Red Dog Soils Growth Trial

Prepared for Teck Cominco Alaska
Red Dog Mine

July 25, 2007

Donald R. Ross
State of Alaska, Dept. of Natural Resources
Division of Agriculture
Plant Materials Center
Palmer, AK

Table of Contents

Red Dog Mine Soils - Plant Growth Trial

I. Introduction

The Alaska Plant Materials Center (PMC) began working with Teck Cominco Alaska in 1987 to help establish effective revegetation techniques at the Red Dog Mine in northwestern Alaska. Test plots, photo points, demonstration plantings, and site monitoring have been part of this process up to the present time. The following project continues this working relationship.

In March of 2006, the PMC initiated a plant growth trial using three soils from the Red Dog Mine site and 25 species of conservation plants with proven or potential value for revegetation of mined lands.

The three soils were: 1) **Type O**, mostly from the Okpikruak formation along with soils from the Ikalukrok formation, collected at the Waste Rock Dump; 2) **Type S**, from the Siksikpuk formation collected from near Drainage Ditch #4; and 3) **Type K**, collected from the Overburden Stockpile derived from the Kivalina formation. These soils may have physical and chemical properties, including high concentrations of lead and zinc, which could suppress plant growth. Samples from the three soils were analyzed for soil texture class, pH, cation exchange capacity (CEC), electrical conductivity (EC), organic matter, macro and micro nutrients, and the presence of selected heavy metals.

II. Methods

Seed from 25 species of plants with proven or potential revegetation value were sown into 72-count plug trays with each of the three soils, yielding 18 cells of each species in each soil (see Table 1, Species List and Seed Source, p.).

Seed sowing was completed in late March of 2006 and the plug trays were moved to the PMC greenhouse under intermittent overhead irrigation.

Plants were evaluated on 4/4/06 and 4/28/06 for germination and vigor. In mid-May, an overhead sprinkler malfunction resulted in the desiccation of several species. These are noted in the evaluation data for June and July. In late May, each species was transplanted into larger 18-count/tray pots: two to four plants each into two pots for each of the three soils. The remaining plants were discarded and the leftover soil was used to fill the larger pots. These trays were again placed in the greenhouse and were further evaluated on 6/6/06 and 7/12/06. Soluble fertilizer (Peters® 15-16-17 Peat-Lite) was added to the overhead irrigation system on approximately 6/30/06 before the final evaluation.

Evaluation of plant vigor took into account plant growth rate, height, color, and symptoms of disease or nutrient deficiency. Digital photographs of the plant trays were taken on 4/5/06, 4/28/06, and 6/27/06.

Table 1 - Red Dog Mine Soils Growth Trial
Spring – 2006
Species List & Seed Source

1.	Kotzebue Germplasm arctic wild chamomile	*Tripleurospermum maritima*	03PMC107
2.	Nelchina Germplasm spike trisetum	*Trisetum spicatum*	SW97-F7-2005
3.	Nome Germplasm glaucous bluegrass	*Poa glauca*	95Nome - 2005
4.	Solomon Germplasm thickspike wheatgrass	*Elymus macrourus*	02PMC12
5.	Teller Germplasm alpine bluegrass	*Poa alpina*	S193-F7-2005
6.	Twenty-Mile Germplasm boreal yarrow	*Achillea millefolium* var. *borealis*	05PMC125
7.	Wainwright Germplasm slender wheatgrass	*Agropyron pauciflorum*	04PMC04-F1
8.	Lowell Point Germplasm meadow barley	*Hordeum brachyantherum*	03PMC20
9.	Decumbent goldenrod	*Solidago decumbens*	05PMC153 /36VZ02
10.	Northern goldenrod	*Solidago multiradiata*	05PMC126
11.	Tall Jacob's ladder	*Polemonium acutiflorum*	(P. Shoen source)
12.	Henderson Ridge Germplasm red fescue	*Festuca rubra*	05PMC111
13.	'Caiggluk' Tilesius wormwood	*Artemisia tilesii*	03PMC12
14.	'Tundra' glaucous bluegrass (Fairbanks)	*Poa glauca*	03PMC24
15.	'Service' big bluegrass	*Poa secunda*	99PMC01
16.	Narcissus-flowered anemone	*Anemone narcissiflora*	11M01
17.	'Alyeska' polargrass	*Arctagrostis latifolia*	03PMC102
18.	'Kenai' polargrass	*Arctagrostis latifolia*	03PMC101
19.	'Norcoast' Bering hairgrass	*Deschampsia beringensis*	03PMC13A
20.	'Nortran' tufted hairgrass	*Deschampsia caespitosa*	04PMC20
21.	Altai fescue	*Festuca altaica*	05PMC121
22.	'Gruening' alpine bluegrass	*Poa alpina*	05PMC127AA
23.	'Arctared' red fescue	*Festuca rubra*	98PMC10A
24.	'Sourdough' bluejoint reedgrass	*Calamagrostis canadensis*	05PMC143
25.	Tall cottongrass	*Eriophorum angustifolium*	(V. Vinette source)

