



Revegetative success of native species following chemical and mechanical treatment of invasive European common reed (*Phragmites australis* ssp. *australis*)

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ABSTRACT

Invasions of nonnative European common reed (*Phragmites australis* ssp. *australis*) result in degraded wetland ecosystems that do not provide the same level or variety of ecological functions as healthy wetlands. Areas impacted by common reed invasions are increasing in frequency and area. This study evaluates the use of vegetative treatments to compete and inhibit the invasion of common reed in wetland restoration projects. Common reed was mechanically and chemically controlled in a dominated wetland in Villas, NJ. Five native species [crimson eyed rosemallow (*Hibiscus moscheutos*), High Tide Germplasm switchgrass (*Panicum virgatum*), Southampton Germplasm prairie cordgrass (*Spartina pectinata*), sugarcane plumegrass (*Saccharum giganteum*), and eastern gamagrass (*Tripsacum dactyloides*)] were planted in replicated single species plots following control measures. The degree of success of the native species was assessed by examining survival, percent coverage, and common reed biomass production after one and two growing seasons. The percent cover of common reed was significantly lower in High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass plots than control plots both years. The amount of common reed biomass production was significantly lower in the High Tide Germplasm switchgrass plots than the control plots after one growing season. Crimson eyed rosemallow had the greatest survival rate. High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass survival were average (both > 50%). While sugarcane plumegrass and eastern gamagrass both had 0% survival after the second growing season. Results suggested that certain native plant species are more apt to coexist in areas impacted by common reed invasions. Additionally, the findings show that appropriate vegetative practices may slow the spread or reinvasion of treated areas; however, they are unlikely to completely prevent either.

INTRODUCTION

The importance of wetland ecosystems and the value of the functions they perform has been extensively documented. However, many of the benefits of wetlands are negatively impacted when these ecosystems become degraded due to invasive plant invasions (Hazelton et al., 2014). One of the most common and aggressive exotic plant invaders of wetlands is nonnative European common reed (*Phragmites australis* ssp. *australis*). Common reed affected areas appear to be increasing in frequency and expanding in area (Ailstock et al., 2001). Studies have linked common reed invasions with reduced plant diversity, degradation of fish and wildlife habitat, and disturbances to biogeochemical cycles (Chambers et al., 1999; Fell et al., 2003; Meyerson et al., 1999). Successful control of common reed is the first step in restoring these degraded wetlands,

but control of common reed does not necessarily lead to successful volunteer establishment of the native plant community. Active native plant establishment following invasive plant control can assist the process of building the native plant community as well as slow or prevent reinvasion (Burdick, 2006; Fargione and Tilman, 2005).

Determining alternative native plants to compete with and control the spread of common reed was identified as a need in the 2014 and 2015 Northeast Region Plant Materials needs assessment survey. A literature review revealed extensive research on common reed control methods and their varying degrees of success. However, there is a lack of research focusing on revegetation success following invasive species control with only one-third of studies reviewed evaluating revegetation success (Kettenring and Adams, 2011). This study examines the use for revegetation of five native species: crimson eyed rosemallow (*Hibiscus moscheutos*), High Tide Germplasm switchgrass (*Panicum virgatum*), Southampton Germplasm prairie cordgrass (*Spartina pectinata*), sugarcane plumegrass (*Saccharum giganteum*), and eastern gamagrass (*Tripsacum dactyloides*).

Crimson eyed rosemallow is a native obligate wetland plant common to brackish and freshwater marshes, swamps, floodplains, and alluvial meadows (Reeves, 2008). The typical environment in which crimson eyed rosemallow thrives is like that of common reed. In the Maryland region of the Chesapeake Bay, they have been reported to frequently occur as codominant species (Sipple, 1978). Hoy and Burdick (2005) reported that crimson eyed rosemallow was surviving at several brackish marsh sites in New Hampshire invaded by common reed. Under ideal conditions, crimson eyed rosemallow can form nearly monospecific stands as the sole dominant plant species which may make it an ideal species to compete against common reed (Cahoon and Stevenson, 1986).

