Appendix C

Do Soil Factors Contribute to the Spread of Reed Canarygrass (*Phalaris arundinacea*), An Invasive Wetland Grass?

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Abstract

Reed canarygrass (*Phalaris arundinacea*) is an aggressive wetland grass that frequently displaces more diverse wetland communities. We studied two wetlands in the Tualatin Valley, Oregon, and examined soils under native and canarygrass stands in order to identify soil factors that may contribute to its establishment and spread. One site was a small remnant wet meadow community. The second was a ten-year-old restored wetland with wet meadow and other wetland plant associations. Soil in the remnant wetland was Cove series clay, and in the restored meadow resembled Concord silty clay loam. For each targeted vegetation community we measured profile development and physical characteristics, pH, and mass of root structure in the A horizon. No consistent physical or chemical differences were found in the soil across all sites. We found evidence of soil disturbance at the reed canarygrass site in the remnant meadow and infer that this disturbance allowed its establishment there. We found tentative evidence that some native wetland species may inhibit the spread of reed canarygrass through well-developed root systems and dense ground cover. Longer-term and more detailed study is required for conclusions on what soil conditions favor the spread of reed canarygrass once it is established on a site.

Introduction

Reed canarygrass (*Phalaris arundinacea*) is an aggressive wetland grass that frequently displaces more diverse wetland communities. Although this grass is relatively well-studied, very little literature exists relating its occurrence and spread to the physical and chemical properties of the soils where it grows. This study examined soils on two wetlands managed by the Wetlands Conservancy in the Tualatin Valley, Oregon. Both contained areas of strong reed canarygrass infestation, as well as areas with well-established native vegetation communities. One wetland, called Knez, is a remnant and relatively undisturbed wet meadow community. The second is a larger site, Cedar Mills, that was restored ten years ago and contains ponded, forested, shrub-scrub, and meadow vegetation areas. Due to the differing age and parent materials of the soils at the two sites, their characteristics are quite different, although both support areas of similar vegetation communities.

We visited the sites in early November and sampled the soil under each targeted vegetation community. By studying similar communities growing on diverse soil types, we hoped to identify soil factors correlating to the establishment and spread of reed canarygrass.

Background

Reed canarygrass grows on every continent in the world except Antarctica (Apfelbaum, 1987). It is a robust and variable species that thrives in wet environments. It is a perennial grass able to spread both by its roots and by seeds. It can grow up to seven feet tall, and in thick stands of up to 1000 stems per square meter (Ho,1979).

There are, or were, varieties native to the United States prior to European arrival (Meriglano and Lesica, 1998). However, many researchers believe that this native variety has either hybridized with or been replaced by more aggressive cultivars introduced from Europe (Antieau, 1998; Maurer *et al* 2003). The native status of reed canarygrass is hotly debated in certain circles, probably because new agricultural varieties are still being introduced and promoted at the same time that some states are adding this species to their official noxious weeds lists.

For the purposes of this paper, reed canarygrass is considered invasive based on its aggressive replacement of more diverse wetland communities.

Reed canarygrass is widely planted for a variety of purposes. For over a hundred and fifty years it has been a popular forage grass for poorly-drained meadows (Meriglano and Lesica, 1998). It produces large quantities of hay without fertilization or annual seeding.

It is also commonly used for erosion control at road, construction, and forestry sites (Groffman *et al*, 1991). It germinates rapidly from seed and quickly establishes groundcover and root structure (Apfelbaum, 1987). This provides bank stabilization and sedimentation control in disturbed areas.

In recent years it has proved successful for bio-remediation of many contaminants. It is well-suited for de-nitrifying waste water (Dubois, 1994; Groffman *et al*, 1991), removing toxic metals such as arsenic from mine tailings (Hansel *et al*, 2002), and even pulling nitrates out of TNT (dynamite) contaminated soils and increasing the rate of decomposition of that chemical (Chekol *et al*, 2002). Reed canarygrass is highly tolerant of salt and toxins (Maeda and Takenaga, 1993), and once established, can survive even in relatively dry soil regimes (Antieau, 1998). These qualities make it an excellent candidate for improving many contaminated soils.