Three soil types from Red Dog Mine:
1. Type "O" --- mostly Okpikruak with Ikalukrok
2. Type "S" --- Siksikpuk
3. Type "K" --- Kivalina

Each species sown into each soil type: 72-count plug trays, 18 cells @ except *Eriophorum* w/ 1 cell/soil. Sown March, 2006.

III. Data

See Appendix 1 -Growth Trial Worksheets, Appendix 2 -Soil Analysis Data, and Appendix 3 - Photos.

IV. Results

Most seedlings germinated readily in each of the soils except two species: *Anemone narcissiflora* and *Eriophorum angustifolium.* These two species often exhibit dormancy that it is difficult to break. Most of the broadleafs were slower to germinate than the grasses. Initial seedling vigor (4/4/06) for all plants ranged from fair to very good, with seedlings in Soil O exhibiting slightly better vigor than seedlings in Soils S and K.

There was a general improvement in seedling vigor from 4/4/06 to 4/28/06. Plants in Soil O were all good to excellent except the two *Solidago* species. The same was true for Soil S, with the two *Solidago* species and *Polemonium acutiflorum* showing only fair vigor. Seedlings in Soil K exhibited a small net loss in vigor: nine species improved slightly, seven showed no change, and seven lost vigor, especially 'Wainwright' wheatgrass, 'Alyeska' polargrass, and 'Sourdough' bluejoint reedgrass. Also during this period, some plants in Soil K had developed small light yellow leaf spots, especially in the broadleaf plants.

Before the seedlings were transplanted in late May, an overhead sprinkler malfunction resulted in the desiccation of several trays of seedlings and the death of some of the plants. While many plants eventually recovered, the vigor data for 6/6/06 plummeted as a result of the dry conditions. Plants in Soil O were the most affected, with "O" seedlings dropping in vigor from an average of 2.48 on 4/28/06 to 5.18 (low number = better vigor). Soil S seedlings experienced moderate drying, and vigor dropped from an average of 2.91 to 4.33. Soil K seedlings had minimal drying, and dropped in vigor from 4.48 to 4.91.

The last evaluation of plant vigor was completed on 7/12/06. Soil O plants improved in vigor from an average of 5.18 to 3.50, with 17 species improving, six showing no change, and none worsening. 'Alyeska' and 'Kenai' polargrasses showed the strongest improvement. Soil S plants improved markedly with 19 species showing improvement, one with no change, and three losing vigor. Two broadleafs, *Solidago multiradiata* and *Polemonium acutiflorum*, were among those showing marked improvement. Soil K plants improved marginally from an average vigor of 4.91 to 3.91: eight species improved, 10 showed no change, and five lost vigor.

In summary, Soil O plants exhibited the best initial vigor, but also suffered most from desiccation. After transplanting and recovery from drying, final vigor for Soil O plants was between Soils S and K. Soil S plants started with vigor slightly better than Soil K and improved rapidly until the desiccation event. With recovery, their vigor rapidly improved and they exhibited the best vigor at the end of trial. Soil K plants showed the least improvement and had the lowest vigor throughout the trial except on 6/6/06, when lack of water temporarily lowered Soil O plant vigor to less than the plants in Soil K. (See Chart 1 –Plant Vigor by Date)