Switchgrass is a native, warm season, perennial grass assigned a wetland indicator status of facultative for the Northcentral and Northeast region; it is equally likely to occur in wetland and non-wetlands within the region (Lichvar, 2014). High Tide Germplasm switchgrass is a tested plant released by the Cape May Plant Materials Center, Cape May, NJ in 2007. High Tide Germplasm switchgrass originates from a collection site near Perryville, MD at the intertidal zone where the Susquehanna River meets the Chesapeake Bay. High Tide Germplasm switchgrass is particularly valuable for stabilizing tidal shorelines and streambanks (USDA-NRCS, 2012). Given its collection location and use in similar environments, it was identified as having a high likelihood to survive and impede the spread of common reed. In a study examining and testing anecdotal accounts of common reed control measures used by salt-hay (saltmeadow cordgrass [*Spartina patens*]) farmers in New Jersey, Bart (2010) reported an account of one farmer that mowed a common reed dominated plot biweekly as a means of control. The common reed was eradicated after one growing season and the plot was repopulated by volunteer switchgrass.

Prairie cordgrass is a native, perennial grass with a facultative wetland indicator status for the Northcentral and Northeast region meaning that it most commonly occurs in wetlands, but may occur in non-wetlands within the region (Lichvar, 2014). Southampton Germplasm prairie cordgrass is a selected class conservation plant released by the Cape May Plant Materials Center, Cape May, NJ in 2013. Southampton Germplasm prairie cordgrass was selected for erosion control applications on streambanks, spillways, and drainage channels (USDA-NRCS, 2013).

Southampton Germplasm prairie cordgrass has displayed some success in impeding the reinvasion of some exotic, invasive species. In a trial from 2007 to 2010 in Lamb's Creek (Mansfield, PA), Southampton Germplasm prairie cordgrass was shown to successfully compete with and minimize the spread of Japanese knotweed (*Polygonum cuspidatum*) following two years of chemical and mechanical treatments (Van der Grinten et al., 2011). Hoy and Burdick (2005) reported that stands of prairie cordgrass coexist at a brackish marsh site in New Hampshire that had been invaded by common reed.

Sugarcane plumegrass is a perennial, facultative wetland grass for all regions (Lichvar, 2014). Forming clumps, it grows best at the edges of ponds and streams, in bogs and saturated ditches, and tidal freshwater marshes (NPIN, 2011). Because it has been documented to spread readily by seed and shares many of the same ideal environmental characteristics with common reed, sugarcane plumegrass was included in this study (Mellichamp, 2014).

Eastern gamagrass is a native, warm season, perennial grass assigned a wetland indicator status of facultative for the Northcentral and Northeast region (Lichvar, 2014). Research has shown that eastern gamagrass regularly forms aerenchyma regardless of soil conditions. The research suggests that the formation of aerenchymous roots may allow eastern gamagrass roots to persist in anaerobic, water logged soils (Clark et al., 1998). This could explain why the native habitat of eastern gamagrass includes swales, salt marsh borders, stream banks, lowlands, and other saturated conditions (NPIN, 2006; Stubbendieck et al., 1992). Given the research findings and the extent of its native habitat conditions, eastern gamagrass was thought to have potential to survive in similar conditions as common reed.

The objective of this study is to evaluate the success of these native species to compete with and inhibit the reinvasion of common reed in wetland restoration projects. The findings of this study could be of value to conservation planners addressing degraded plant condition resource concerns with inadequate structure and composition or excessive plant pest pressure in a wetland environment. These findings could be applicable to conservation practices Wetland Wildlife Habitat Management (644), Wetland Restoration (657), Wetland Creation (658), and Wetland Enhancement (659).

MATERIALS AND METHODS

This study was conducted in an area of a tidally influenced, fresh water high marsh ecosystem at the north end of Villas, NJ (39.038023, -74.929142). The soil type of the entire study area is a Mispillion-Transquaking-Appoquinimink complex (MmtAv). The common reed infestation of the study area formed a dense monoculture lacking almost any native vegetation. Initial plant populations were determined by sampling four randomly placed transects through the entire width of the study area. Sample points were examined at 10 ft intervals along each transect. Each species and the percent coverage within a 1 ft radius of the sample point was recorded.

