Plant Selection for Ditch Regrades

Final Report

Prepared for:

Stormwater Action Monitoring and

Washington State Department of Ecology

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Executive Summary

Regraded roadside ditches provide a very challenging environment to grow and establish plants. The ditches often are filled with water for months during the rainy season. and subjected to heat and drought stress at other times. The soils exposed in re-graded ditches is not topsoil; therefore, lacking carbon and other organic matter to hold water and provide the essential nutrients for plants survival. Many plant species do adapt to a particular environments but species that thrive in drought do poorly in waterlogged areas, and those adapted to salt stress do not tolerate prolonged drought. Species adapted to shade do not compete well in full sun. Species adapted to full sun often do not even germinate in shaded environments. This study evaluated various grass blends to determine plant establishment and growth when planted in three cleaned-out ditches under varying degrees of shade, water stress, and season. The study was conducted at three sites, two in western Washington and one in eastern Washington. The WSDOT blend had the most utility of the blends tested. The combination of perennial ryegrass and strong creeping red fescue was very effective at colonizing the full sun and dry sites. The WSDOT blend is recommended as a fast-establishing utility blend that could be planted in many environments, especially those requiring fast germination. WSU blend 2 could be a good choice for sites with slower growth requirements. The blend of hard and sheep fescues has slower growth than the other blends, especially after winter dormancy, with acceptable coverage and growth over time. WSU blend 2 would be good for areas with shade and drought and where slow growth is preferred. WSU blends 1 and 6 had acceptable growth and coverage ando grew faster after winter dormancy compared with WSU blend 2. The PT-442 native blend was not a good candidate for this type of planting. The weed and environmental pressure was too great for the native species to establish and grow.

GRASS SPECIES

FESTUCA RUBRA

50% OF WSU BLEND #1

LOLIUM PERENNE

50% OF WSDOT BLEND

FESTUCA RUBRA SSP. COMMUTATA

40% OF WSU BLEND #6

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Acknowledgments

The Western Washington Stormwater Permittees selected this study through the Stormwater Action Monitoring (SAM) Program. The work was performed under an Inter-Agency Agreement (#. C2200016) between the State of Washington Department of Ecology and Washington State University.

LEAD ENTITY

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1. Introduction

1.1. Study overview and scope change

This work would not have been possible without the support of the Stormwater Action Monitoring (SAM) and the municipal stormwater entities that pay into that program. We are truly grateful for their support. This study was initially intended to be both a water quality and a study of plants. For reasons out of our control, the site chosen for the water quality piece became unviable, and alternative sites could not be found. The scope and budget of this study changed with SAM's approval and focused solely on plants and plant establishment in re-graded ditches.

1.2. Introduction to the Ditch Planting Study

Roadside ditches directly receive road runoff, which carries contaminants from the road surface, such as spills, vehicles (oil, fuel, tires, brakes), and atmospheric depositions. Runoff can wash along the roadsides, picking up trash, bacteria, sediment, many different types of metals, organic chemicals from deicing and agricultural chemicals, and a set of emerging pollutants yet to be identified (Bannerman et al., 1993; Peter et al., 2018; Maestre and Pitt, 2006; Opher and Friedler, 2010; Herrera, 2008; Tian et al., 2021). In addition, the ditch may be a sediment source from bank and bed erosion, particularly after maintenance or reconstruction.

Ditches and their maintenance and vegetation choices represent an opportunity to improve stormwater quality. Using plants that can quickly establish after maintenance or reconstruction will limit bank erosion and transport of sediments and associated pollutants. If those plants are also low-growing and outcompete invasive plants significantly, then less frequent ditch maintenance and mowing will be needed.

After multiple conversations with permittees to develop this project, we found that installing ditches that require minor maintenance over time was their highest priority in terms of ditch management in the Puget Sound region. Reportedly, constant ditch maintenance is a considerable expense, and poorly maintained ditches (either neglected or maintained in a manner that promotes erosion) can become pollutant sources.

Ditch maintenance is triggered by complaints from residents (overgrown with invasive plants) or when the jurisdiction determines the ditch has lost conveyance due to sediments or vegetation. Hundreds of miles of roadside ditches in Washington provide an opportunity to gain efficiency of maintenance workloads if vegetation choices were optimized to limit invasive plants, prevent erosion, and maintain conveyance.

This work aimed to identify plant blends that establish quickly in a ditch system, are low-growing, and outcompete invasives, yielding lower long-term maintenance effort. This research provides information that will help jurisdictions ensure that recently re-graded ditches can be planted with species that establish quickly and outcompete invasives.

Figure 1. Fife ditch before renovation activities in 2019

1.3. Results of Prior Studies

Roadside plants are subjected to harsh biotic and abiotic conditions, making species selection a critical factor in determining planting success. Plants chosen to provide ground cover near roads should encompass the desired characteristics of the site and be able to outcompete any undesirable species successfully. They need to be competitive but not in themselves invasive. Low-maintenance turfgrass species with their tolerance for periodic mowing, low growth habit, low fertility requirements, and ability to tolerate a wide range of growing conditions are often used (Friel et al., 2020). Several other low-growing, native,

and introduced non-turf species can either persist in harsh conditions as native plants or fix nitrogen for use by the turf plants (Oberson 2013). Below are the individual plant species considered for use in the roadside planting pallets and their justification for inclusion. The non-native turf species selected for blends have all been commonly used in our region for sports turf, reclamation, and utility turf (OSU 2024).

Perennial ryegrass- (*Lolium perenne* L.) is a bunch-type grass native to southern and central Europe, northern Africa, the Middle East, and southwestern Asia. It is commonly used in blends with other turf grasses due to its ability to tolerate various soil types and pH ranges. Perennial ryegrass is most known for its use as a nurse grass for other species due to its rapid germination and establishment (Friel et al., 2020). It is common in commercially available roadside and residential grass seed blends. Perennial ryegrass is already well-established in Washington. The fast germination rate of perennial ryegrass makes it an excellent candidate for erosion control in disturbed sites.

Creeping red fescue- (*Festuca rubra* L.) is a rhizomatous turfgrass species with a wide distribution, including Asia, America, and Europe. It is adapted to shade, drought, sandy soils, and pH from 5.5 to 6.5 (Friel et al., 2020). Creeping red fescue is common in many commercially available turfgrass seed blends. It is already present in Washington and comprises one of the more common turf species in the region, especially in shade areas.

Slender Creeping Red fescue- (*Festuca rubra ssp. litorallis*)is similar to creeping red fescue but has shorter rhizomes and greater salt tolerance (Friel et al., 2020). This species was replaced by Molate red fescue (*Festuca rubra molate*), a native species with nearly identical characteristics due to poor seed availability of slender creeping red fescue at the time of seed purchase.

Chewings fescue- (*Festuca rubra subsp. commutata*) is a bunch-type turfgrass species similar to creeping red fescue but lacking rhizomes (Friel et al., 2020).

Hard fescue- (*Festuca trachyphylla*) is a bunch-type turfgrass species that is less drought tolerant but more tolerant of moist soils than sheep fescue. Hard fescue is often used as a utility turf but can also be found in many blends due to its tolerance of shade (Turgeon 2019).

Sheep fescue (*Festuca* ovina) is a bunch-type turfgrass species that is like hard fescue but is more tolerant of drought. Sheep fescue is often used as a utility turf but can be found in many blends due to its tolerance of shady environments (Turgeon 2019).

Idaho fescue- (*Festuca idahohensis*) is a bunch-type turfgrass species primarily used in utility turf and reclamation plantings. It is native to this region and shares many qualities as sheep and hard fescue.

Redtop Bentgrass- (*Agrostis gigantea* Roth) is a coarse-textured rhizomatous cool-season turfgrass. It is used as a component in seed mixtures to promote rapid cover. Redtop is often used in moist, poorly drained, infertile sites (Turgeon 2019).

Highland Bentgrass- Also known as Colonial bent (*Agrostis capillaris* L. or *Agrostis tenuis* Sibth), highland bentgrass is often misidentified. It is a fine-textured, weakly rhizomatous, weakly stoloniferous species first characterized as distinct from Colonial bentgrass in Oregon in 1926, used in turf in the Willamette Valley. Highland is often the predominant species in old lawns west of the Cascades. Bentgrass is the most persistent grass we grow west of the Cascade Mountains. It will grow on the most nutrient-deficient sites, survive prolonged drought stress, and grow on wet sites and in shade (Oregon 2023).

Tufted Hair grass- (*Deschampsia cespitosa* (L.) P. Beauv.) is a cool season bunch grass with circumboreal adaptation. Often colonizing disturbed sites, tufted hairgrass is found in moist but not flooded soils, bogs, salt marshes, poorly drained flats and basins of higher elevation forests, and often on nutrient-poor soils. Tufted hair grass is also tolerant to multiple soil contaminants (Friel et al., 2020). Members of WSU's grass breeding and ecology farm have collected this species and prairie junegrass (*Koeleria macrantha*) from almost every type of environment in Washington state, where they both have naturalized but not become invasive.

Meadow Foxtail- (*Alopecuris pratensis*) is a cool-season pasture grass often found on moist, fertile sites. It has been naturalized in the Pacific Northwest and is common in Western Washington (Barnes 2003).