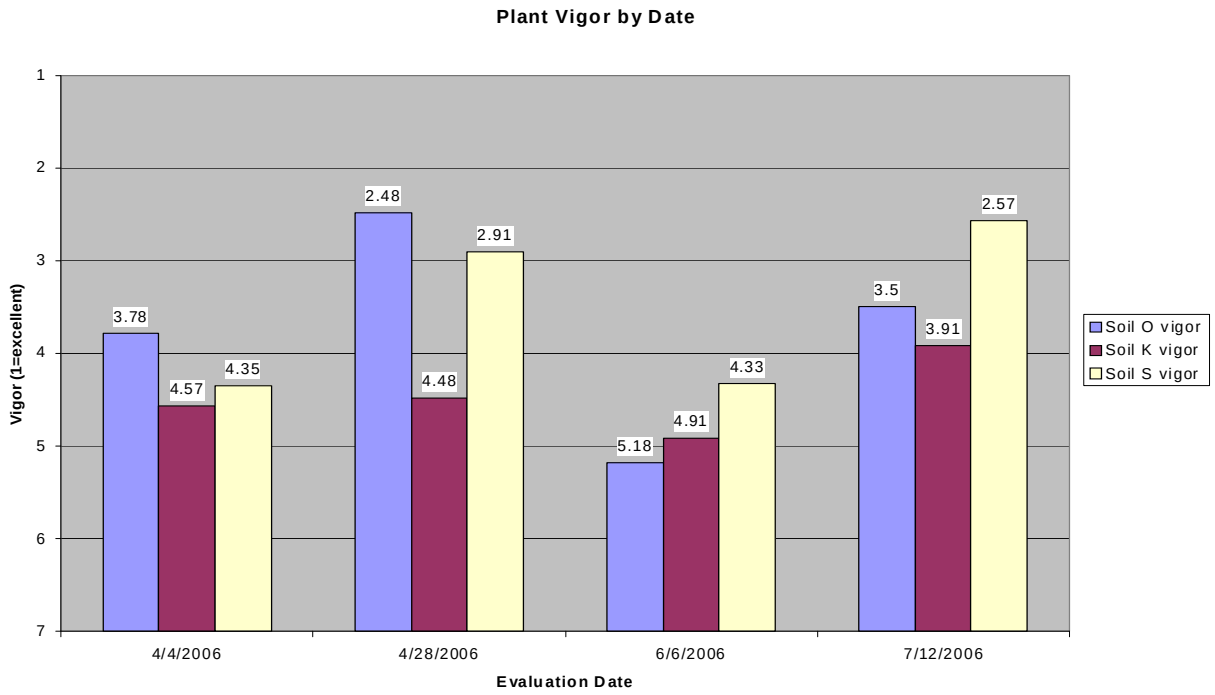


Chart 1

Table 2 shows each species vigor rank (1st, 2nd, 3rd) in each of the three soils. None of the species grew best in Soil K. Fifteen species were ranked first in Soil S while Soil O had eight species ranked first.

Table 2 – Individual Species Vigor Rank in Each Soil

Sp.#	Name (Abbreviation)	Performance Ranking in @ Soil (1=best)		
1……	*Tripleurospermum maritima* 'Kotzebue'	1-S	2-K	3-O
2……	*Trisetum spicatum* 'Nelchina'	1-S	2-K	3-O
3……	*Poa glauca* 'Nome'	1-S	2-O	3-K
4……	*Elymus macrourus* 'Solomon'	1-O	2-S	3-K
5……	'Teller' alpine bluegrass	1-S	2-O	3-K
6……...	'Twenty-Mile' boreal yarrow	1-S	2-K	3-O
7……...	'Wainwright' slender wheatgrass	1-O	2-S	3-K
8……...	*Hordeum brachyantherum* 'Lowell Point'	1-S	2-K	3-O
9……..	*Solidago decumbens* (Sode)	1-S	2-K	3-O
10……	*Solidago multiradiata* (Somu)	1-S	2-K	3-O
11……	*Polemonium acutiflorum* (Poac)	1-S	2-K	3-O
12……	'Henderson Ridge' red fescue	1-S	2-O	3-K
13……	*Artemisia tilesii* (Arti)	1-S	2-O	3-K
14……	'Tundra' glaucous bluegrass	1-O	2-K	3-S
15……	'Service' big bluegrass	1-S	2-O	3-K
16……	*Anemone narcissiflora* (Anna)	N/A		
17……	'Alyeska' polargrass	1-O	2-S	3-K
18……	'Kenai' polargrass	1-O	2-K	3-S
19……	'Norcoast' Bering hairgrass	1-S	2-K,O (tie)	
20……	'Nortran' tufted hairgrass	1-S	2-O	3-K
21……	'Sourdough' bluejoint	1-O	2-S	3-K
22……	'Arctared' red fescue	1-S	2-K,O (tie)	
23……	'Gruening' alpine bluegrass	1-O	2-S	3-K
24……	*Festuca altaica* (Feal)	1-O	2-K	3-S
25……	*Eriophorum angustifolium*	N/A		

Table 3 lists the top performing grass and forb species for each soil, and comprises the final recommendations for revegetation species tested in this trial.