The common reed control procedures for the entire plot area began with the initial mowing treatment in late July of 2016. After allowing a month of regrowth following the mowing, the initial chemical treatment was applied the last week of August 2016. A non-selective, systemic glyphosate herbicide labeled for aquatic sites was applied evenly at the label recommended rate over the entire study area. The plot area was mowed again after all plants had gone dormant in November 2016. A follow up chemical spot treatment was done the first week of May 2017.

using the same herbicide applied with a low volume backpack sprayer [Jacto Incorporated (Tualatin, OR)] to conclude the treatment measures.

The entire plot area measured 26x146 ft and consisted of 24 10x10 ft plots arranged in a randomized complete block design with four replications of each treatment. Each plot, except for the control plots, was planted with a single native species. All plots had a 2 ft wide spacing between them and around the outer edges. The purpose of the spacing between and around the outer edges of the plots was to maintain uniformity and consistency between plots and throughout each plot.

The plants used for revegetation were sourced from the Cape May Plant Materials Center (PMC). The five species used for revegetation were crimson eyed rosemallow, High Tide Germplasm switchgrass, Southampton Germplasm prairie cordgrass, sugarcane plumegrass, and eastern gamagrass. All species are local genotypes and have had excellent survival and longevity at the Cape May PMC. Except for the rosemallow, all plants were produced by field digging and splitting mature individuals and repotting the propagules in quart sized containers. The rosemallow plants were started from seed and grown out in trays with cells measuring 2x2x4.5 in. The plots were planted with the five native plant species the last week of May 2017, three weeks after the final control treatment to avoid any damage due to residual chemical from the control treatment. All species were planted at a rate of 1 plant/2 ft² following the row spacing and in row plant spacing guidelines in the planting diagram.

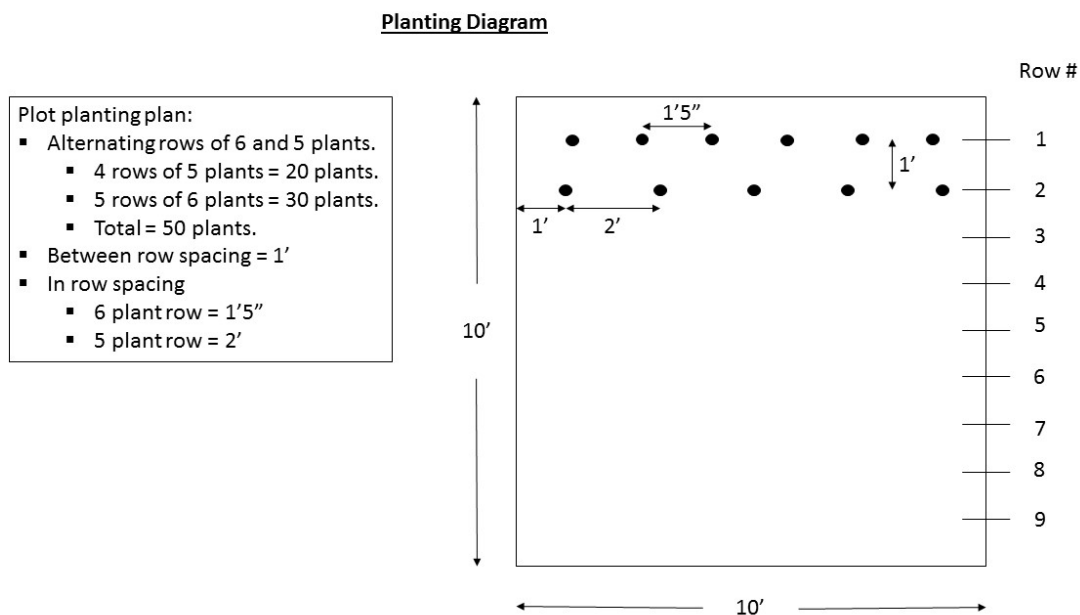


Figure 1 The planting diagram shows the row spacing and in row plant spacing used for all five species tested in the study.

Evaluations were performed the last week of October at the end of the 2017 and 2018 growing seasons. Survival counts of the planted native species were performed for each plot by placing a 5x5 ft quadrat in the center of each plot and recording the number of surviving native species. Species diversity within plots was evaluated by sampling four non-overlapping 1 m² quadrats in each plot. Each species present was identified and recorded in addition to its percent coverage in

the quadrat. Additionally, common reed biomass data was also collected. All common reed was cut at the water level and collected from each of the 1 m² sampling quadrats. The biomass cuttings were then dried at 70°C until their weights remained constant (about 48 hours) before recording dry weights. All data were analyzed using ANOVA and Tukey's honestly significant difference (HSD) in Statistix 10 software.