The same qualities that make this grass so useful – rapid growth, hardiness, production of thick, dense stands, and indifference to poor soil conditions – create problems when the grass achieves a foothold in a native wetland community (Apfelbaum, 1987). Breeders have encouraged its aggression and hardiness, and these varieties have dispersed and hybridized to the point where many wetland land managers consider invasion inevitable where it has not yet occurred (Cherney *et al*, 2003).

Study Sites

We studied two sites, both small wetlands that had areas of well-established native wet meadow vegetation, and areas where reed canarygrass formed large monotypic stands. The Knez wetland is a two-acre wet meadow community surrounded by light-industrial development. It supports large areas of tufted hairgrass (*Deschampsia cespitosa*), a native perennial low-growing grass. It also contains areas of sedge meadow (*Carex sp*.). Its edges have the highest concentrations of non-native species, including large areas of reed canarygrass. Other non-natives in this area included Himalayan blackberry, teasel, and Canadian thistle.

The Cedar Mills wetland is a sixteen-acre site with more diverse vegetation types. It includes year-round ponds, forested upland, scrub-shrub areas, and wet meadow communities, which were the focus of our sampling. This site is surrounded by steep, forested ridges and is downslope from low-density housing and a commercial nursery and landscaping company. Cedar Mills is a restored wetland that was graded and planted ten years ago. The soils in our study site may have been imported at the time of construction. As at Knez wetland, the reed canarygrass was concentrated near the edges of the site. We sampled an area where it had recently displaced a stand of cattails. For our sampling of native vegetation, we used a nearby stand of slough sedge (*Carex obnupta*) that was robust and spreading through the adjacent stands of willow and rose thickets.

Methods

For each vegetation site, we hand-dug one soil pit approximately 25 inches deep and 18 inches across. Plants were identified based on Hitchcock and Cronquist (1976). We estimated vegetation cover based on a diagram showing percent coverage in Birkeland (1999). We used methodology from Birkeland to characterize soil development, color, structure, consistence, texture, clay films, and horizon boundaries. We determined pH in the lab using a color index and reagent kit.

We took samples from each identifiable layer of the soil and stored them outside in zip-lock bags until laboratory testing. Portions of the samples were air-dried on newspaper for five days before determining dry color values using the Munsell color index.

We removed roots from moist soil samples using a #25 sieve and hand-sorting visible roots that passed through this sieve. After removal, roots were air-dried for 24 hours and weighed. This weight was subtracted from the weight of the moist soil sample and used to determine the percent of roots to soil in the A horizons. Since many of the roots were quite fine, and the soil particles easily adhered to them, root sorting was difficult. This is a common problem in root-soil studies (Katterer and Andren, 1999; Bolinder *et al,* 2002).

We could not recover most of the fine roots, and the mass of the roots is therefore underestimated, but useful for comparative purposes since we used the same technique for roots of all species studied. Dry soil samples proved impossible to sieve, as the clay particles prevalent in the soils adhered to each other and the roots, forming almost unbreakable peds. This also contributed to the underestimation of root percentage, since much of the weight of the moist sample was likely to be water. Again, since this was a comparative procedure among samples treated the same way, we considered it worthwhile.

Results

The Washington County Soil Survey maps the soil at the Knez wetland as a Verboort series silty clay loam, a Typic Argialboll. Our research and a previous study of this site (Pardue, 1997) show that this site is actually a Cove series, which the soil survey lists as a Vertic Haplaquoll. This corresponds to a current taxonomy of a Vertic Argiaquoll. Refer to the appendix at the end of this paper for formal characterizations of each soil profile. All soil samples at Knez fell within this category but displayed some unique characteristics, probably due to vegetation and land-use history. In all cases, soil color description are for dry samples.

Site 1 at Knez was primarily a sedge meadow with 40% bare ground and trace amounts of teasel and bull thistle. The A layer primarily differed from the underlying Bg by color. It was a 7.5 YR 4/1 dark gray, with a fairly high root concentration and a pH of 5.5. It was primarily gleyed with a few small yellowish brown mottles, typically next to roots. The Bg layer began at 4 inches and was completely gleyed, with a color of Gley 1 3/N very dark gray, a pH of 7 and very few, fine roots penetrating the clay.