Table 3 - Final Recommendations **Red Dog Soils Growth Trial**

For Soil **O**:

Grasses: 'Nortran' tufted hairgrass, 'Gruening' alpine bluegrass, 'Teller' alpine bluegrass, 'Solomon' thickspike wheatgrass (*Elymus macrourus*), 'Kenai' polargrass

Forbs: 'Twenty-Mile' boreal yarrow, 'Caiggluk' tilesius wormwood (*Artemisia tilesii*)

For Soil **K**:

Grasses: 'Tundra' glaucous bluegrass, 'Nome' glaucous bluegrass (*Poa glauca*), 'Teller' alpine bluegrass, 'Nortran' tufted hairgrass, 'Gruening' alpine bluegrass

Forbs: 'Kotzebue' arctic wild chamomile (*Tripleurospermum maritima*), 'Caiggluk' tilesius wormwood (*Artemisia tilesii*), 'Twenty-Mile' boreal yarrow, *Solidago multiradiata*

For Soil **S**:

Grasses: 'Teller' alpine bluegrass, 'Nome' glaucous bluegrass (*Poa glauca*), 'Gruening' alpine bluegrass, 'Nelchina' spike trisetum (*Trisetum spicatum*), 'Nortran' tufted hairgrass

Forbs: 'Kotzebue' arctic wild chamomile (*Tripleurospermum maritima*), 'Caiggluk' tilesius wormwood (*Artemisia tilesii*), 'Twenty-Mile' boreal yarrow, *Solidago multiradiata, Polemonium acutiflorum*

V. Discussion

Soil Analysis

As the growth trial progressed, it became apparent that Soil K was the most limiting of the group in terms of plant growth and vigor. The Kivalina formation from which it is derived is composed of banded calcareous turbidite and black calcareous shale. Soil test results indicate several factors that are limiting to plant growth: the calcium to magnesium ratio is very high. The extremely high levels of calcium and zinc can interfere with macro and micro nutrient absorption, and along with the extremely high sulfate content, skew the cation exchange capacity and electrical conductivity so that the soil could be classified as saline. The CEC is very high (48.6meq/100g) for a sandy loam soil with little organic matter and only 4% clay content, but the high content of calcium sulfate along with other metallic sulfates could account for this anomaly. Leaching of these salts could improve the soil's plant growth capacity. During the early stages of the growth trial, seedlings with small yellow leaf spots were indicative of toxic soil conditions. With continuous watering, these symptoms gradually subsided. Soil K also had very high lead concentrations, and while lead may not be directly toxic to plant growth, its presence in high concentrations may interfere with nutrient availability and absorption.

Laboratory tests of Soils O and S indicate fewer limitations for plant growth than Soil K. Soil O is from the Okpikruak formation and is derived from fine-grained graywacke deposits. Soil S is derived from the cherts and shales of the Siksikpuk formation. Soil O is classified as a loam with a CEC of 13.7 meq/100g and Soil S is a clay (CEC=6.0 meq/100g). EC levels in Soils O and S are substantially lower than in Soil K, and both soils have much lower levels of calcium, zinc, sulfates, and lead compared to Soil K. Additionally, nitrate-nitrogen levels are higher than in Soil K, and are more favorable to plant growth. Interestingly, all three soils had very high concentrations of organic nitrogen (see "Total Kjeldahl Nitrogen" in soil laboratory analysis) which is believed to be a result of these soils' marine origins and their incorporation of terrestrial derived amino acids from ancient rivers; however, this form of nitrogen is largely unavailable for plant uptake.

Laboratory analyses of the three soils clearly indicate that Soil K has chemical and physical properties that limit plant growth. Soils O and S, while having low fertility, have properties more conducive to plant growth. Results from the growth trial back up these conclusions.

Management Considerations

Revegetation of Soil K areas may be difficult. Leaching with water could improve the plant growth potential of Soil K, but this is impractical in most field situations. Applications of a standard agricultural fertilizer such as 20-10-10 may improve chances of success along with the utilization of the top performing five grasses and three forbs. Where feasible, a layer of top soil may be applied over the area before seeding.

Soils O and S are less challenging. Sowing seed of the best performing grasses and forbs along with occasional fertilization with a commercially available fertilizer such as 20-20-10 should result in a satisfactory ground cover barring further disturbance.