RESULTS AND DISCUSSION

Results presented in the following tables use the USDA-NRCS Plants Database symbol to refer to plant species. The symbols for all species reported in this study are displayed in Table 1. Data from the random transect sampling method of the initial plant population assessment supported the initial observational assessment that the trial site had degraded to nearly a monospecific stand of common reed. Common reed was observed at 100% coverage at all 56 sample points. The three other species recorded (crimson eyed mallow, manyflower marshpennywort, and swamp smartweed) are all natives, but occurred at a much lower frequency (2%, 4%, and 43% respectively). Even when present, the percent coverage of the native species was minor compared to the common reed coverage.

Table 1. The USDA-NRCS Plants Database symbols used to identify species.

Symbol	scientific name	common name
CYOD	<i>Cyperus odoratus</i>	fragrant flatsedge
ECWA	<i>Echinochloa walteri</i>	coast cockspur grass
HIMO	<i>Hibiscus moscheutos</i>	crimson eyed rosemallow
HYUM	<i>Hydrocotyle umbellata</i>	manyflower marshpennywort
PAVI2	<i>Panicum virgatum</i>	switchgrass
PHAUA7	<i>Phragmites australis</i>	European common reed
PLOD	<i>Pluchea odorata</i>	sweetscent
POHY2	<i>Polygonum hydropiperoides</i>	swamp smartweed
SAGI	<i>Saccharum giganteum</i>	sugarcane plumegrass
SPPE	<i>Spartina pectinata</i>	prairie cordgrass
TRDA3	<i>Tripsacum dactyloides</i>	eastern gamagrass

Table 2. Results from the August 2016 survey of existing vegetation at the study area prior to the application of any common reed control measures at the trial site in Villas, NJ carried out by the Cape May Plant Materials Center staff.

Species	Times Present	Frequency (%)	Avg. % cover (when present)
HIMO	1	2	3
HYUM	2	4	2
PHAUA7	56	100	100
POHY2	24	43	3

Results from the plant survival counts performed in October of 2017 and 2018 showed distinct differences between the species tested and are displayed in Table 3. The crimson eyed rosemallow, High Tide Germplasm switchgrass, and Southampton Germplasm prairie cordgrass

plants all had excellent survival after a single growing season with all three species consistently displaying nearly 100% survival. The sugarcane plumegrass and eastern gamagrass plants were less successful. Sugarcane plumegrass had less than 50% survival and eastern gamagrass had 0% survival after one growing season. Crimson eyed rosemallow, High Tide Germplasm switchgrass, and Southampton Germplasm prairie cordgrass continued to be the top performing species after two growing seasons. Crimson eyed rosemallow maintained over 90% survival while High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass both maintained over 50% survival. The high survival rate of crimson eyed rosemallow reinforces the reports from Sipple (1978) as well as Hoy and Burdick (2005) of it coexisting as a codominant species with common reed. Sugarcane plumegrass and eastern gamagrass both had 0% survival after the second growing season.

Table 3. Results from the 2017 and 2018 end of season plant species survival evaluations showing the average sample count from all replications and the calculated occurrence rate (plants/ft²) of the study trial plots in Villas, NJ carried out by the Cape May Plant Materials Center staff.

Plot	2017		2018	
	avg sample count	avg plants/ft ²	avg sample count	avg plants/ft ²
HIMO	16	0.6	12	0.5
PAVI2	16	0.6	7	0.3
SAGI	4	0.2	0	0.0
SPPE	16	0.6	7	0.3
TRDA3	0	0.0	0	0.0

The 2017 end of season plant diversity evaluations showed an overall increase in plant biodiversity over the initial plant population assessment. While common reed was still present in all plots, it was not the most common or most dominant species in two of the five plot treatments. In both High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass plots the native plants had a higher average percent coverage than common reed. These two plot treatments displayed a statistically significant lower average percent cover of common reed compared to the control treatment plots. High Tide Germplasm switchgrass plots also showed a statistically significant difference compared to eastern gamagrass, sugarcane plumegrass, and crimson eyed rosemallow plots. Southampton Germplasm prairie cordgrass plots only displayed a statistically significant difference compared to eastern gamagrass plots when compared to the other vegetative treatments.

