuterius and Caldwell, 1984). Senescence of leaves occurs year-round, with a minor peak during the cooler winter months (Eleuterius and Caldwell, 1981).

For the present study, both *S. alterniflora* and *J. roemerianus* were grown from native Gulf of Mexico seed, planted in a 50:50 sand:topsoil mixture in 730 cm⁻³ (“4-inch”) diameter pots, and maintained in greenhouse culture at the Center for Coastal Plant Restoration (CPR) located at the University of Southern Mississippi’s GulfCast Research Laboratory (GCLR). Plants were fertilized with dried solids removed from intensive shrimp and finfish culture, and plant biomass and tissue nutrient content were compared to unfertilized controls.

2.1. Shrimp biofloc solids experiment

Shrimp biofloc solids were collected from intensive, minimal-exchange culture systems for *Litopenaeus vannamei* (Pacific white shrimp) at the University of Southern Mississippi’s Thad Cochran Marine Aquaculture Center (CMAC). A detailed report of shrimp culture conditions and management protocols is provided by Ray et al. (2011). Settling chambers were used to control the concentration of suspended biofloc particles, and settled material with a solids concentration of approximately 10 g/L was removed from the chambers once per week during a 13-week trial. This material was placed in a 22.9 × 1.2 × 0.6 m (L × W × D) polyethylene-lined drying basin contained under a greenhouse covered with opaque plastic sheeting for three months until thoroughly dried, at which time the solids were collected and stored at −20 °C prior to the experiment. Before being applied to plants, shrimp biofloc solids were ground to consistency in a commercial blender, rinsed three times with deionized water to remove debris, and dried at 65 °C for at least 48 h.

The nutrient addition experiment was conducted at the CMAC from November 2011 to March 2012. Mean monthly air temperatures in the greenhouse ranged from 17.7 °C in December 2011 to 24.2 °C in March 2012, and mean monthly light intensity (measured as photosynthetically active radiation or PAR) ranged from 86.4 μmol m⁻² s⁻¹ in February 2012 to 132.8 μmol m⁻² s⁻¹ in March 2012 (Table 1). These monthly greenhouse air temperatures and light intensity are representative of typical growing conditions for plant nursery production in this region. Six pots of each plant species were placed in 5.5 cm deep nursery trays for a total of 16 trays per species (n = 96 pots/species). Trays were randomly arranged in a 3.0 × 3.6 m greenhouse, sub-irrigated daily by filling trays using a timed watering system, and manually sprayed with water from above once a week. For each species, eight trays were randomly assigned one of the following two treatments (n = 16 trays/per species): (1) Control (C) treatment, with the addition of 30 mL water, and (2) shrimp solids (SS) treatment, with the addition of 7 g of ground dried shrimp biofloc solids and 30 mL water. Dried shrimp biofloc solids had a total nitrogen content of 532 mg/dose (434 mg NH₄⁺, 42 mg NO₃⁻, and 56 mg organic nitrogen) and 77 mg/dose of total phosphorus. There were no significant differences in plant biomass or tissue nutrient content in either *S. alterniflora* or *J. roemerianus* plants at the beginning of the experiment. Nutrient additions were made weekly from November 4 to December 9, 2011, for a total of six weeks (dosing period), and plants remained in the greenhouse until March 20, 2012 (~12 weeks) to allow for conversion of assimilated nutrients into plant biomass during spring growth (response period).

2.2. Fish solids experiment

The recirculating aquaculture system (RAS) used for this research was a prototype of a commercial-scale spotted seatrout (*Cynoscion nebulosus*) production facility designed in collaboration with Aquaculture Systems Technology, LLC, New Orleans, LA (for details see Ebeling et al., 2011). The facility, located at CMAC, consisted of nursery, fingerling, and growout systems designed to accommodate 30–40 kg/m³ biomass. Water from the culture units circulated through a propeller-washed bead filter, a UV unit, a heat pump, a moving-bed biofilter, and a foam fractionator. Approximately 3500 L of effluent at 4 g/L solids was collected from the bead filters and pumped into a 3.0 × 3.7 m geotextile bag. The geotextile bag was loaded up to 85% of its volume and allowed to drain and consolidate. Dried fish solids were collected from the geotextile bag approximately 12 months after the last backwash of the bead filters. Before being applied to plants, dried fish solids were ground to consistency in a commercial blender, rinsed three times with deionized water to remove debris, and dried at 65 °C for at least 48 h.