Strawberry Clover- (*Trifolium fragiferum* L.) is a cool-season perennial prostrate legume with moderate drought and salt tolerance but mediocre shade tolerance. When the correct inoculum is present in the soil, strawberry clover will fix nitrogen and make it available for plants (Barnes 2003). Strawberry clover is common in forage blends, and like the other legumes, its presence in the blend provides nitrogen to plants and is a pollen source for insects.

White Clover- (*Trifolium repens*) is a cool-season perennial legume widely grown in humid, wet regions. The white Dutch type used in the blends is known to be short-growing and possibly amendable to mixed turf planting. When the correct inoculum is present in the soil, strawberry clover will fix nitrogen and make it available for plants (Barnes 2003). White clover's presence in the blend provides nitrogen to plants and is a pollen source for insects.

Yarrow- (*Achillea millefolium*) common yarrow is a native plant in the *Asteraceae* family. It is widely distributed throughout North America and can be found in many dry, disturbed sites in Washington State. Its inclusion in the blends stems from the trend for low-maintenance lawns to be comprised of yarrow and strong creeping red fescue.

PT 442 BES Grassy Swale Native Mix- a commercially available blend of native grasses was included in the study due to its presence in Portland, Oregon's 2020 stormwater management manual. https://www.portland.gov/bes/stormwater/swmm#toc-vegetation-and-soils. PT-442 represented our best commercially available native seed blend specifically developed for bioswales.

1.4. Study Goals

This study evaluated plant growth and establishment in three ditches just after the ditches were cleaned out. Seeding blends developed by WSDOT, WSU, and the City of Tacoma were used to make up each blend.

The study objectives were to:

1. Quantify the percent establishment of plant blends.
2. Quantify quality ratings of plant blends.
3. Quantify the survival of plant blends.
4. Identify planting blends for Washington ditches establish quickly and outcompete invasives.

2. Methods

This study occurred at three field locations. Initially, the three sites were to be complete replicates, but due to space limitations at the 78th Street site and poor performance at the Fife site, two blends were removed from the 78th Street and Pullman sites.

1. Fife Ditch: The Fife Ditch is a flat, low-lying system that drains directly into the Puyallup River. It is dominated by the presence of colonial bentgrass (*Agrostis capillaris*), reed canary grass (*Phalaris arundinacea*), and non-native blackberry (*Rubis armeniacus*). This ditch system is located adjacent to many industrial-zoned and commercial businesses. The Fife ditch is prone to flooding and has very slow drainage.

2. 78th Ave Ditch: The 78th Ave Ditch is in a heavy-traffic residential area. The ditch's longitudinal slope was adequate to ensure drainage and prevent standing water. The plants on site are a combination of grasses and forbs that were planted when the ditch was constructed and do not include any aggressive non-native species.

3. Pullman Farm Ditch: The ditch at the Grass Breeding and Ecology Farm at WSU Pullman receives the runoff from 5 acres of irrigated agricultural plots before it enters Paradise Creek and, ultimately, the Palouse River. It is graded at roughly a 3% slope and was planted initially into perennial ryegrass in 2019. This site had several complications described later and was abandoned mid-study.

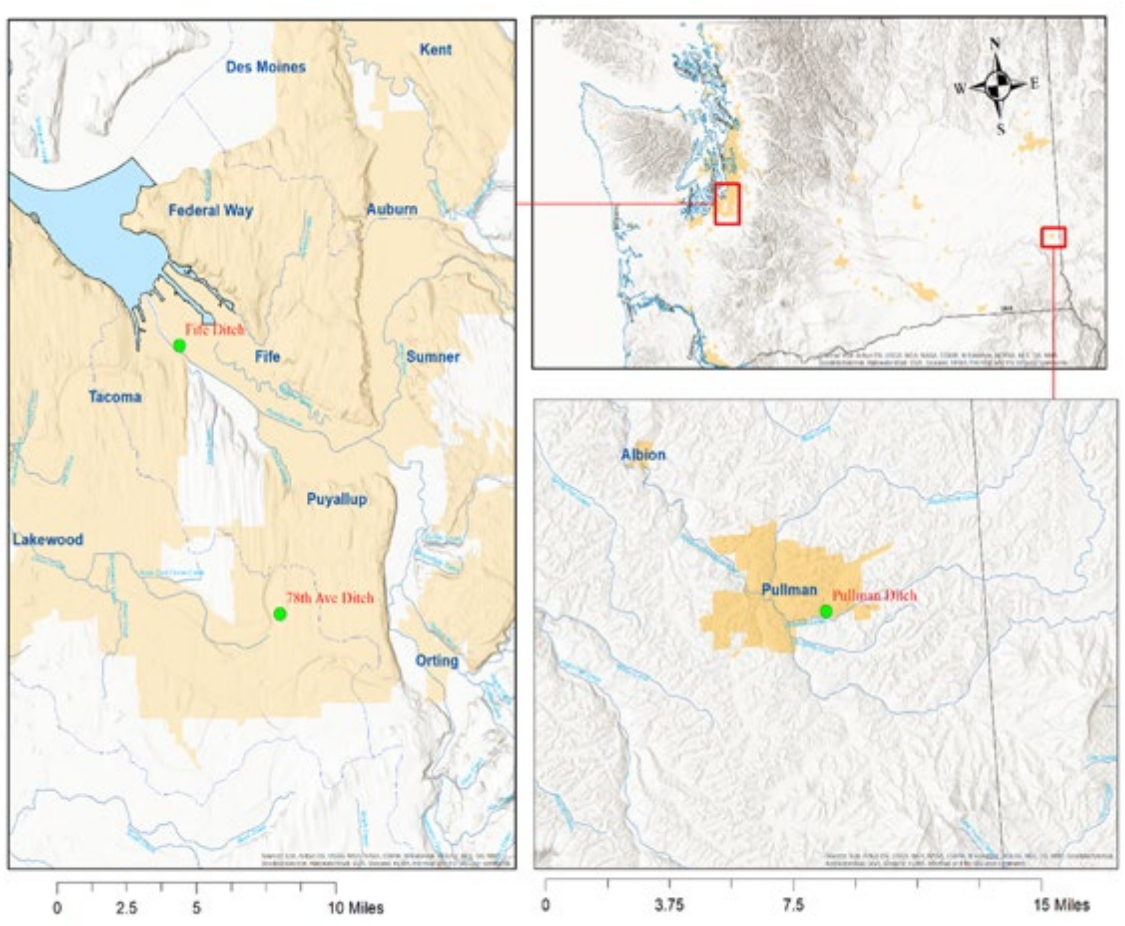


Figure 2. Location of the three ditch sites in Washington. Locations are marked with green circles, two are close to Fife and Puyallup, and one located in Pullman.

2.1. Seed Sources and Seed Blending

We purchased raw seed on the open market and blended them according to their appropriate seeding rate. The WSU's grass breeding and ecology farm used seed industry brokers from 2 companies, Landmark Seed and Barenbrug's Jacklin Seed, as the source for all but the PT-442 blend purchased from PT Lawn Seed. There was some difficulty and expense of the seed blends due to supply shortages produced by the COVID-19 pandemic.

Table 1. Seed and source for blends used in this study

Species	***Source***
Perennial Ryegrass	Landmark Seed
Creeping red fescue	Landmark Seed
Chewings fescue	Landmark Seed
Hard fescue	Landmark Seed
Sheep fescue	Landmark Seed
Idaho fescue	Landmark Seed
Molate Native red fescue (Added)	Landmark Seed
Red top bentgrass	Landmark Seed
Highland Bentgrass	Landmark Seed
Meadow Foxtail	Landmark Seed
Strawberry clover	Landmark Seed
White clover (Dutch)	Landmark Seed
Tufted hairgrass	Landmark Seed
Yarrow	Landmark Seed
Perennial Ryegrass	Barenbrug
Strong Creeping Red Fescue	Barenbrug
Chewings Fescue	Barenbrug
Hard Fescue Ecostar Plus	Barenbrug
white clover forage varieties	Barenbrug
PT-442 Blend	PT Seed

The seed blends were developed using a % of the blend by weight method. Smaller seeded species are typically blended at lower rates due to the high number of seeds per pound, with larger seeded species planted at higher rates to increase their number. More aggressive species were planted at lower rates to compensate for that characteristic.

Each blend was weighed to the specifications, and each component was packaged independently to broadcast evenly across each plot. The exception was PT-442, which was already blended when we purchased the seed. The seeding rate for each blend was 6lb/1k sq. ft. PT-442 was recommended to be seeded at 1lb/1k sq. ft. This rate was followed for all sites except 1 plot at the 78th Ave site, which had PT-442 seeded at 6lbs. /1k sq. ft. to determine if the seeding rate would affect that blend performance.