Without additional control treatments, the common reed reinvasion became more aggressive during the second growing season. The 2018 end of season plant diversity evaluations reflected this as common reed reestablished as the most dominant plant with the highest average percent cover for all plot treatments. Both High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass plots again exhibited a statistically significant lower average percent cover of common reed compared to the control treatment plots. High Tide Germplasm switchgrass plots were significantly different than crimson eyed rosemallow, eastern gamagrass, and sugarcane plumegrass plots while Southampton Germplasm prairie cordgrass plots only displayed a significant difference to crimson eyed rosemallow and eastern gamagrass plots.

Several native species that were not present in the initial plant survey volunteered in the trial area after one growing season. While sweetscent (*Pluchea odorata*) was only present in one sampling quadrat, fragrant flatsedge (*Cyperus odoratus*) was present in all but one sampling quadrat with average percent coverages in treatment plots ranging from 19% to 44%. Fragrant flatsedge still commonly occurred after two growing seasons at lower coverage percentages. Coast cockspur grass (*Echinochloa walteri*) was an additional native obligate wetland plant that volunteered frequently after the second growing season. Other native species (manyflower marshpennywort and swamp smartweed) that were present prior to treatments occurred more frequently after two growing seasons following treatments.

Table 4. Results from the 2017 end of season plant species diversity evaluations showing the species present and their average percent cover of the study trial plots in Villas, NJ carried out by the Cape May Plant Materials Center staff.

Plot	Average Percent Coverage of Species								
	CYOD	HIMO	PAVI2	PHAU7	PLOD	POHY2	SAGI	SPPE	TRDA3
control	38.4	0.6	0.0	49.1 ^A	0.0	0.0	0.0	0.0	0.0
TRDA3	36.3	0.1	0.0	46.6 ^A	0.1	0.0	0.0	0.0	0.0
SAGI	44.1	1.3	0.0	44.4 ^{AB}	0.0	0.3	5.3	0.0	0.0
HIMO	29.1	35.3	0.0	40.3 ^{AB}	0.0	0.3	0.0	0.0	0.0
SPPE	19.4	0.0	0.0	27.8 ^{BC}	0.0	0.0	0.0	52.2	0.0
PAVI2	23.8	0.3	62.2	18.4 ^C	0.0	0.0	0.0	0.0	0.0

*Means in the PHAU7 column followed by the same letter are not significantly different according to Tukey's HSD at P=0.05

Table 5. Results from the 2018 end of season plant species diversity evaluations showing the species present and their average percent cover of the study trial plots in Villas, NJ carried out by the Cape May Plant Materials Center staff.

Plot	Average Percent Coverage of Species										
	CYOD	ECWA	HIMO	HYUM	PAVI2	PHAU7	PLOD	POHY2	SAGI	SPPE	TRDA
control	6.5	2.0	0.0	0.0	0.0	86.9 ^A	0.0	1.8	0.0	0.0	0.0
HIMO	8.9	0.9	28.4	0.0	0.0	75.9 ^A	0.0	2.6	0.0	0.0	0.0
TRDA	3.3	4.4	0.0	2.8	0.0	72.7 ^A	0.0	0.8	0.0	0.0	0.0
SAGI	1.9	4.6	0.4	0.3	0.0	69.4 ^{AB}	0.0	1.1	0.3	0.0	0.0
SPPE	3.4	1.4	0.0	0.0	0.0	46.6 ^{BC}	0.0	0.9	0.2	46.3	0.0
PAVI2	12.1	1.7	0.7	0.0	31.6	43.8 ^C	0.0	0.4	0.0	0.0	0.0

*Means in the PHAU7 column followed by the same letter are not significantly different according to Tukey's HSD at P=0.05

Common reed biomass production data aligned closely to percent coverage data, most distinctly at the upper and lower extremes after one growing season. High Tide Germplasm switchgrass was the only treatment that resulted in a statistically significant lower average common reed biomass production than the control treatment after the 2017 growing season. Common reed biomass production data after the 2018 growing season showed no significant differences in response to any of the treatments that data was collected for. Because sugarcane plume grass and eastern gamagrass both had 0% survival after the second growing season, 2018 common reed biomass production data was not collected for those treatments. Both species also had poor survival at the end of 2017 (32% and 0% respectively). Without any of the planted native

vegetation surviving, those trial plots essentially became additional control plots and were dropped from the study.