Appendix 1: Growth Trial Worksheets

Red Dog Mine Soils – Growth Trial Worksheet Date: 4/4/06 Soil: K

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	4	Sown 3/14. 1-4/cell but 4 empty cells.
2.	*Trisetum spicatum* (blue)	4	3/14. All up. 1-5 plants/cell.
3.	*Poa glauca* (tan)	4	3/14. Most up. 1-4 plants/cell.
4.	*Elymus macrourus* (pink)	4	3/14. All up. 2-5/cell. Tall.
5.	Teller alpine bg (ylw)	5	Sown 3/23. All up. 1-4/cell. Small.
6.	Twenty-Mile yarrow (orange)	4	3/23. 1-4/cell.
7.	Wainwright wg (white)	4	3/23. Soggy. Only 2 cells emerged.
8.	Lowell Point *Hordeum brachy.*…(red)	4	3/23. All but 2 cells emerged. 1-4/cell
9.	*Solidago decumbens* (Sode) (purple)	5	3/23. 3-6/cell. Small.
10.	*Solidago multiradiata* (Somu) (green)	5	3/23. 1-4/cell w/1 empty cell. Small.
11.	*Polemonium acutiflorum* (Poac) (tan)	5	3/23. 1-4/cell w/8 empty cells. Small.
12.	Henderson Ridge rf (gray)	5	3/23. 1-4/cell w/1 empty cell. Small.
13.	*Artemisia tilesii* (Arti) (pink)	5	3/24. 1-4/cell w/ 1 empty cell. Small.
14.	'Tundra' bg (blue)	4	3/24. All up, 3-5/cell.
15.	'Service' bg (ylw)	4	3/24. 1-4/cell. Small.
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	3/24. No emergence.
17.	'Alyeska' pg (red)	5	3/24. 2-4/cell. Very small.
18.	'Kenai' pg (green)	5	3/24. 3-5/cell w/ 1 empty cell. Small.
19.	'Norcoast' hg (tan)	5	3/24. 1-4/cell. Small.
20.	'Nortran' hg (gray)	4	3/24. 3-5/cell.
21.	'Sourdough' (blue)	5	3/28. A few cells: just now emerging.
22.	'Arctared' rf (white)	5	3/28. Just now emerging.
23.	'Gruening' bg (pink)	5	3/28. Just now emerging.
24.	*Festuca altaica* (Feal) (ylw)	5	3/28. Just now emerging.
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	3/29. No emergence.

Red Dog Mine Soils – Growth Trial Worksheet Date: 4/4/06 Soil: O

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	3	Sown 3/14. All germinated. 3-5/cell.
2.	*Trisetum spicatum* (blue)	3	3/14. All up. 3-5 plants/cell.
3.	*Poa glauca* (tan)	3	3/14. Most up. 1-4 plants/cell.
4.	*Elymus macrourus* (pink)	3	3/14. All up. 2-5/cell. Tall.
5.	Teller alpine bg (ylw)	2	Sown 3/23. Most up. Small.
6.	Twenty-Mile yarrow (orange)	3	3/23. 2-5/cell.
7.	Wainwright wg (white)	4	3/23. 1-4/cell w/1 empty cell. Tall.
8.	Lowell Point *Hordeum brachy.*…(red)	3	3/23. All up. 3-5/cell. Tall.
9.	*Solidago decumbens* (Sode) (purple)	3	3/23. 1-5/cell, just emerging.
10.	*Solidago multiradiata* (Somu) (green)	5	3/23. Half of cells no emergence.
11.	*Polemonium acutiflorum* (Poac) (tan)	5	3/23. 1-3/cell except 4 cells: none
12.	Henderson Ridge rf (gray)	3	3/23. 2-5/cell.
13.	*Artemisia tilesii* (Arti) (pink)	5	3/24. 1-4/cell except 2 cells: none.
14.	'Tundra' bg (blue)	3	3/24. All up, 3-5/cell.
15.	'Service' bg (ylw)	3	3/24. 1-4/cell.
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	3/24. No emergence.
17.	'Alyeska' pg (red)	4	3/24. Just now emerging. 1-3/cell.
18.	'Kenai' pg (green)	4	3/24. Just now emerging. 1-3/cell.
19.	'Norcoast' hg (tan)	4	3/24. Just now emerging. 1-3/cell.
20.	'Nortran' hg (gray)	4	3/24. Just now emerging. 1-3/cell.
21.	'Sourdough' (blue)	5	3/28. Just now emerging.
22.	'Arctared' rf (white)	5	3/28. Just emerging. 1-3/cell.
23.	'Gruening' bg (pink)	5	3/28. Just emerging. 1-3/cell but 1.
24.	*Festuca altaica* (Feal) (ylw)	5	3/28. Just emerging. 1-3/cell.
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	3/29. No emergence.