Table 2. Composition of the commercially available blends

Blend ID	% of Blend By Weight	Species	Common Name
PT442 BES Grassy Swale Native Mix	25%	*Hordeum brachyantherum*	Meadow Barley
	15%	*Danthonia californica*	California Oatgrass
	10%	*Elymus glaucus*	Blue Wildrye
	10%	*Bromus carinatus*	California Brome
	10%	*Festuca idahohensis*	Roemer's Fescue
	10%	*Deschampsia cespitosa*	Tufted Hairgrass
	10%	*Agrostis exarata*	Spike Bentgrass
	5%	*Alopecurus geniculatus*	Water Foxtail
	5%	*Deschampsia elongata*	Slender Hairgrass
WSDOT Blend	50%	*Lolium perenne*	Perennial ryegrass
	40%	*Festuca rubra*	Creeping Red Fescue
	10%	*Trifolium repens*	White Clover

Table 3. Composition of the WSU experimental blends

Blend ID	% of Blend By Weight	Species	Common Name
WSU Blend 1	50%	*Festuca rubra*	Creeping Red Fescue
	40%	*Festuca rubra ssp. commutata*	Chewings Fescue
	10%	*Agrostis tenuis*	Highland Bentgrass
WSU Blend 2	50%	*Festuca trachyphylla/Festuca ovina*	Hard/Sheep Fescue
	35%	*Trifolium fragiferum*	Strawberry Clover
	15%	*Achillea millefolium*	Yarrow
WSU Blend 3	35%	*Festuca idahohensis*	Roemer's Fescue
	35%	*Deschampsia cespitosa*	Tufted Hairgrass
	30%	*Trifolium fragiferum*	Strawberry Clover
WSU Blend 4	70%	*Festuca rubra*	Creeping Red Fescue
	15%	*Achillea millefolium*	Yarrow
	15%	*Alopecurus pratensis*	Meadow Foxtail
WSU Blend 5	50%	*Agrostis gigantea*	Redtop Bentgrass
	50%	*Agrostis tenuis*	Highland Bentgrass
WSU Blend 6	50%	*Festuca rubra ssp. Molate*	Molate Red Fescue
	40%	*Festuca rubra ssp. commutata*	Chewings Fescue
	10%	*Agrostis gigantea*	Redtop Bentgrass

2.2. Plant Establishment

The Fife site was the first to be planted. City crews first cleared the site, intending to include a multi-shape ditch trial with the plantings. Three complete replicates of all the blends were planted in a random complete block design, with each plot numerically coded to prevent rating bias. Each plot was surveyed, staked, and flagged to outline each plot for planting. Each block of plots was planted at the same dimension and at the seeding rates discussed in

Figure 3. Layout of the Fife ditch.

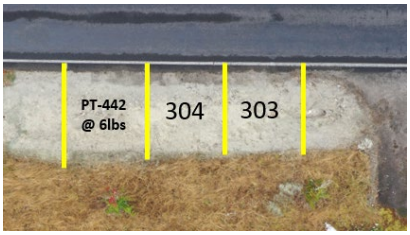
Key to replicates: blue plots = 2-stage ditch 25 x 25 sq. ft., green plots = skip cleaned 13 x 25 sq. ft., yellow plots =U-shaped ditch 22 x 25 sq ft.

section 2.1 (see Fig. 3).

On October 6, 2021, the seed was broadcast evenly by hand across each plot at the designated seeding rate. Once all plots were planted, border seed of perennial ryegrass was applied to any remaining areas that contained bare soil. A research-sized hydroseeder sprayed hydro-mulch across the newly seeded plots. This was done to prevent seed movement outside of its designated plot. The hydroseeder never contained seed, which could contaminate the site, and was only used to spread mulch.

Figure 4. Seed applied to bare soil in each plot followed by the application of hydro mulch to stabalize the plot

Once the hydro-mulch was applied, the site was left until the first rating period to establish and grow without any intervention or amendments. The same techniques were used for both the 78th Ave and Pullman sites, with the Pullman site receiving mulch pellets post-planting to prevent seed movement instead of the hydro-mulch technique. The information from the Fife site was used to adjust the number of blends at the 78th Ave and Pullman sites. Blends 3 and 4 were removed from 78th Ave and Pullman due to their poor performance in Fife, and blend 5 was removed from the Pullman plots due to the potential for those species to interfere with breeding activities at the Grass Breeding and Ecology farm. The 78th Ave site was planted on September 27, 2022, and the Pullman site was planted on September 21, 2022.



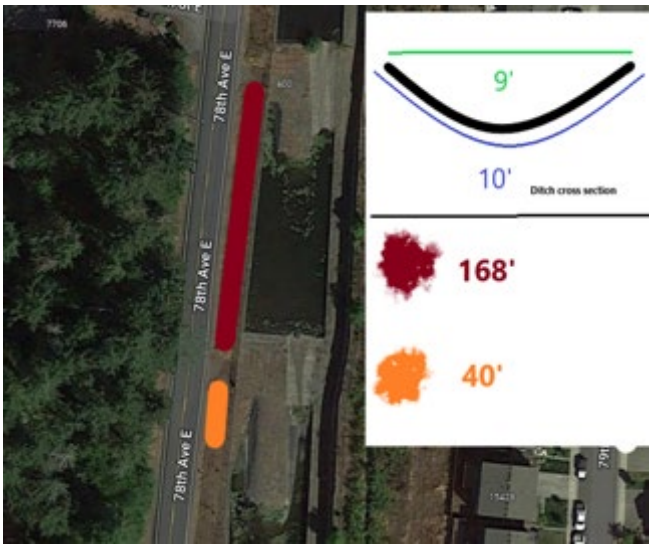


Figure 5. 78th Ave site overview

Figure 6. 78th Ave site seeding and hydro mulch. Seeding date 9/27/22

2.3. Monitoring of seed blends

Each site underwent a series of ratings designed to determine the success of the initial planting and the species outcome for each plot. Ratings were composed of % cover, Turfgrass quality, and species composition at the end of each trial. Turfgrass quality is measured on a scale of 1 to 9, with 9 being ideal turf and 1 being dead bare soil. % cover ratings are based on the % of ground cover that comprised crop, soil, or weeds, with the total for each plot = 100%. The % Establishment rating was based on the % of ground cover germinating from seed at the time of rating the crop(s) planted. Each plot had the potential to achieve 100% ground cover. A percentage of groundcover estimate was the quickest and most effective estimate of species growth and development, as the sites were completely bare of vegetation at the time of planting, and the turf species planted generally produced a very uniform stand. This percentage groundcover estimation was used throughout the study to determine the planting success. The final monitoring parameter was the species inventory at each plot based on species composition. Any species of plant present in the plot at the time of rating was included in the inventory. Individual abundance of any one species was not included in this estimate due to the impracticality of quantifying every plantlet by species across such a large area. An initial % establishment rating was taken 1 month after the installation of each site (late October-early November).The second rating period occurred in early spring (mid-late March of the year following planting), with % crop and turfgrass quality ratings being taken. The third rating was taken in mid-late Summer (August) and comprised % cover and turfgrass quality. The fourth rating was a species inventory of each plot, which occurred in late Fall (November). At the Fife site, environmental conditions between the ditch walls versus the flat top area were so great that ratings were broken down into each area. This was not necessary for 78th Ave or Pullman.

PT-442	303	308	302	301	304	201	202	203	204	208	108	104	103	102	101

Figure 5. WSU Pullman site at the Grass Breeding and Ecology Farm. Water pooling problems already evident.

2.4. Statistical Analysis

Each site was evaluated independently with results presented for each location. Each blend was replicated in one plot at each site three times in a random complete block design, with each block containing a complete set of blends. Plots were rated blindly, with each plot coded to prevent rating bias. The mean, median, mode and interquartile ranges were calculated for each blend across the three replicates at each site. Advanced statistical analysis was not carried out due to the non-normal distribution of the data and the small number of samples.

3. Results & Discussion

The Fife site was the first to be established in August 2021 in our series of ditch sites. We used it as a model for the other sites and applied what we learned to the 78th Ave and Pullman sites established in August 2022. The Pullman site was a gamble as our bioswale at the Grass Breeding and Ecology farm often holds water for extended periods. Following establishment, winter 2022-23 was unusually cold in Pullman, reaching -20°F for over a week. With the plots submerged during this period, no plants could survive the harsh winter conditions, and the Pullman trial was abandoned. The two western Washington sites did not experience this extreme cold; the results are presented below. As mentioned, blends 5 and 6 were removed from the 78th Ave site due to their poor performance at the Fife site the previous year.

3.1. Blend Establishment

Establishment ratings were taken at the Fife site on November 10, 2021. The Fife site was unique because the ditch cuts were so significant that the study became two distinct areas of interest. The upper portion of the ditch, which is labeled on the diagrams as “top,” is composed of the flat level ground that was seeded at the same time as the “wall,” which refers to the vertical surface that forms the wall and floor of the ditch. The purpose of this distinction was to identify differences in microclimate that would affect the performance of the blends and to try to tease out that effect across the plots.

The Fife site was also heavily inundated with colonial bentgrass (*Agrostis capillaris*), the predominant weed on the “top” of each plot. This distinction was not necessary at the 78th Ave site as there was no apparent difference in microclimate in that ditch system, nor were there any aggressive weedy grass species on site that could impact the study.

WSU blend #1 had the best overall establishment at the Fife site on the "wall" and the "top." The WSDOT blend had the second-best establishment. WSU blends #2, #4, and #6 all had comparable establishment rates. WSU blend #3, and Pt-442 had the worst establishment at the site (see Fig. 8).