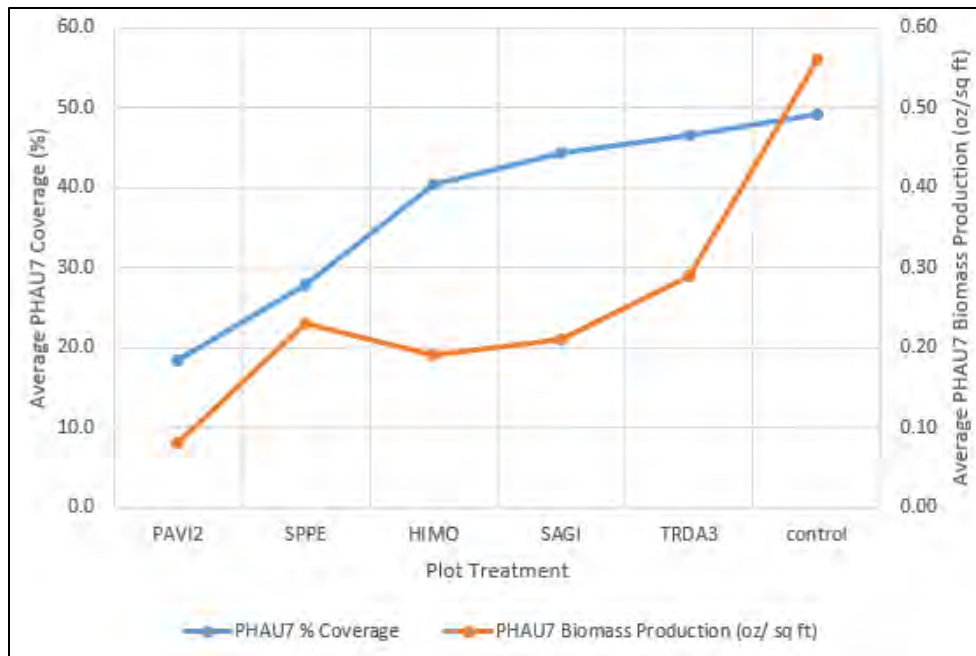


Figure 2. Average results of common reed (PHAUA7) percent coverage and biomass production for each plot treatment after the 2017 growing season following initial control treatments and revegetative planting of the study plots in Villas, NJ. Data collection was carried out by the Cape May Plant Materials Center staff in October 2017.