The nutrient addition experiment was conducted at the CMAC from September 2012 to March 2013. Mean monthly air temperatures in the greenhouse ranged from 19.0 °C in December 2012 to 28.5 °C in September 2012, and mean monthly light

<table>
<thead>
<tr>
<th>Date</th>
<th>Air temperature (°C)</th>
<th>PAR (µmol m⁻² s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 2011</td>
<td>18.2</td>
<td>107.2</td>
</tr>
<tr>
<td>Dec 2011</td>
<td>17.7</td>
<td>96.4</td>
</tr>
<tr>
<td>Jan 2012</td>
<td>20.1</td>
<td>99.6</td>
</tr>
<tr>
<td>Feb 2012</td>
<td>21.0</td>
<td>86.4</td>
</tr>
<tr>
<td>Mar 2012</td>
<td>24.2</td>
<td>132.8</td>
</tr>
<tr>
<td>Sep 2012</td>
<td>28.5</td>
<td>147.5</td>
</tr>
<tr>
<td>Oct 2012</td>
<td>23.6</td>
<td>123.3</td>
</tr>
<tr>
<td>Nov 2012</td>
<td>19.6</td>
<td>97.0</td>
</tr>
<tr>
<td>Dec 2012</td>
<td>19.0</td>
<td>78.9</td>
</tr>
<tr>
<td>Jan 2013</td>
<td>19.1</td>
<td>81.9</td>
</tr>
<tr>
<td>Feb 2013</td>
<td>19.6</td>
<td>92.3</td>
</tr>
<tr>
<td>Mar 2013</td>
<td>22.3</td>
<td>133.5</td>
</tr>
</tbody>
</table>

Table 1 Monthly mean air temperature (°C) and light intensity [measured as photosynthetically active radiation (PAR; µmol m⁻² s⁻¹)] in the greenhouse during the period of the shrimp solids and fish solids experiment.
**Spartina alterniflora:**

**Fig. 1.** Aboveground dead, aboveground live, and belowground biomass for *Spartina alterniflora* (top) and *Juncus roemerianus* (bottom) at the end of the dosing and response periods in the shrimp solids experiment (shrimp control and shrimp solids) and fish solids experiment (fish control and fish solids). The zero line represents the soil line. Significant differences ($P \leq 0.050$) for total biomass are represented by asterisks (*) and for live and/or dead biomass by pluses (+).

**Juncus roemerianus:**

**Fig. 2.** Total percent nitrogen and phosphorus in aboveground dead, aboveground live, and belowground tissue for *Spartina alterniflora* plants in the shrimp solids experiment (shrimp control and shrimp solids) and the fish solids experiment (fish control and fish solids) at the end of the dosing (top) and response (bottom) periods. The zero line represents the soil line. Significant differences ($P \leq 0.050$) for total biomass are represented by asterisks (*) and for live and/or dead biomass by pluses (+).
intensity (PAR) ranged from 78.9 μmol m$^{-2}$ s$^{-1}$ in December 2012 to 147.5 μmol m$^{-2}$ s$^{-1}$ in September 2012 (Table 1). As in the shrimp solids experiment, these growing conditions are representative of plant nursery production in this region. Five pots of *S. alterniflora* and *J. roemerianus* were placed in 5.5 cm deep nursery trays for a total of 16 trays per species (n = 80 pots/species). Trays were randomly arranged in a 3.0 × 3.6 m greenhouse and both sub-irrigated daily and watered once a week as described above. For each species, eight trays were randomly assigned one of the following treatments (n = 16 trays/species): (1) Control (C) treatment, with the addition of 30 ml water, and (2) fish solids (FS) treatment, with the addition of 14 g of ground dried fish solids and 30 ml water. Dried fish solids had a total nitrogen content of 476 mg/dose (all as organic nitrogen) and 70 mg/dose of total phosphorus. There were no significant differences in plant biomass or tissue nutrient content in either *S. alterniflora* or *J. roemerianus* at the beginning of the experiment. Nutrient additions were made weekly from September 21 to October 26, 2012, for a total of six weeks (dosing period), and plants subsequently remained in the greenhouse until March 18, 2013 (~26 weeks) to allow for conversion of assimilated nutrients into plant biomass during spring growth (response period).