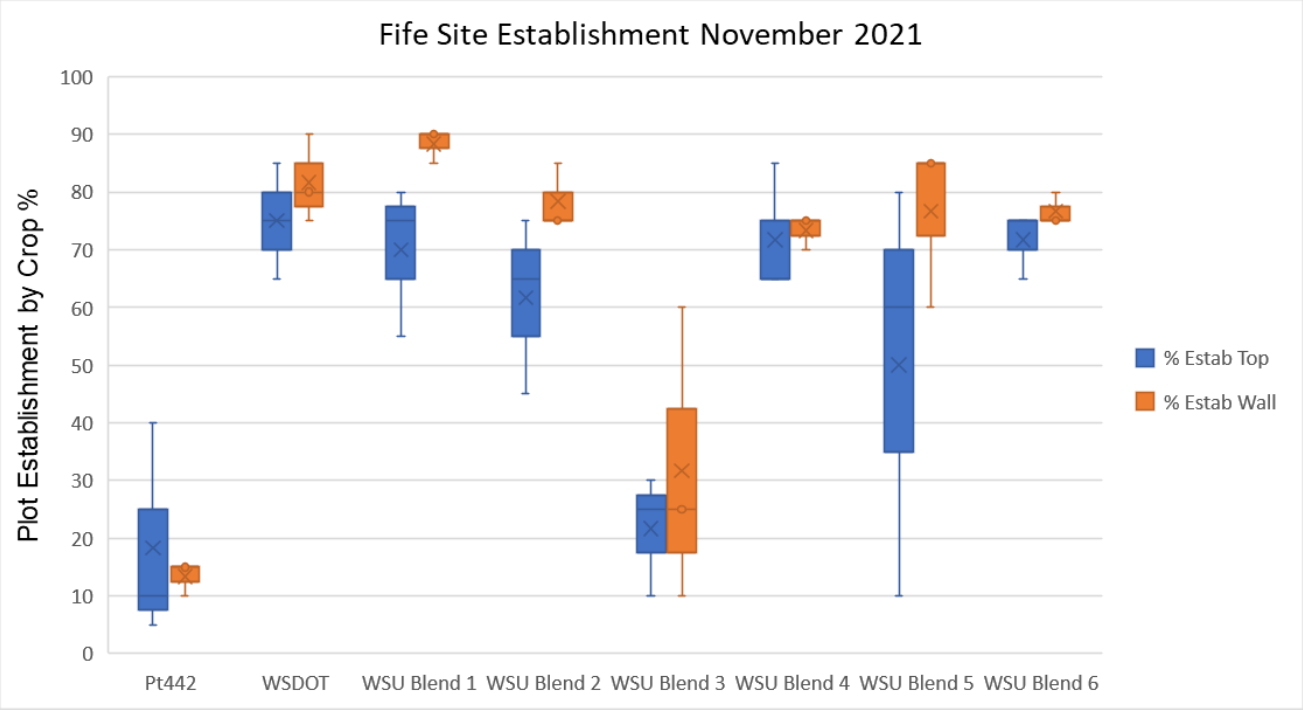


Figure 6: Initial establishment ratings at Fife site.

Figure 7. PT-442 Blend Establishment at Fife site

Figure 10. WSDOT Blend Establishment at Fife site

Figure 11. WSU Blend 1 Establishment at Fife site

Figure 12. WSU Blend 2 Establishment at Fife site

Figure 13. WSU Blend 3 Establishment at Fife site

Figure 14. WSU Blend 4 Establishment at Fife site

Figure 15. WSU Blend 5 Establishment at Fife site

Figure 16. WSU Blend 6 Estalishment at Fife site

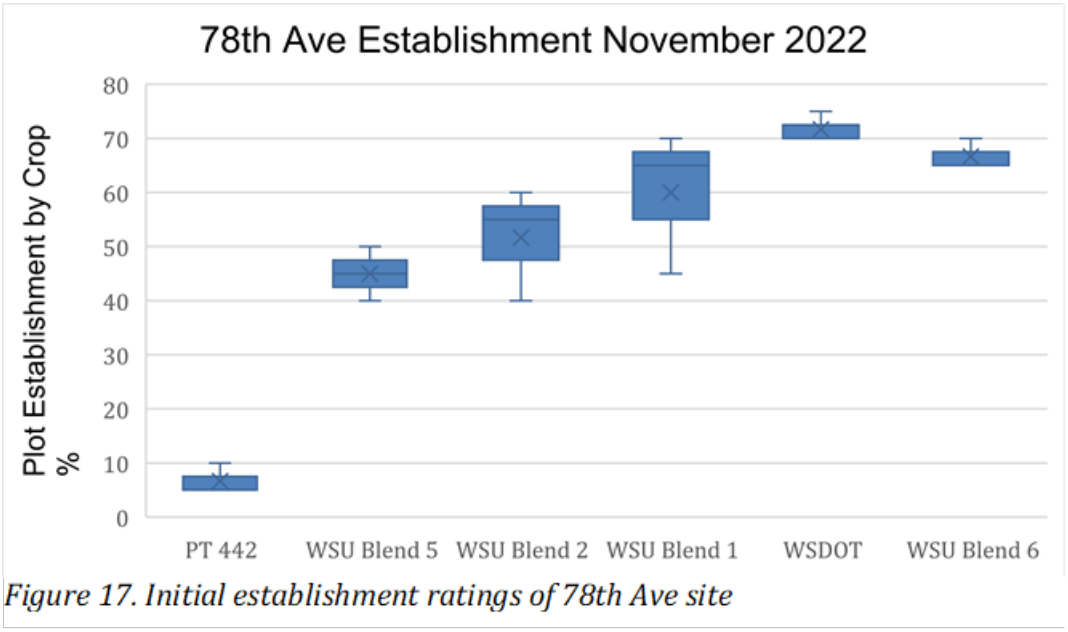


Figure 17. Initial establishment ratings of 78th Ave site

The establishment ratings occurred at the 78th Street site on November 8, 2022. The 78th Ave site had a completely different environment due to heavier shade, less developed soil, and a significantly lower seed bank of grasses. At the 78th Ave site, the WSDOT blend had the greatest establishment, followed closely by WSU blend #6. WSU blend #5, PT442, and PT442 @ 6lbs./1k sq. ft. had the worst establishment at the site (see Fig. 17).

Figure 18. PT-442 Blend Establishment at 78th Ave site

Figure 19. WSDOT Blend Establishment at 78th Ave site

Figure 20. WSU Blend 1 Establishment at 78th Ave site

Figure 21. WSU Blend 2 Establishment at 78th Ave site

Figure 22. WSU Blend 5 Establishment at 78th Ave site

Figure 23. WSU Blend 6 at 78th Ave site

Figure 24. PT-442 Blend at 6X recommended seeding rate 78th Ave site

3.2. Blend Survival and Growth

Survival and growth estimates were taken at the Fife site on 3/16/22 and 8/19/22. To assess these parameters, we used the percentage crop rating combined with a turfgrass quality rating. The criteria for these ratings were outlined in section 2.3. The rationale for the timing was to evaluate how well the grasses came out of winter, in the case of the 3/16/22 rating, and how well they handled summer drought/heat stress, which was the rational for the August rating. After initial establishment, WSU blend #1 had the best turfgrass quality and the greatest ammount of groundcover (crop %) in the trial. It was followed closely by the WSDOT blend in groundcover, but WSU blends #4, #5, and #6 all had slightly higher, although not significant, turfgrass quality (see Figs. 25 and 26).