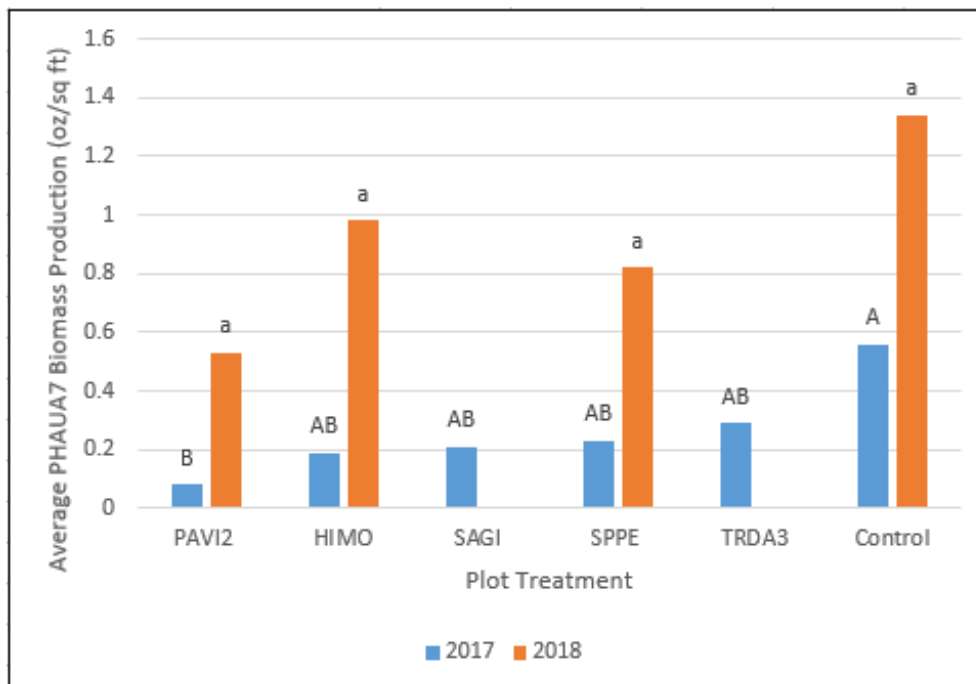


Figure 3. Average results of common reed (PHAUA7) biomass production for each plot treatment after the 2017 and 2018 growing seasons following initial control treatments and revegetative planting of the study plots in Villas, NJ. Data collection was carried out by the Cape May Plant Materials Center staff in October 2017 and 2018.

Plot treatments followed by the same letter are not significantly different according to Tukey's HSD at $P=0.05$

CONCLUSION

While none of the vegetative treatments tested prevented the reinvasion of common reed, several (crimson eyed rosemallow, High Tide Germplasm switchgrass, and Southampton Germplasm prairie cordgrass) showed potential to coexist with and combat monospecific stands of common reed. The significantly lower common reed percent coverage resulting from the High Tide Germplasm switchgrass and Southampton Germplasm prairie cordgrass treatments for two years without additional control measures suggests that they may slow the spread of common reed. The significantly lower common reed biomass production resulting from the High Tide Germplasm switchgrass treatment after one growing season even more strongly supports that claim for High Tide Germplasm switchgrass. Although the crimson eyed rosemallow plots did not show a significant difference in common reed percent coverage or common reed biomass production when compared to the control plots, this species had the best survival of all the native species examined. While there is no evidence that crimson eyed rosemallow slowed common reed reinvasion, the high survival rate did support the previous claims that common reed and crimson eyed rosemallow can coexist as codominant species (Sipple, 1978).

It is unlikely that any vegetative treatment will be exclusively responsible for preventing the spread or reinvasion of common reed. However, the findings of this study suggest that appropriate vegetative practices may slow the spread or reinvasion of treated areas. The findings also suggest that certain native species may be able to tolerate common reed invasion despite its aggressive qualities. Based on these findings vegetative treatments should be considered for common reed control plans. Likely the most efficient and beneficial use of vegetative treatments for common reed control are around the perimeter of common reed impacted sites that are under management to slow spread and at the edges of recently treated areas to discourage reinvasion.

The New Jersey Field Office Technical Guide (NJ FOTG) provides guidance for invasive species control and plant species selection in the standards for conservation practices Wetland Wildlife Habitat Management (644), Wetland Restoration (657), Wetland Creation (658), and Wetland Enhancement (659). When applicable, the findings from this study should be considered by planners when making plant species recommendations for projects implementing these conservation practices.

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APPENDIX



November 18, 2016 after control treatments.



June 12, 2018 study area.



April 4, 2017 prior to planting.



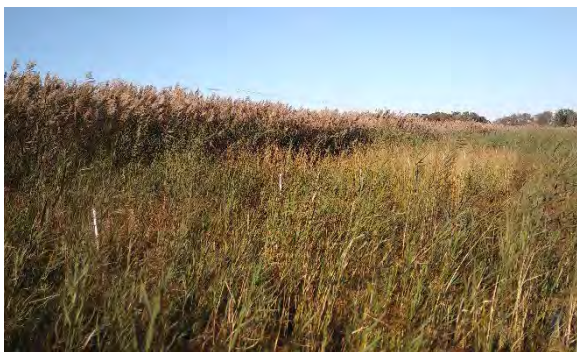
October 31, 2018 study area.



April 26, 2017 study plots surrounded by untreated area.



October 30, 2018 control plot.



October 30, 2017 study area adjacent to untreated area.



October 30, 2018 switchgrass plot.

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