Red Dog Mine Soils – Growth Trial Worksheet Date: **4/4/06 Soil: S**

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	4	Sown 3/14. 1-4/cell but 5 empty cells.
2.	*Trisetum spicatum* (blue)	4	3/14. All up. 3-5 plants/cell.
3.	*Poa glauca* (tan)	4	3/14. Most up. 1-4 plants/cell.
4.	*Elymus macrourus* (pink)	4	3/14. All up. 1-5/cell. Tall.
5.	Teller alpine bg (ylw)	4	Sown 3/23. All up. 1-4/cell. Small.
6.	Twenty-Mile yarrow (orange)	4	3/23. 2-5/cell.
7.	Wainwright wg (white)	4	3/23. 1-4/cell w/4 empty cells. Tall.
8.	Lowell Point *Hordeum brachy.*…(red)	4	3/23. All up. 3-5/cell. Tall.
9.	*Solidago decumbens* (Sode) (purple)	4	3/23. 3-5/cell. Small.
10.	*Solidago multiradiata* (Somu) (green)	5	3/23. 1-4/cell w/4 empty cells. Small.
11.	*Polemonium acutiflorum* (Poac) (tan)	5	3/23. 1-3/cell w/6 empty cells. Small.
12.	Henderson Ridge rf (gray)	4	3/23. 2-5/cell.
13.	*Artemisia tilesii* (Arti) (pink)	5	3/24. 1-4/cell. Small.
14.	'Tundra' bg (blue)	4	3/24. All up, 3-5/cell.
15.	'Service' bg (ylw)	4	3/24. 1-4/cell.
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	3/24. No emergence.
17.	'Alyeska' pg (red)	5	3/24. 2-4/cell. Still small.
18.	'Kenai' pg (green)	4	3/24. 3-5/cell.
19.	'Norcoast' hg (tan)	4	3/24. Recently emerged. 1-4/cell.
20.	'Nortran' hg (gray)	4	3/24. Recently emerged. 1-4/cell.
21.	'Sourdough' (blue)	5	3/28. Still small. 3-6/cell.
22.	'Arctared' rf (white)	5	3/28. 2-5/cell. Small.
23.	'Gruening' bg (pink)	5	3/28. 3-5/cell. Small.
24.	*Festuca altaica* (Feal) (ylw)	5	3/28. 2-5/cell. Small.
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	3/29. No emergence.

Red Dog Mine Soils – Growth Trial Worksheet Date: 4/28/06 Soil: K

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	5	
2.	*Trisetum spicatum* (blue)	5	
3.	*Poa glauca* (tan)	5	
4.	*Elymus macrourus* (pink)	3	
5.	Teller alpine bg (ylw)	3	
6.	Twenty-Mile yarrow (orange)	3	
7.	Wainwright wg (white)	6	
8.	Lowell Point *Hordeum brachy.*…(red)	3	
9.	*Solidago decumbens* (Sode) (purple)	5	
10.	*Solidago multiradiata* (Somu) (green)	5	
11.	*Polemonium acutiflorum* (Poac) (tan)	5	
12.	Henderson Ridge rf (gray)	5	
13.	*Artemisia tilesii* (Arti) (pink)	6	
14.	'Tundra' bg (blue)	3	
15.	'Service' bg (ylw)	3	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	7	
18.	'Kenai' pg (green)	5	
19.	'Norcoast' hg (tan)	5	
20.	'Nortran' hg (gray)	3	
21.	'Sourdough' (blue)	7	
22.	'Arctared' rf (white)	3	
23.	'Gruening' bg (pink)	5	
24.	*Festuca altaica* (Feal) (ylw)	3	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 4/28/06 Soil: O

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	3	Some leaf-tip browning
2.	*Trisetum spicatum* (blue)	3	
3.	*Poa glauca* (tan)	3	
4.	*Elymus macrourus* (pink)	3	
5.	Teller alpine bg (ylw)	1	
6.	Twenty-Mile yarrow (orange)	3	
7.	Wainwright wg (white)	3	
8.	Lowell Point *Hordeum brachy…*(red)	1	
9.	*Solidago decumbens* (Sode) (purple)	5	
10.	*Solidago multiradiata* (Somu) (green)	5	
11.	*Polemonium acutiflorum* (Poac) (tan)	3	
12.	Henderson Ridge rf (gray)	1	
13.	*Artemisia tilesii* (Arti) (pink)	3	
14.	'Tundra' bg (blue)	1	
15.	'Service' bg (ylw)	3	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	3	
18.	'Kenai' pg (green)	1	
19.	'Norcoast' hg (tan)	3	
20.	'Nortran' hg (gray)	1	
21.	'Sourdough' (blue)	3	
22.	'Arctared' rf (white)	1	
23.	'Gruening' bg (pink)	3	
24.	*Festuca altaica* (Feal) (ylw)	1	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 4/28/06 Soil: S