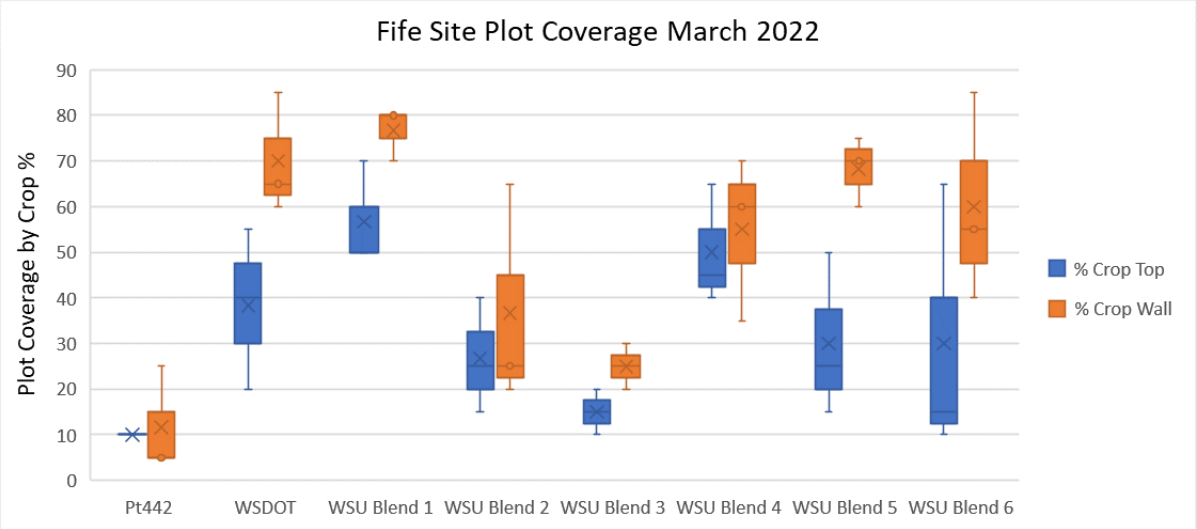


Figure 25. Percentage of ground cover identified as "crop" species

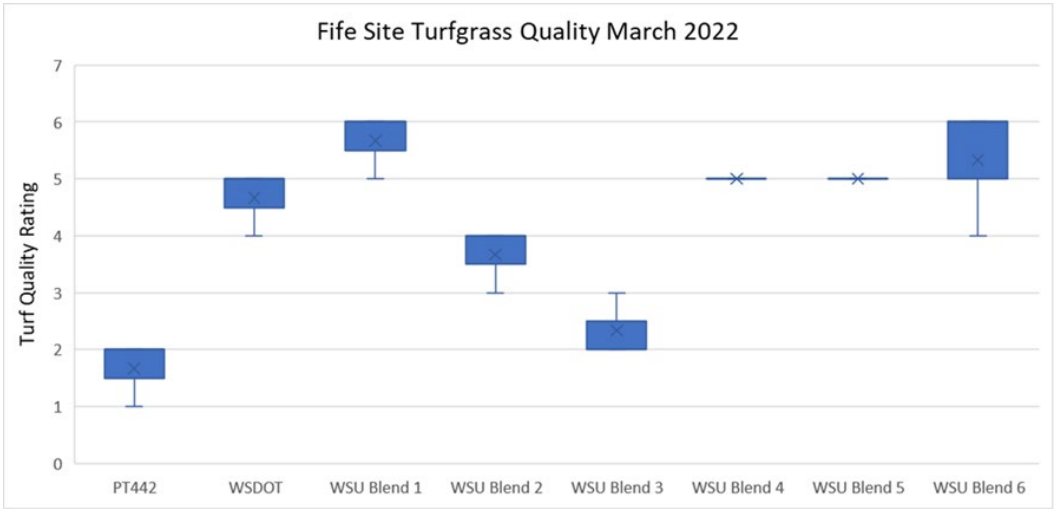


Figure 26. Turfgrass quality rating of the top portion of Fife ditch, wall portion had not established well enough to rate beyond percentage groundcover at this time.

Figure 27. PT-442 Blend at Fife site 3/3/22

Figure 28. WSDOT Blend at Fife site 3/3/22

Figure 29. WSU Blend 1 Fife site 3/3/22

Figure 30. WSU Blend 2 Fife site 3/3/22

Figure 31. WSU Blend 3 Fife site 3/3/22

Figure 32. WSU Blend 4 Fife site 3/3/22

Figure 33. WSU Blend 5 Fife site 3/3/22

Figure 34. WSU Blend 6 Fife site 3/3/22

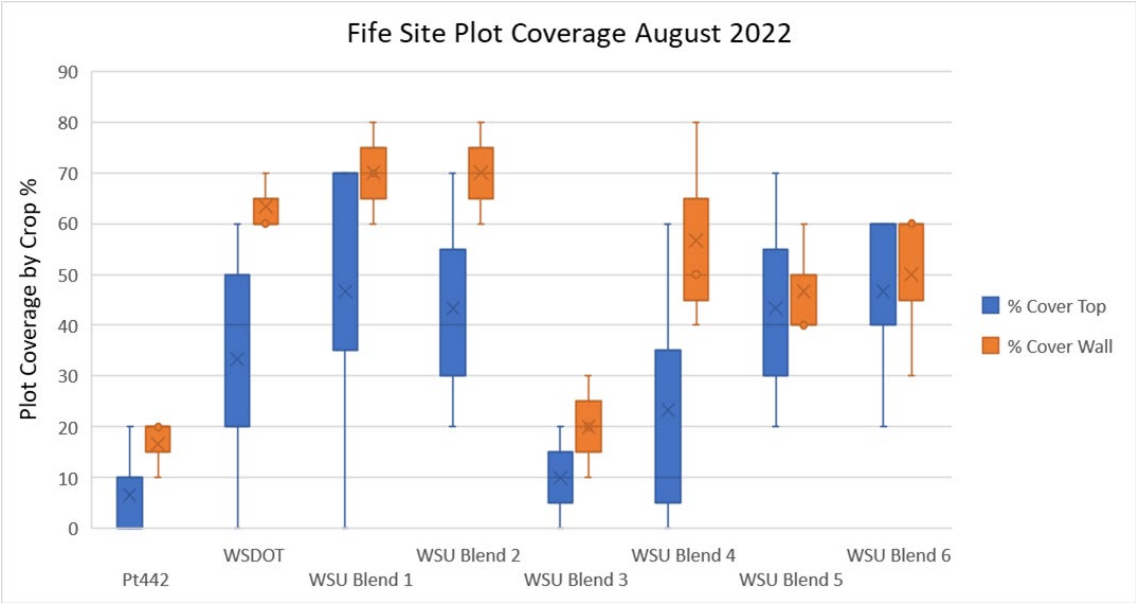


Figure 35. Percentage of groundcover that is "crop" at Fife site broken down to the flat "top" of ditch and verticle "wall" of ditch.

The performance of several WSU Blends shifted in response to summer drought and heat. WSU blend 2, which had initially not done well, began to increase its coverage and turfgrass quality (fig. 35 and 36). WSU blend 4 began to lose coverage and saw a loss in turfgrass quality after summer heat and drought stress . As the site matured, the top of the plots became overrun with the *Agrostis* species that had heavily colonized the site before renovation. The WSDOT blend, as well as WSU blends 1 and 2, had the most crop species present post-summer drought (see fig. 35). Post-summer heat/drought stress, WSU blend 2 displayed the greatest degree of turfgrass quality (fig. 36.). It should be noted that none of the quality ratings would be deemed acceptable for anything other than reclamation plantings as a plot rating of 5 would be the bare minimum that would be recommended for home lawns. WSU blend 2 significantly increased quality post-summer drought, demonstrating this blend's drought and heat tolerance. The other blends continued their performance trends, with WSDOT, WSU blends 1, 5, and 6 all continuing to perform acceptably.

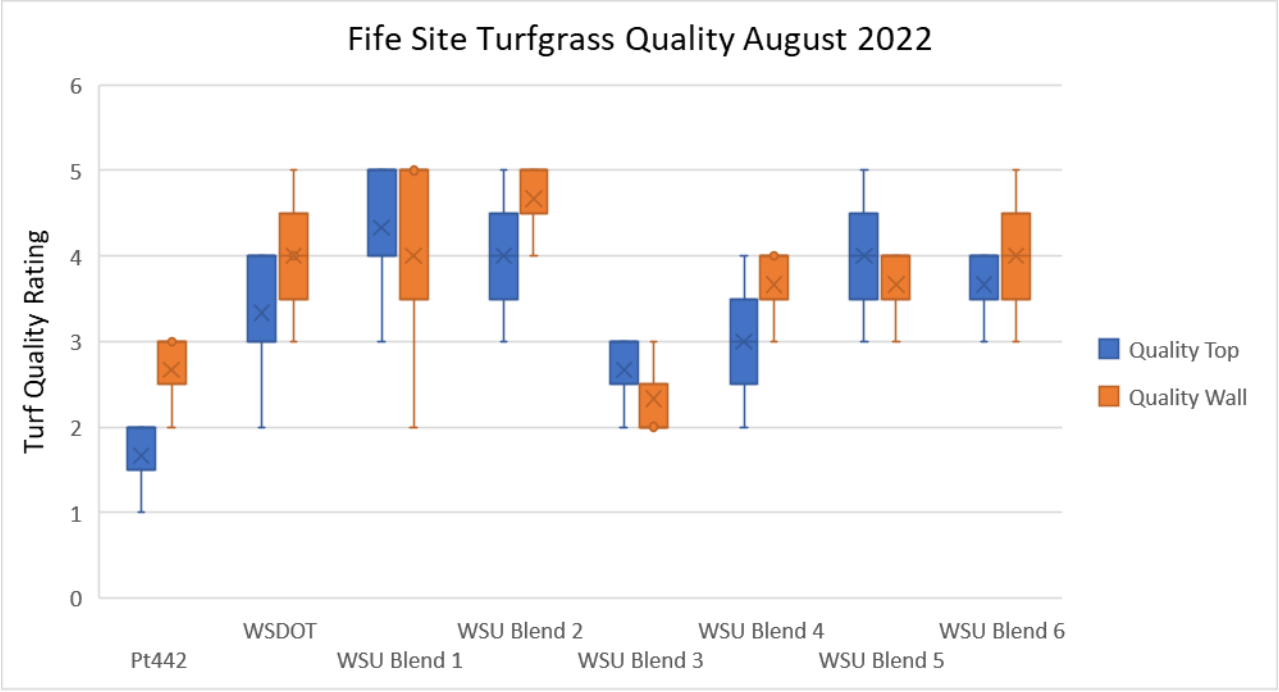


Figure 36. Turfgrass quality at summer drought. Plots broken into top and wall of the ditch.