### 2.3. Plant biomass and nutrient allocation

For both experiments, plant biomass and tissue nutrient allocation measurements were made at the end of both the dosing period (Week 6) and at the end of the response (i.e., spring growth) period (Week 18 for shrimp biofloc solids experiment and Week 26 for fish solids experiment). Recovery times differed between the two experiments to avoid potential complications in the fish solids experiment that may have resulted from making nutrient additions during natural winter senescence for both species. Measurements were made at each of these periods rather than only at the end of the experiment to accurately depict how plants respond to nutrient availability. Plant biomass and tissue nutrient content measurements during the dosing period reflected plant growth response to nutrients immediately available for plant uptake and allocation whereas measurements during the response period signified spring plant growth response to nutrients stored over winter.

Aboveground (AG) live and dead biomass and belowground (BG) biomass were measured for both species at the end of the dosing and response periods, with the exception of the shrimp biofloc solids experiment in which BG was not measured at the end of the dosing period. The AG biomass of one randomly chosen pot/tray (n = 16) for each species in both treatments was harvested, sorted into live and dead fractions, dried at 65 °C for at least 48 h, and measured for dry weight. Similarly, BG biomass was harvested, washed to remove soil, and dried at 65 °C for at least 48 h, after which dry weight was measured. All dried biomass was ground to pass through a number 40-ieve, and powdered tissue was stored in clean 20 mL glass scintillation vials in a desiccator at <50% humidity for tissue-nutrient (N and P) analysis. Treatment effects on plant biomass for both species within measurement periods were compared between nutrient addition treatments (either SS or FS) and the C treatment using a one-way ANOVA.

Plant tissue content of nitrogen and phosphorus was analyzed from ground AG live/dead and BG tissue for each species at the end of the dosing and response periods. For total percent nitrogen (%N), samples were analyzed by elemental combustion. For total percent phosphorus (%P), samples were prepared for phosphorus digestion following the standard operating procedure outlined by EPA (2004), and total phosphorus (measured as phosphate) concentrations were determined colorimetrically (Strickland and Parsons, 1968). Duplicate %N subsamples for both species within measurement periods were compared between nutrient addition treatments (either SS or FS) and the C treatment using a three-factor nested ANOVA (i.e., treatment, flat [treatment], and sample). Mean %P for both species within measurement periods was compared between nutrient addition treatments (either SS or FS) and the C treatment using a one-way ANOVA.

### 3. Results

#### 3.1. Shrimp biofloc solids experiment

There was no effect of nutrient addition on plant biomass for *S. alterniflora* in the SS treatment at the end of either the dosing or response period (Fig. 1). For *J. roemerianus*, AG live biomass ($F_{1,15} = 6.479, P = 0.023$), total AG biomass ($F_{1,15} = 5.254, P = 0.038$), and total BG biomass ($F_{1,15} = 8.191, P = 0.013$) were all significantly greater in the SS treatment compared to the C treatment at the end of the response period (Fig. 1). The total %P of AG live tissue was significantly greater for *S. alterniflora* plants in the SS treatment compared to the C treatment at the end of the dosing period ($F_{1,15} = 10.754, P = 0.006$), and there was significantly greater total %P in BG tissue in SS-dosed plants compared to the C treatment at the end of the response period ($F_{1,15} = 50.925, P = 0.001$; Fig. 2). At the end of the response period, *J. roemerianus* plants in the SS treatment had significantly less total %N in BG tissue ($F_{1,14} = 8.071, P = 0.013$) and significantly greater total %P in BG tissue ($F_{1,15} = 12.667, P = 0.031$) compared to the C treatment (Fig. 3).

These results suggest that in *S. alterniflora*, mainly the phosphorus present in the shrimp solids was absorbed and assimilated into plant tissues, resulting in significantly greater phosphorus content in plant tissues in the SS treatment compared to the C treatment. However, the greater concentration of phosphorus in tissues did not translate into increased biomass or productivity for this species during the experiment. The results also indicate that available nutrients were absorbed and incorporated into plant tissues in *J. roemerianus* plants, resulting in significantly greater total AG and BG biomass in the SS treatment compared to the C treatment.