Site 2 was a reed canarygrass monoculture without bare ground or other plant species. This area was generally separated from the native communities by a small ditch that runs across the property. The A horizon at this site was thicker and much less distinct, differing by a value of only 1 from the Bg beneath it. The A layer had a noticeably high percentage of roots and a pH of 7. Its color was 10YR 4/1 dark gray. The Bg layer contained few, fine roots, had a pH of 7.5 and a color of 10YR 3/1 very dark gray. Otherwise, physical characteristics of the profile layers were similar or identical. Upon laboratory examination of dry samples from the Bg horizon, we discovered visual evidence of a seedbank in this layer of the soil.

Site 3 was in a large tufted hairgrass meadow and showed the most developed profile. Tufted hairgrass in a bunch grass that forms small mounds as it grows atop its own previous year's thatch. These mounds averaged 8 inches across and 2 – 3 inches high. Combined with the vertic properties of the soil, this provided considerable micro-relief in this part of the wetland. Walking through it was at times difficult.

The A horizon was a dark grayish brown 10 YR 4/2, extending 6 inches, with a pH of 5.5. Roots in this layer were fine and few, perhaps as a result of roots being concentrated in the micro-mounds. A distinct transition layer, Bg1, extended below this horizon for four inches. It had a transitional texture that was much more granular than the Bg2 layer beneath it and showed small oxidation mottles near fine roots. It had a pH of 6.5, and the main soil matrix color was a 10YR 3/1 very dark gray. The Bg2 layer was a Gley 1 3/N very dark gray. It had a pH of 8, and showed no roots or mottles.

Soils at Cedar Mills were of much younger age and of a silty clay loam parent material. With enough time they may develop characteristics closer to those at Knez (Stolt *et al*, 2000), but currently they offer an interesting set of contrasts. Both sampling sites at Cedar Mills keyed out to a Typic Endoaquent. This soil is a silty clay loam with redoxymorphic features within the top one inch of soil. The Soil Survey maps this area as a Wapato series silty clay loam, but the soil we found is much too light for that series. The profile most closely resembles a Concord series silty clay loam, although this series has a glaciolacustrine parent material that is inconsistent with its location. It may have been imported during wetland construction. We labeled the Cedar Mills sampling sites as 4 and 5.

Site 4 was a reed canarygrass meadow with trace amounts of cattail, spikerush, and veronica. According to Wetlands Conservancy staff, reed canarygrass had extended into this area within the past several years. This profile had a thin A horizon to 3 inches in depth. It was 10YR 7/3 very pale brown in the matrix and had frequent, small mottles of yellowish brown 10YR 5/8 along the ped faces. Although this site was relatively dry at the time we sampled it, redoxymorphic features extended to within one inch of the soil surface, indicating frequent inundation. The pH was 5.5. Roots were common in this layer. Underneath this thin layer was a Cg with a light brownish gray 10YR 6/2 matrix and many small mottles of yellowish brown 10YR 5/8. There were also a few, small black mottles, which were too small to characterize with the Munsell index. The pH in this layer was 7.5. We found only a few, very fine roots in this layer.

Site 5 was within a dense and thriving stand of slough sedge. The A horizon extended four inches and was primarily distinguished from the underlying Cg by fainter mottles and many more roots. The matrix color was 2.5Y 6/2 light brownish gray, and contained mottles of 2.5Y 7/8 yellow. We found trace gravel content in the lab, and a pH of 7. The Cg layer at this site had the same matrix color, but more frequent and darker mottles of 2.5 Y 5/6 light olive brown. The small amount of gravel in this layer was coarser than that above it. The pH in this layer was 8.

In the laboratory, we estimated the percentage by weight of roots in the A horizons, for comparative purposes. Both sedge and reed canarygrass communities showed a large percentage of root material per given amount of soil. The tufted hairgrass meadow showed a much lower level of root development in the A layer. This may derive from a shallow, O horizon rooting pattern, or roots that remained connected to the plant when the soil was sampled. Since we decided to measure this only after we collected our soil samples, it would be advisable to resurvey this data with more careful collection techniques. Consider conclusions based on this data as the basis of future testable hypotheses.

Table 1, below, summarizes the primary field characteristics, described above, of the soil profiles for each sampling site.