Figure 37. PT-442 Blend Fife site 8/19/22

Figure 38. WSDOT Blend Fife site 8/19/22

Figure 39. WSU Blend 1 Fife site 8/19/22

Figure 40. WSU Blend 2 Fife site 8/19/22

Figure 41. WSU Blend 3 Fife site 8/19/22

Figure 42. WSU Blend 4 Fife site 8/19/22

Figure 43. WSU Blend 5 Fife site 8/19/22

Figure 44. WSU Blend 6 Fife site 8/19/22

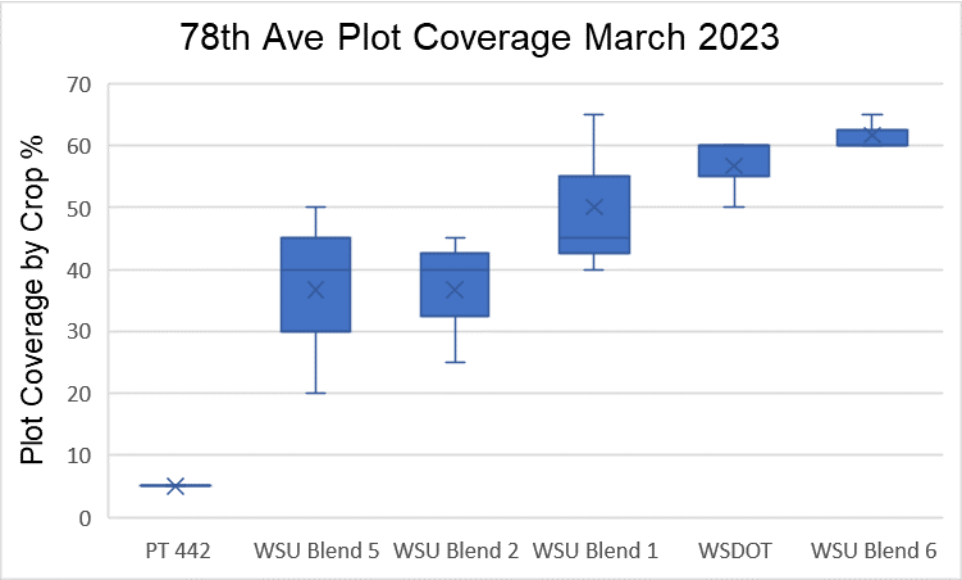


Figure 45. Ground cover percentage identified as "crop" at 78th Ave site

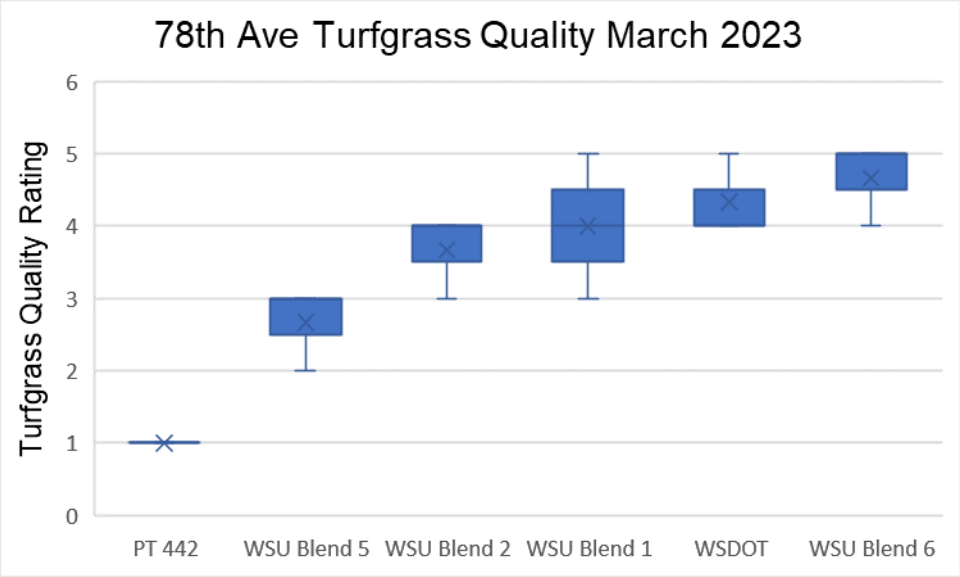


Figure 46. Turgrass quality rating 78th Ave site

Figure 47. PT-442 Blend at 78th Ave site 3/17/23

Figure 48. WSDOT Blend at 78th Ave site 3/17/23

Figure 49. WSU Blend 1 at 78th Ave site 3/17/23

Figure 50. WSU Blend 2 at 78th Ave site 3/17/23

Figure 51. WSU Blend 5 at 78th Ave 3/17/23

Figure 52. WSU Blend 6 at 78th Ave site 3/17/23

Figure 53. PT-442 6X rate 78th Ave site 3/17/23

The plot growth at the 78th Street site followed a slightly different pattern. There was no standing water in this ditch system that we could observe at any time. The site was also shaded from the west by a large, tall grove of coniferous trees. The WSDOT and WSU blend #6 had the least bare ground coverage. PT-442 had little to no coverage at the time of rating. WSU blends 1, 2, and 5 had over 30% coverage at the time of rating (fig. 45).

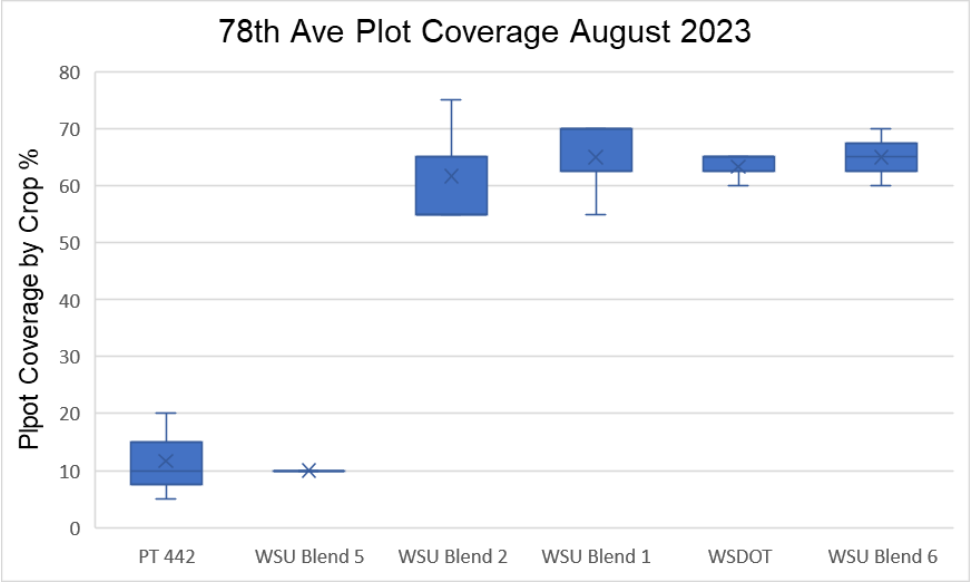


Figure 54. Percentage of ground cover that appears to be a component of the blend

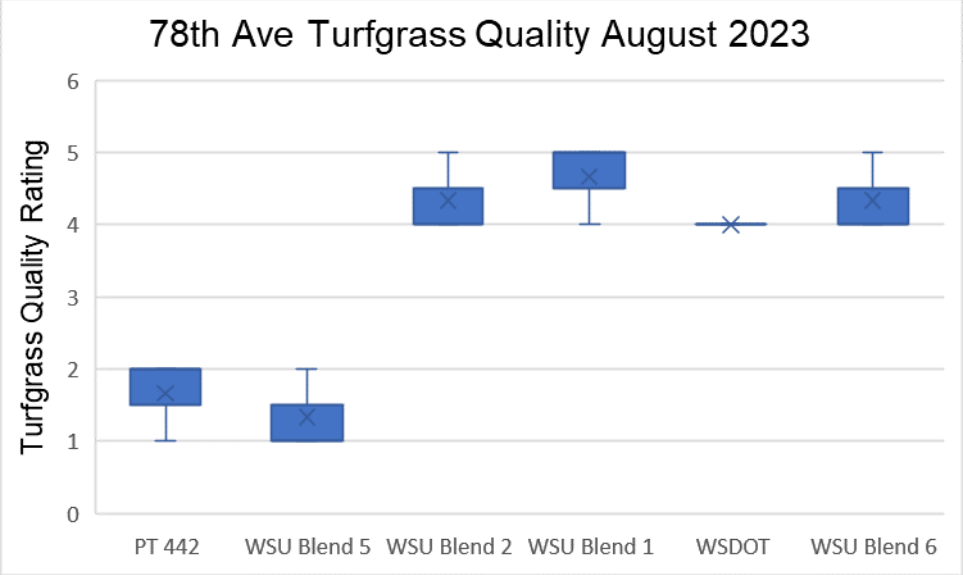


Figure 55. Turfgrass quality ratings 8/23/23

The turfgrass quality was the greatest with WSU blend 6, which rated slightly below 5, almost achieving acceptable quality for turf. WSDOT and WSU blends 1 and 2 had very similar quality at the time of rating (see Fig. 46).