#### 3.2. Fish solids experiment

For *S. alterniflora*, there was no significant effect of FS on total plant biomass at the end of either the dosing or response period (Fig. 1). For *J. roemerianus* at the end of the dosing period, there was significantly less BG biomass in FS-dosed plants compared to the control ($F_{1,14} = 5.026, P = 0.0431$; Fig. 1). At the end of the response period, the ratio of AG live-to-dead biomass was significantly greater ($F_{1,15} = 6.750, P = 0.021$) in FS-dosed *J. roemerianus* plants (1.89) compared to the C treatment (0.89) due to a higher amount of AG live compared to dead biomass in plants in the FS treatment. *S. alterniflora* plants dosed with FS had significantly greater %P in BG biomass compared to the C treatment at the end of both the dosing period ($F_{1,13} = 7.577, P = 0.018$) and the response period ($F_{1,15} = 5.180, P = 0.039$; Fig. 2). For *J. roemerianus*, plants in the FS treatment had significantly greater %P in BG biomass compared to the C treatment at the end of the dosing period ($F_{1,15} = 17.159, P = 0.001$; Fig. 3). At the end of the response period, *J. roemerianus* plants in the FS treatment had significantly greater %N in AG live biomass ($F_{1,13} = 7.194, P = 0.019$), %P in AG live biomass ($F_{1,13} = 13.609, P = 0.002$), and %P in BG biomass ($F_{1,15} = 20.956, P < 0.001$).

The results from this experiment indicate that the phosphorus in fish solids was absorbed and assimilated into *S. alterniflora* plant tissues, resulting in significantly greater phosphorus content in plant tissues, especially in BG tissues, in the FS treatment compared to the control. Similar to the shrimp solids experiment, this increased assimilation of phosphorus did not result in a significant increase
in plant biomass in *S. alterniflora* during the experiment. On the other hand, the results suggest that *J. roemerianus* plants in the FS treatment incorporated both nitrogen and phosphorus into plant tissues, resulting in significantly greater nitrogen content in AG live tissues and phosphorus content in all plant tissues compared to plants in the C treatment, but this did not stimulate significant growth of new biomass during the experiment.

### 4. Discussion

The results of this study demonstrate a response of *S. alterniflora* and *J. roemerianus* to nutrient additions from marine aquaculture waste solids and generally reinforce the enhancement of growth for salt marsh plants in response to nutrient additions, especially nitrogen and phosphorus, found in other studies (Brewer, 2003; Fox et al., 2012; Levine et al., 1998; McFarlin et al., 2008; Mozdzer et al., 2010; Pennings et al., 2002). There were relatively weak growth responses of *S. alterniflora* to nutrient addition in both the shrimp and fish solids treatments, indicating that this plant species may not be an ideal candidate for remediation of marine aquaculture solids. However, the significant growth response of *J. roemerianus* plants in both nutrient addition treatments indicate the potential use of recovered marine aquaculture solids as a nutrient source in the nursery production of this species.

In both nutrient addition experiments, *S. alterniflora* plants responded more to available phosphorus in marine aquaculture solids than to available nitrogen. These results suggest a number of potential mechanisms for reduced nitrogen assimilation, such as a lack of suitable forms of nitrogen for assimilation, preferential uptake of phosphate, or inhibition in either nutrient (primarily nitrogen) uptake and/or subsequent incorporation into new biomass. Although results suggested that phosphorus was readily absorbed and incorporated into living tissue in both nutrient addition treatments, this did not result in significant increases in plant biomass. It is possible that a fertilization response in the FS treatment was obscured by the overall decline in plant biomass observed for *S. alterniflora* during the experiment, likely due to natural winter senescence of this species. Alternatively, the weak growth response in this treatment may have been due to limitation in the absorption and/or subsequent incorporation of nutrients into growth and biomass.