Site	Vegetation	Depth (in)	Horizon	Color (dry)	Consistence		Texture	pH	Root %
					Wet	Dry			
1	sedge *sp.*	0 – 4	A	7.5 YR 4/1 dark gray	vs vp	h	SC	5.5	8.6
		4 – 22+	Bg	Gley 1 3/N very dark gray	vs vp	vh	C	7	
2	reed canarygrass	0 – 7.5	A	10 YR 4/1 dark gray	s vp	vh	SCL	7	8.9
		7.5 – 23+	Bg	10YR 3/1 very dark gray	vs vp	vh	CL	7.5	
3	tufted hairgrass	0 – 6	A	10YR 4/2 dark grayish brown	s vp	h	SCL	5.5	1.7
		6 – 10	Bg1	10 YR 3/1 very dark grayish brown 7.5 YR 5/8 strong brown mottles	vs vp	vh	CL	6.5	
		10 – 25+	Bg2	Gley 1 3/N very dark gray	vs vp	vh	C	8	

4	reed canarygrass	0 – 3	A	10YR 7/3 very pale brown 10YR 5/8 yellowish brown mottles	ss sp	sh	SCL	5.5	7.6
		3 – 25+	Cg	10 YR 6/2 light brownish gray 10 YR 5/8 yellowish brown mottles	s p	h	SCL	7.5	
5	slough sedge	0 – 4	A	2.5 Y 6/2 light brownish gray 2.5 Y 7/8 yellow mottles	ss sp	h	SCL	7	6.8
		4 – 24+	Cg	2.5 Y 6/2 light brownish gray 2.5 Y 5/6 light olive brown mottles	s p	h	SCL	8	

Table 1. Summary of major soil characteristics

Discussion

The goal of this study was to determine if there were identifiable soil characteristics that either aided or defended against the spread of reed canarygrass. Most characteristics of the soils differed in varying ways and did not display consistency across vegetation type. Many of the soil characteristics were also inconsistent between the same communities in the remnant and restored wetlands, which shows these plants are adaptable to a range of soil conditions as long as the necessary hydrology is in place.

The exception to these inconclusive findings was the good evidence we uncovered for disturbed soil where the reed canarygrass was growing at Knez. Here we identified three factors that favor this interpretation. The Bg layer, which we sampled at approximately 17 inches depth, appears to contain seeds, indicating that at some point in the relatively recent past, this soil must have been at the surface. Wetland seedbanks can last for upwards of 50 years and remain viable (Paveglio and Kilbride, 2000, and personal observation), so estimating the date of disturbance would difficult within this time frame.

We also found corroborating evidence in the soil pH and profile development. Both of the native vegetation sites at Knez showed a progression of pH levels from 5.5 in the A horizon, descending to neutral or alkaline pH as the profile descended. The reed canarygrass site contrasted this development with a 7 pH in the A, differing only slightly from the 7.5 shown in the Bg. We interpret this to indicate that this soil may have been tilled to mix its A and B layers, or that Bg soil from nearby was mixed into the A layer. Since the A layer here is thicker than the other two we found at Knez, either interpretation is plausible. It is possible this occurred during the construction of the nearby ditch, but the Wetlands Conservancy has no records of disturbance or construction events.

The weakly differentiated colors of the profile are also consistent with the interpretation of disturbance. It would be interesting to revisit this site after an interval of some years to check if any increased profile development occurs. This might enable us to extrapolate back to the date of disturbance of the soil.

Cedar Mills did not offer us any similar keys to the presence and success of reed canarygrass. Unlike the sites at Knez, at Cedar Mills the soil development under the reed canarygrass was slightly more pronounced than in the adjoining sedge meadow.

Since both of the wetlands are relatively small systems surrounded by and downslope of human development, it is likely that nearby, naturalized sources of reed canarygrass were available to spread into the reserves whenever conditions were ripe. Since most of the soil at Knez had never been plowed or filled, well-established native vegetation had enough ground cover, and possibly root development, to exclude opportunistic species (Paveglio and Kilbride, 2000). Once some amount of soil was mixed or buried there, this aggressive species was able to germinate and spread into surrounding areas by root in some communities, and by seed where ground cover is thin.

At Cedar Mills, it is very likely that reed canarygrass became established prior to or at the beginning of the restoration efforts. Since the area was re-graded at that time, large areas of new soil were exposed and lacked any established vegetation. Reed canarygrass thrives in these conditions because it is so fast-growing and forms dense stands that exclude other plants. Through seeding and active management some native plant communities have become well-established here, but once given a foothold, the reed canarygrass has spread to cover large areas.