Figure 56. PT-442 Blend 78th Ave site 10/31/23

Figure 57. WSDOT Blend 78th Ave site 10/31/23

Figure 58. WSU Blend 1 78th Ave site 10/31/23

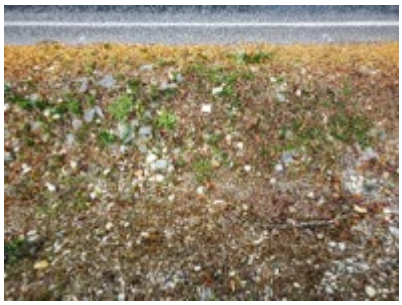


Figure 59. WSU Blend 2 78th Ave site 10/31/23

Figure 60. WSU Blend 5 78th Ave site 10/31/23

Figure 61. WSU Blend 6 78th Ave site 10/31/23

Figure 62. PT-442 6X rate 78th Ave site 10/31/23

In the percentage crop rating, after a period of summer drought, the WSDOT plot, WSU blends 1,2 and 6 all had over 60% coverage, PT-442 had less than 10% coverage regardless of seeding rate. WSU blend 5 lost a significant amount of coverage post-drought and also

dropped to roughly 10% (fig. 54). The WSDOT blend, as well as WSU Blends 1, 2, and 6, all had quality ratings more significant than 4, while PT-442 rated between 1 and 2 (fig. 55).

3.3. Species Inventory

The species inventory for each plot is listed below. The inventory was taken in the fall after each study. Species that are components of each blend are highlighted in bold. The remaining plants represent the weed species established during the study and are part of the soil seed bank. Each blend is listed as the sum of the three replications at each site.

PT 442 blend at Fife

Prairie Junegrass (*Koeleria macrantha*), Canada Thistle (*Cirsium arvense*), Broadleaf Plaintain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea),* Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Sow thistle (*Sonchus* spp.), Mullein (*Verbascum thapsus*), field sorel (*Rumex acetosella*), Shotweed (*Cardamine hirsuta*), St. John's-wort (*Hypericum perforatum*).

WSDOT blend at Fife

Canada Thistle (*Cirsium arvense*), Broadleaf Plantain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Sow thistle (*Sonchus* spp.), Field sorel (*Rumex acetosella*), Tall fescue (*Festuca arundinacea*), **Fine fescue (*Festuca* spp.)**, Prickly lettuce (*Lactuca serriola*), Cattail (*Typha latifolia*), **Perennial Ryegrass (*Lolium perenne*)**, Red clover (*Trifolium pretense*), Willow (*Salix* spp.), Cottonwood (*Populus deltoides*).

WSU Blend 1 at Fife

Canada Thistle (*Cirsium arvense),* Broadleaf plantain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Field sorel (*Rumex acetosella*), St. John's-wort (*Hypericum perforatum),* Tall fescue (*Festucca arundinacea*), **Fine fescue (*Festuca* spp.)**, Red clover (*Trifolium pretense*), Scotch broom (*Cytisus scoparius*).

WSU Blend 2 at Fife

Canada Thistle (*Cirsium arvense*), Broadleaf Plantain (*Plantago major*) Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*),

Sow thistle (*Sonchus* spp.), Field sorel (*Rumex acetosella*), St. John's-wort (*Hypericum perforatum),* **Fine fescue (*Festuca* spp.)**, Prickly lettuce (*Lactuca serriola*), Red clover (*Trifolium pretense*), **Yarrow (*Achillea millefolium*)**, wild geranium (*Geranium maculatum*), smooth cat's ear (*Hypochaeris glabra*).

WSU Blend 3 at Fife

Canada Thistle (*Cirsium arvense*), Broadleaf Plantain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Field sorel (*Rumex acetosella*), Tall fescue (*Festuca arundinacea*), **Fine fescue (*Festuca* spp.)**, Prickly lettuce (*Lactuca serriola*), Red clover (*Trifolium pretense*), Scotch broom (*Cytisus scoparius*), annual ryegrass (*Lolium multiflorum*), Mullein (*Verbascum thapsus*).

WSU Blend 4 at Fife

Broadleaf Plantain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Field sorel (*Rumex acetosella*), Tall fescue (*Festuca arundinacea*), **Fine fescue (*Festuca* spp.)**, Prickly lettuce (*Lactuca serriola*), Red clover (*Trifolium pretense*), **Yarrow (*Achillea millefolium*)**, Mullein (*Verbascum thapsus*), Canadian horseweed (*Erigeron canadensis*), Douglas spirea (*Spirea douglasii*), Sweet Vernal Grass (*Anthoxanthum odorata*).

WSU Blend 5 at Fife

Broadleaf Plantain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), **Colonial bentgrass (*Agrostis capillaris*)**, Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Fine fescue (*Festuca* spp.), Prickly lettuce (*Lactuca serriola*), Canadian horseweed (*Erigeron canadensis*), Sweet Vernal Grass (*Anthoxanthum odorata*).

WSU Blend 6 at Fife

Canada Thistle (*Cirsium arvense*), Broadleaf Plaintain (*Plantago major*), Himalayan blackberry (*Rubus armeniacus*), Colonial bentgrass (*Agrostis capillaris*), Reed canary grass (*Phalaris arundinacea*), Fireweed (*Chamaenerion angustifolium*), Horsetail (*Equisetum*), Field sorel (*Rumex acetosella*), Tall fescue (*Festuca arundinacea*), **Fine fescue (*Festuca* spp.)**, Prickly lettuce (*Lactuca serriola*), Red clover (*Trifolium pretense*), Canadian horseweed (*Erigeron canadensis*), Sweet Vernal Grass (*Anthoxanthum odorata*), Lupine (*Lupinus polyphyllus*), Hairy bittercress (*Cardamine hersuta*).

PT-442 at 78th Ave

Brome (*Bromus* spp.), Bentgrass (*Agrostis* spp.), **Fine fescue (*Festuca* spp.)**, Broadleaf plantain (*Plantago major*), Kentucky bluegrass (*Poa pratensis*), Orchard grass (*Dactylis glomerata*), Trailing blackberry (*Rubus ursinus*).

WSDOT at 78th Ave

Perennial ryegrass (*Lolium perenne*), **Clover (*Trifolium* spp.)**, Broadleaf plantain (*Plantago major*), Bishop's weed (*Aegopodium podagraria*), Bentgrass (*Agrostis* spp.), Trailing blackberry (*Rubus ursinus*), smooth cat's ear (*Hypochaeris glabra*).

WSU Blend 1 at 78th Ave

Perennial ryegrass (*Lolium perenne*), **Fine fescue (*Festuca* spp.)**, Broadleaf plantain (*Plantago major*), Bentgrass (*Agrostis* spp.), Willow Herb (*Epilobium brachycarpum*), Hawkbit (*Leontodon* spp.), Myrtle spurge (*Euphorbia myrsinites*), Dandelion (*Teraxacum* spp.)

WSU Blend 2 at 78th Ave

Fine fescue (*Festuca* spp.), Perennial ryegrass (*Lolium perenne*), Broadleaf plantain (*Plantago major*), Bentgrass (*Agrostis* spp.), Willow Herb (*Epilobium brachycarpum*), Hawkbit (*Leontodon* spp.), Myrtle spurge (*Euphorbia myrsinites*), Dandelion (*Teraxacum* spp.)

WSU Blend 3 at 78th Ave

Fine fescue (*Festuca spp.*), Yarrow (*Achillea millefolium*), Bentgrass (*Agrostis* spp.), Tall fescue (*Festuca arundinacea*), Trailing blackberry (*Rubus ursinus*), Dandelion (*Teraxacum* spp.), Broadleaf plantain (*Plantago major*), Hawkbit (*Leontodon* spp.)

WSU Blend 5 at 78th Ave

Perennial ryegrass (*Lolium perenne*), Broadleaf plantain (*Plantago major*), **Bentgrass (*Agrostis* spp.)**, Myrtle spurge (*Euphorbia myrsinites*), Dandelion (*Teraxacum* spp.) Orchard grass (*Dactylis glomerata*), Trailing blackberry (*Rubus ursinus*), Tall fescue (*Festuca arundinacea*), Yarrow (*Achillea millefolium*), Douglas fir (*Pseudotsuga menziesii*), wild carrot (*Daucus carota*), Fine fescue (*Festuca* spp.)

WSU Blend 6 at 78th Ave

Perennial ryegrass (*Lolium perenne*), Broadleaf plantain (*Plantago major*), Bentgrass (*Agrostis* spp.), Myrtle spurge (*Euphorbia myrsinites*), Dandelion (*Teraxacum* spp.) trailing blackberry (*Rubus ursinus*), Tall fescue (*Festuca arundinacea*), **Fine fescue (*Festuca* spp.)**, field sorel (*Rumex acetosella*), Canada Thistle (*Cirsium arvense*)

PT442 at 6 lbs at 78th Ave

Brome (*Bromus* spp.), **Fine fescue (*Festuca* spp.)**, Broadleaf plantain (*Plantago major*), Trailing blackberry (*Rubus ursinus*)

4. Conclusions (Key Findings)

Roadside ditches provide a very challenging environment to grow and establish plants. The ditches often contain trash and are filled with water for months during the rainy season. Alternatively, during the spring and summer, the ditches are subjected to heat and drought stress. The soil exposed in re-graded ditches is not topsoil; therefore, it is often underdeveloped--it lacks carbon and other organic matter to hold water and provide the essential nutrients for plants to survive. Many plant species are adapted to a particular environment. Often, species that thrive in drought do poorly in waterlogged areas. Those adapted to salt stress do not tolerate prolonged drought. Species adapted to shade do not compete well in full sun. Species adapted to full sun often do not even germinate in shaded environments. When first setting up the experimental blends, we spoke with the Tacoma maintenance crews about their biggest challenges. They wanted to find grasses that would hold the bank in place post-renovation, outcompete weeds on the site, and not produce so much top growth that excessive mowing would be required.