Nutrient additions from both shrimp and fish solids stimulated plant growth in *J. roemerianus*, suggesting that *J. roemerianus* was able to absorb available nitrogen and phosphorus and assimilate them into new growth. Although there were no detected fertilization effects in the SS treatment at the end of the dosing period, likely due to the slow growth rate characteristic of *J. roemerianus*, plants did have significantly greater total AG and BG biomass and %P in BG tissue compared to the C treatment at the end of the response period. There also was an increase in total AG biomass for plants in the SS treatment between the end of the dosing period and the end of the response period (Fig. 1). Furthermore, the \( \sim 28\% \) increase in total BG biomass in the SS treatment compared to the C treatment at the end of the response period is a desirable result for successful salt marsh restoration, since a well-developed root system functions to increase sediment retention. Similarly, there was a significant growth response in *J. roemerianus* plants to nutrient additions from fish solids. At the end of the dosing period, there was significantly greater %P in BG tissue, and at the end of the response period, plants had significantly greater AG live: dead biomass, %N in AG live tissue and %P in AG live and BG tissue compared to the C treatment. However, total BG biomass was significantly lower in the FS treatment compared to the C treatment at the end of the dosing period, and although not significant, this trend continued at the end of the response period. The allocation of biomass aboveground versus belowground depends on the amount of...
nutrients available for uptake (Larcher, 2003). If nutrient supply is low, plants will allocate more biomass belowground to increase root growth and surface area for nutrient absorption, but if a steady supply of nutrients is available, plants will allocate less biomass to belowground production and more to aboveground production to increase shoot growth. The significantly greater AG live: dead biomass and %N and %P in AG live tissue in F-dosed plants at the end of the response period suggests that these plants were allocating more biomass to aboveground production as a response to readily available nutrients.

Assimilation efficiency of nitrogen is of particular interest to marine aquaculture management, as animal wastes cause nitrates levels in aquatic environments to become elevated and potentially toxic. While the estimated nitrogen removal efficiencies were low in these two studies (ranging from 0.5% to 4% of dosed), results suggest that some nitrogen translocation occurred from the dosing medium into the plant tissues, primarily the roots. This may indicate that substantial microbial denitrification was occurring in the compact waterlogged soils and that a soil mix with coarser components, such as pine bark mulch, is necessary to maintain more aerobic soil conditions to facilitate nitrogen uptake by the plants (Lasala et al., 2001; Nacry et al., 2013). Estimated phosphorus removal efficiencies were high (ranging from 27% to 52% of dosed) suggesting that plants, especially J. roemerianus, readily absorbed phosphorus into the roots and used it for plant growth. This may indicate that P-limitation had occurred in the plants grown in greenhouse culture prior to the experiment. Allowing for continued plant growth with a longer recovery period may have permitted the measurement of increased nutrient contents in the living shoot and leaf tissues. Based on the results obtained in these studies, it is recommended that more attention be focused on measuring all components (water, soil, plant tissue) over time to permit a more detailed nutrient (N and P) budget to be constructed and that plants be allowed to recover for longer periods of time after dosing is completed to allow for more complete nutrient assimilation into new growth.

To meet increasing demand and be economically competitive, intensive, minimal-exchange culture systems must use high stock densities that require intensive feeding and waste management to maintain appropriate culture conditions. Regardless of whether management focuses on removing only a portion of the particles, as in the case of shrimp biofloc systems (see Ray et al., 2011), or minimizing the number of particles, as in RAS used for marine finfish, marine aquaculture solids are generally considered a waste-by-product and disposal of these solids represent an environmental and economic barrier to sustainable marine fish and shrimp aquaculture production. The results from this study suggest that solids removed from marine aquaculture systems can be used as a nutrient source in the nursery production of salt-tolerant coastal marsh plants for restoration, especially J. roemerianus. Reusing and repurposing the solid waste could help mitigate some of the known potential environmental impacts of marine aquaculture systems and provide a value-added product for use in increasingly important saltmarsh restoration projects, further contributing to the increasing economic and environmental sustainability of aquaculture.

Statement of relevance

The research in this manuscript investigates the potential repurposing of solid waste from marine aquaculture as a fertilizer for salt marsh plants. The repurposing of these solids would increase the sustainability and potential profitability of marine aquaculture by reducing economic and environmental challenges in proper waste disposal, as well as providing a secondary marketable crop.

Acknowledgements

We wish to thank Lynnae Manuel, Viviani Mazzei, Linh Pham, Steve Giddens, and Tamela Jones for assistance in data collection. The National Grant (R/SP-24-NSI) funded this project.

References