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	3	
2.	*Trisetum spicatum* (blue)	3	
3.	*Poa glauca* (tan)	3	
4.	*Elymus macrourus* (pink)	3	
5.	Teller alpine bg (ylw)	3	
6.	Twenty-Mile yarrow (orange)	3	
7.	Wainwright wg (white)	3	
8.	Lowell Point *Hordeum brachy.*…(red)	1	
9.	*Solidago decumbens* (Sode) (purple)	5	
10.	*Solidago multiradiata* (Somu) (green)	5	
11.	*Polemonium acutiflorum* (Poac) (tan)	5	
12.	Henderson Ridge rf (gray)	3	
13.	*Artemisia tilesii* (Arti) (pink)	3	
14.	'Tundra' bg (blue)	3	
15.	'Service' bg (ylw)	3	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	3	
18.	'Kenai' pg (green)	1	
19.	'Norcoast' hg (tan)	3	
20.	'Nortran' hg (gray)	1	
21.	'Sourdough' (blue)	3	
22.	'Arctared' rf (white)	3	
23.	'Gruening' bg (pink)	3	
24.	*Festuca altaica* (Feal) (ylw)	1	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 6/6/06 Soil: K

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	6	Some drying, recovering
2.	*Trisetum spicatum* (blue)	6	
3.	*Poa glauca* (tan)	6	
4.	*Elymus macrourus* (pink)	5	
5.	Teller alpine bg (ylw)	5	
6.	Twenty-Mile yarrow (orange)	5	
7.	Wainwright wg (white)	6	
8.	Lowell Point *Hordeum brachy…*(red)	6	
9.	*Solidago decumbens* (Sode) (purple)	6	Small plants, little growth
10.	*Solidago multiradiata* (Somu) (green)	5	
11.	*Polemonium acutiflorum* (Poac) (tan)	5	
12.	Henderson Ridge rf (gray)	4	
13.	*Artemisia tilesii* (Arti) (pink)	4	
14.	'Tundra' bg (blue)	4	
15.	'Service' bg (ylw)	4	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	4	
18.	'Kenai' pg (green)	3	
19.	'Norcoast' hg (tan)	4	
20.	'Nortran' hg (gray)	4	
21.	'Sourdough' (blue)	6	
22.	'Arctared' rf (white)	5	
23.	'Gruening' bg (pink)	5	
24.	*Festuca altaica* (Feal) (ylw)	4	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 6/6/06 Soil: O

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	n/a	Dried up; sprinkler malfunction
2.	*Trisetum spicatum* (blue)	n/a	Same as above. May recover.
3.	*Poa glauca* (tan)	5	
4.	*Elymus macrourus* (pink)	3	
5.	Teller alpine bg (ylw)	6	Same as above. May recover.
6.	Twenty-Mile yarrow (orange)	6	Same as above. Recovering.
7.	Wainwright wg (white)	7	One dead, one recovering.
8.	Lowell Point *Hordeum brachy.…*(red)	7	Same drying problem, may recover.
9.	*Solidago decumbens* (Sode) (purple)	n/a	Dead
10.	*Solidago multiradiata* (Somu) (green)	7	One dead, one may recover
11.	*Polemonium acutiflorum* (Poac) (tan)	n/a	Dead
12.	Henderson Ridge rf (gray)	6	Same drying problem, may recover.
13.	*Artemisia tilesii* (Arti) (pink)	5	Some drying, recovering.
14.	'Tundra' bg (blue)	5	
15.	'Service' bg (ylw)	5	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	4	
18.	'Kenai' pg (green)	4	
19.	'Norcoast' hg (tan)	6	Some drying, recovering.
20.	'Nortran' hg (gray)	3	
21.	'Sourdough' (blue)	5	Some drying, recovering.
22.	'Arctared' rf (white)	5	Some drying, recovering.
23.	'Gruening' bg (pink)	5	
24.	*Festuca altaica* (Feal) (ylw)	3/6	One ok, other dried & recovering.
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 6/6/06 Soil: S