These challenges set the stage for the importance of our work done at the Fife site. The Fife site comprised three sections, with the majority in full sun (see Fig. 3). Our best native seed blend, PT-442, performed terribly. PT-442 did so poorly that we conducted an ad hoc germination screen after the study to determine if something was wrong (anecdotal desktop germination in a petri dish at room temp). The germination screen turned out fine, with almost 100% germination. That led us to believe the seedlings could not establish and persist on the site. This results was further demonstrated by the species inventories of the plots containing PT-442 conducted at the end. We could not identify any plants that were components of the PT-442 blend in Fife. Blend components identified in the species inventory are in bold (see section 3.3).

WSU blend 3 also had poor establishment at the Fife site. It was a mixture of two native grasses, Roemer's fescue and tufted hairgrass and clover. The other six blends, WSDOT, WSU blend 1, 2, 4, 5, and 6, all established quickly and produced over 70% cover on the wall portion of the ditch (see Fig. 8). The most successful components of the six blends were the fine fescues (see bolded names in section 3.3 species inventory). These include Strong creeping red fescue, hard fescue, sheep fescue, molate red fescue, and chewings fescue. The other species that established well were the bentgrasses. WSU blend 5, one of our better

performers at the Fife site, was a 50/50 mix of two bentgrass species. Perennial ryegrass was also very good at establishment and was a significant component of the WSDOT blend. Coming out of winter, the blends with the best persistence and coverage at the Fife site were WSDOT and WSU Blends 1, 4, 5, and 6 (see Fig 25). WSU blend 2 was slow to come out of winter as it was a blend of hard and sheep fescue and lacked the strong creeping red fescue the other blends had. WSU blend 1 had turf quality almost at acceptable levels for a home lawn on the March rating (see fig. 26). At the height of summer heat and drought stress, the differences between the six most successful blends at Fife were not very distinct. WSU blend 2 had grown and filled in since the March rating (see fig. 35). The clover components of WSU blends 2 and 3 did not establish well and often appeared in plots that were not planted. This was also true for the yarrow component of WSU blends 2 and 4 and may have been due to the flooding that the site experienced post-planting or other similar events.

The 78th Ave site differed from the Fife site in that there was a great deal of afternoon shade from the forest across the street and a more rocky, less developed soil. Most importantly, it drained well compared to Fife. These site differences affected what blends and components were successful at the site. The WSDOT blend and WSU blends 1 and 6 all had close to 70% establishment (see Fig. 17). PT-442 had the worst establishment at less than 10%, and WSU blends 2 and 5 had close to 50% establishment (see Fig. 17). Post winter, the WSDOT blend, WSU blend 1, and WSU blend 6 all had over 50% cover as well as a turf quality rating of 4 or greater. PT-442 was the poorest, with less than 10% cover and a turf quality of 1 (see figs 45 and 46). Post-summer drought and heat stress, PT-442 and WSU blend 5 had less than 10% cover and turf quality of 2 or less. WSDOT blend and WSU blends 1, 2, and 6 all had over 50% cover and 4 or greater turf quality (see figs. 54 and 55). The fine fescue components of WSU blends, including Strong creeping red fescue, hard fescue, sheep fescue, molate red fescue and chewings fescue, all performed well at the 78th Ave site. The perennial ryegrass component of the WSDOT blend also performed well (see section 3.3). The Sheep fescue/hard fescue components of WSU blend 2 were once again slow to come out of winter dormancy but could fill in to match the other successful plots by summer. The bentgrass components of WSU blend 5 could not persist in the drought and shade at the 78th Ave site, even though they germinated and were established in the fall post-planting. Similar to the Fife site, the yarrow and clover components of the WSU blends were unsuccessful at establishing and colonizing the site in the time frame that the surveys were taken.

4.1. Planting Recommendations

The WSDOT blend had the most utility of the blends tested. The combination of perennial ryegrass and strong creeping red fescue was very effective at colonizing the full sun Fife site and the more xeric, shady 78th Ave site. The clover component of the blend did not appear in our species surveys at an acceptable rate and could be removed from this blend. The WSDOT blend is recommended as a fast-establishing utility blend that could be planted in many environments, especially those requiring fast germination. WSU blend 2 could be a good choice for sites with slower growth requirements.

The blend of hard and sheep fescues has slower growth than the other blends, especially after winter dormancy, with acceptable coverage and growth over time.

WSU blend 2 would be good for areas with shade and drought and where slow growth is preferred.

WSU blends 1 and 6 had acceptable growth and coverage at the Fife and 78th Ave sites. They also grew faster after winter dormancy compared with WSU blend 2. Once again, these blends' yarrow and clover components could likely be omitted due to their poor establishment at both sites. WSU blends 1 and 6 could each be interchangeable with the WSDOT blend and are recommended for most environments, including shade.

WSU blend 5 was good at colonizing the Fife site but struggled to persist in the xeric, shady 78th Ave site. This blend could be helpful for revegetating areas already inundated with bentgrass, such as the Fife site, but should be avoided in areas of moderate to heavy shade and poor available soil moisture. WSU blend 5 is recommended for use in full sun, primarily where other bentgrass species have already dominated the site.

The PT-442 native blend was not a good candidate for this type of planting. The weed and environmental pressure was too great for the native species to establish and grow. We could only see components of this blend at the 78th Ave site and then only 7-8 plants in a 10 ft plot. PT-442 is recommended for native sites with little weed competition and minimal disturbance.

Table 4. Blend recommendations for different ditch conditions

Ditch condition	**Blend recommendation**	**Notes**	**Blend mix %**	**Blend common names**
Native site, little-to-no weed competition or soil disturbance	PT-442	Blend struggled to establish in sites lacking topsoil and large adjacent weed seed quantities.	25% *Hordeum brachyantherum* 15% *Danthonia californica* 10% *Elymus glaucus* 10% *Bromus carinatus* 10% *Festuca idahohensis* 10% *Dechampsia cespitosa* *10%Agrostis exarata* 5% *Alopecurus geniculatus* 5% *Dechampsia elongata*	Meadow Barley California Oatgrass Blue Wildrye California Brome Roemer's Fescue Tufted Hairgrass Spike Bentgrass Water Foxtail Slender Hairgrass
Wide range of ditch conditions	WSDOT	Fast establishing utility blend. The combination of perennial rye grass and strong creeping red fescue effectively colonized in full sun and more xeric sites.	50% *Lolium perenne* 40% *Festuca rubra* 10% *Trifolium repens*	Perennial ryegrass Creeping Red Fescue White Clover
Wide range of ditch conditions	WSU Blend 1	Could be used interchangeably with WSDOT blend, good for shady sites.	50% *Festuca rubra* *40% Festuca rubra ssp. commutata* *10% Argostis tenuis*	Creeping Red Fescue Chewings Fescue Highland Bentgrass
Wide range of ditch conditions	WSU Blend 6	Could be used interchangeably with WSDOT blend, good for shady sites.	50% *Festuca rubra ssp. Molate* 40% *Festuca rubra ssp. commutata* 10% *Agrostis gigantea*	Molate Red Fescue Chewings Fescue Redtop Bentgrass
Sites that will allow for extended establishment	WSU Blend 2	Hard and sheep fescues have slower growth, but the blend worked well for areas with shade and drought.	50% *Festuca trachyphylla/Festuca ovina* 35% *Trifolium fragiferum* 15% *Achillea millefolium*	Hard/Sheep Fescue Strawberry Clover Yarrow
Full sun, regenative sites	WSU Blend 5	Useful blend for sites inundated with bentgrass. Not recommended for shady sites	50% *Agrostis gigantea* 50% *Agrostis tenuis*	Redtop Bentgrass Highland Bentgrass

4.2. Other Recommendations

- Numerous native and turfgrass species were not tested in this study but were seen growing adjacent to the plots at each site. Some examples include Kentucky bluegrass, tall fescue, prairie junegrass, and sweet vernal grass. Including these species in future studies could give different results in other environments.
- Seeding rates also have an impact on species establishment and persistence. Our plots were tested at 6lbs. per 1k sq. ft. seeding rate. At lower grass seeding rates, the yarrow and clover components of the blends may have a better opportunity to establish.
- Grass mono stands are not ideal for insect pollinators or wildlife. It would be necessary for future studies to include some flowering plants that would be attractive to pollinators.
- Further work is necessary to develop native blends that are more aggressive, and that will colonize disturbed areas quickly to protect species diversity as well as water quality.

The Grass Breeding and Ecology farm at WSU Pullman has over 20 active breeding programs for salt tolerance, wear tolerance, native, forage, and sports turf applications. We are a relatively new program at WSU, and this work will guide our future endeavors regarding urban reclamation, water quality, and potential breeding targets.

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