Disturbed soil, therefore, was the one consistent factor we could identify at both sites where the grass was a problem. Future study is merited to try to identify, in both the soils and the plant communities, factors that may stem its spread when it is already established. The scope of this research was too short to carefully treat that question.

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Appendix : Formal soil descriptions of sampling sites

All color notations are for dry soils.

Site 1
Classification: Cove Series Vertic Argiaquoll.
Location: Knez Wetland, Tigard Oregon, 45.5225 N 122.7901 W; north-central portion of meadow.
Physiographic Position: Depression lowland, approx. 150 feet elevation.
Topography: Less than 1 meter relief, gradient close to horizontal, stream on site draining to the south.
Drainage: Poorly drained; very slow permeability.
Vegetation: Sedge (*Carex sp.*), trace amounts of Bull thistle (*Cirsium vulgaris*) and teasel (*Dipsacus sylvestris*) .
Parent materials: Depositional clay and silt from upslope Missoula flood deposits.
Sampled by: Susan Garland and Corey Raspone.
Remarks: Extremely dark, extremely sticky, moist throughout.

Horizon	Description
A	0 – 4 inches (0 – 10 cm); Dark gray 7.5 YR 4/1 silty clay contains few, small mottles near roots of 10 YR 5/8 yellowish brown; strong, very coarse, subangular blocky structure; no gravel; very sticky and very plastic (wet); hard (dry); abundant faint clay films; pH 5.5; abundant roots; clear, smooth boundary.
Bg	4 – 22+ inches (10 – 56 cm); Very dark gray Gley 1 3/N clay; strong, very coarse, subangular blocky structure; no gravel; very sticky and very plastic (wet); very hard (dry); abundant prominent clay films; pH 7; few, very fine roots.

Site 2
Classification: Cove Series Vertic Argiaquoll.
Location: Knez Wetland, Tigard Oregon, 45.5225 N 122.7901 W; north-west portion of meadow.
Physiographic Position: Depression lowland, approx. 150 feet elevation.
Topography: Less than 1 meter relief, gradient close to horizontal, stream on site draining to the south.
Drainage: Poorly drained; very slow permeability.
Vegetation: Reed canarygrass (*Phalaris arundinacea*) 100%.
Parent materials: Depositional clay and silt from upslope Missoula flood deposits.
Sampled by: Susan Garland and Corey Raspone.
Remarks: Extremely dark, extremely sticky, moist to wet.

Horizon	Description
A	0 – 7.5 inches (0 – 19 cm); Dark gray 10 YR 4/1 silty clay loam ; strong, very coarse, subangular blocky structure; no gravel; sticky and very plastic (wet); very hard (dry); abundant prominent clay films; pH 7; abundant roots; clear, smooth boundary.
Bg	7.5 – 23+ inches (19 – 58.5 cm); Very dark gray 10 YR 3/1 clay loam; strong, very coarse subangular blocky structure; no gravel; very sticky and very plastic (wet); very hard (dry); abundant prominent clay films; pH 7.5; few, very fine roots; water seeping from sides of pit; seeds embedded in the layer.

Site 3
Classification: Cove Series Vertic Argiaquoll.
Location: Knez Wetland, Tigard Oregon, 45.5225 N 122.7901 W; north-east portion of meadow.
Physiographic Position: Depression lowland, approx. 150 feet elevation.
Topography: Less than 1 meter relief, gradient close to horizontal, stream on site draining to the south. Land surface consists of continuous, small hummocks, approximately 1 – 3 inches tall and 8 inches across, formed by the vegetation.
Drainage: Poorly drained; very slow permeability.
Vegetation: Tufted hairgrass (*Deschampsia cespitosa*) 100%.
Parent materials: Depositional clay and silt from upslope Missoula flood deposits.
Sampled by: Susan Garland and Corey Raspone.
Remarks: Extremely dark, extremely sticky, moist throughout, with a transitional layer of intermediate texture, color and pH.

Horizon	Description
A	0 – 6 inches (0 – 15 cm); Dark grayish brown 10 YR 4/2 silty clay loam; moderate, very coarse, subangular blocky structure; no gravel; sticky and very plastic (wet); hard (dry); common faint clay films; pH 5.5; moderate roots; clear, wavy boundary.
Bg1	6 – 10 inches (15 – 25.4 cm); Very dark gray 10 YR 3/1 with small oxidation sites near roots of 7.5 YR 5/8 strong brown; clay loam; strong, very coarse, subangular blocky structure; no gravel; very sticky and very plastic (wet); very hard (dry); common prominent clay films; pH 6.5; very few, very fine roots; clear, smooth boundary.
Bg2	10 – 25+ inches (25.4 – 63.5 cm); Very dark gray Gley 1 3/N clay; strong, very coarse, subangular blocky structure; no gravel; very sticky and very plastic (wet); very hard (dry); abundant prominent clay films; pH 8; no roots.

Site 4
Classification: Resembles Concord series silty clay loam, Typic Endoaquent.
Location: Cedar Mills Wetland, Cedar Mills Oregon; 45.5227 N 122.7903 W; north approx. 110 meters into the preserve near the western property boundary.
Physiographic Position: Depression lowland, approx. 280 feet elevation.
Topography: Less than 3 meters relief, local gradient close to horizontal. Surrounded by steep, forested ridges on three sides and draining toward the south.
Drainage: Poorly drained; slow permeability
Vegetation: Reed canarygrass (*Phalaris arundinacea*) 95% with 5% cattail (*Typhus latifolia*), and trace amounts of ovoid spikerush (*Eleocharis ovata*) and veronica (*Veronica beccabunga*).
Parent materials: Silt and clay, possible Missoula flood deposits, area was re-graded ten years prior, soil may have been imported to site, if so, source of parent material uncertain.
Sampled by: Susan Garland.
Remarks: Soil light in color, moist but not wet.

Horizon	Description
A	0 – 3 inches (0 – 7.6 cm); Very pale brown 10 YR 7/3 silty clay loam with many 10 YR 5/8 yellowish brown small mottles along ped faces; moderate, medium, subangular blocky structure; no gravel; slightly sticky and slightly plastic (wet); slightly hard (dry); common faint clay films; pH 5.5; abundant roots, some large and tuberous; clear, smooth boundary.
Cg	3 – 25+ inches (7.6 – 63.5 cm); Light brownish gray 10 YR 6/2 matrix with small common mottles of 10 YR 5/8 yellowish brown along ped faces; silty clay loam; strong, medium, subangular blocky structure; no gravel; sticky and plastic (wet); hard (dry); common faint clay films; pH 7.5; few, fine roots.

Site 5
Classification: Resembles Concord series silty clay loam, Typic Endoaquent.
Location: Cedar Mills Wetland, Cedar Mills Oregon; 45.5227 N 122.7903 W; north approx. 100 meters into the preserve near the western property boundary.
Physiographic Position: Depression lowland, approx. 280 feet elevation.
Topography: Less than 3 meters relief, local gradient close to horizontal. Surrounded by steep, forested ridges on three sides and draining toward the south.
Drainage: Poorly drained; slow permeability.
Vegetation: Slough sedge (*Carex Obnupta*) 100%.
Parent materials: Silt and clay, possible Missoula flood deposits, area was re-graded ten years prior, soil may have been imported to site, if so, source of parent material uncertain.
Sampled by: Susan Garland.
Remarks: Light and yellowish in color, little differentiation among horizons except for presence of roots.

Horizon	Description
A	0 – 4 inches (0 – 10 cm); Light brownish gray 2.5 Y 6/2 matrix, with faint, small mottles of 2.5 Y 7/8 yellow; silty clay loam; moderate, medium, subangular blocky structure; trace medium gravel; slightly sticky and slightly plastic (wet); hard (dry); common, faint clay films; pH 7; abundant roots; clear, smooth boundary – horizons very similar except for roots.
Cg	4 – 24 + inches (10 – 61 cm); Light brownish gray 2.5 Y 6/2 matrix, with small mottles of 2.5 Y 5/6 light olive brown; silty clay loam; moderate, medium, subangular blocky structure; trace coarse gravel; slightly sticky and slightly plastic (wet); hard (dry); common faint clay films; pH 8; few, fine roots.