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	5	This tray had sufficient water
2.	*Trisetum spicatum* (blue)	4	
3.	*Poa glauca* (tan)	4	
4.	*Elymus macrourus* (pink)	4	
5.	Teller alpine bg (ylw)	5	
6.	Twenty-Mile yarrow (orange)	5/7	One ok, other desiccated but recover
7.	Wainwright wg (white)	5	Some purple color in leaves
8.	Lowell Point *Hordeum brachy.*…(red)	5	Some purple color in leaves
9.	*Solidago decumbens* (Sode) (purple)	4	
10.	*Solidago multiradiata* (Somu) (green)	4	
11.	*Polemonium acutiflorum* (Poac) (tan)	5	
12.	Henderson Ridge rf (gray)	4	
13.	*Artemisia tilesii* (Arti) (pink)	3	
14.	'Tundra' bg (blue)	4	
15.	'Service' bg (ylw)	5	
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	4/5	One ok, other desiccated but recover
18.	'Kenai' pg (green)	2	
19.	'Norcoast' hg (tan)	4	
20.	'Nortran' hg (gray)	5	
21.	'Sourdough' (blue)	4	
22.	'Arctared' rf (white)	4	
23.	'Gruening' bg (pink)	5	
24.	*Festuca altaica* (Feal) (ylw)	4	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 7/12/06 Soil: K

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	5	Still recovering from drying
2.	*Trisetum spicatum* (blue)	5	
3.	*Poa glauca* (tan)	4	
4.	*Elymus macrourus* (pink)	5	Some powdery mildew
5.	Teller alpine bg (ylw)	3	Slow growing
6.	Twenty-Mile yarrow (orange)	5	
7.	Wainwright wg (white)	6	
8.	Lowell Point *Hordeum brachy…*(red)	4	
9.	*Solidago decumbens* (Sode) (purple)	7	
10.	*Solidago multiradiata* (Somu) (green)	5	
11.	*Polemonium acutiflorum* (Poac) (tan)	5	
12.	Henderson Ridge rf (gray)	4	Some powdery mildew
13.	*Artemisia tilesii* (Arti) (pink)	5	
14.	'Tundra' bg (blue)	4	
15.	'Service' bg (ylw)	5	Some powdery mildew
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	5	
18.	'Kenai' pg (green)	5	
19.	'Norcoast' hg (tan)	5	Some powdery mildew
20.	'Nortran' hg (gray)	3	
21.	'Sourdough' (blue)	6	
22.	'Arctared' rf (white)	5	
23.	'Gruening' bg (pink)	3	
24.	*Festuca altaica* (Feal) (ylw)	4	
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 7/12/06 Soil: O

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	n/a	Dried up, no recovery
2.	*Trisetum spicatum* (blue)	6	
3.	*Poa glauca* (tan)	3	
4.	*Elymus macrourus* (pink)	2	Some powdery mildew on leaves
5.	Teller alpine bg (ylw)	2	
6.	Twenty-Mile yarrow (orange)	5	
7.	Wainwright wg (white)	5	
8.	Lowell Point *Hordeum brachy.*…(red)	5	
9.	*Solidago decumbens* (Sode) (purple)	n/a	Dried up, no recovery
10.	*Solidago multiradiata* (Somu) (green)	6	One barely recovering from drying
11.	*Polemonium acutiflorum* (Poac) (tan)	n/a	Dried up, no recovery
12.	Henderson Ridge rf (gray)	5	Some powdery mildew
13.	*Artemisia tilesii* (Arti) (pink)	3	
14.	'Tundra' bg (blue)	2	
15.	'Service' bg (ylw)	4	Some powdery mildew
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	1	Trace of powdery mildew
18.	'Kenai' pg (green)	1	Trace of powdery mildew
19.	'Norcoast' hg (tan)	4	
20.	'Nortran' hg (gray)	3	
21.	'Sourdough' (blue)	3	
22.	'Arctared' rf (white)	5	Some powdery mildew
23.	'Gruening' bg (pink)	2	
24.	*Festuca altaica* (Feal) (ylw)	3	Some powdery mildew
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Red Dog Mine Soils – Growth Trial Worksheet Date: 7/12/06 Soil: S

Vigor: 1=excellent 2=very good 3=good 4=fair-good 5=fair 6=poor-fair 7=poor

	Species (tag color)	Vigor	Notes
1.	*Tripleurospermum maritima* (green)	4	
2.	*Trisetum spicatum* (blue)	2	
3.	*Poa glauca* (tan)	2	
4.	*Elymus macrourus* (pink)	3	
5.	Teller alpine bg (ylw)	1	
6.	Twenty-Mile yarrow (orange)	4	
7.	Wainwright wg (white)	5	
8.	Lowell Point *Hordeum brachy.*…(red)	3	
9.	*Solidago decumbens* (Sode) (purple)	3	
10.	*Solidago multiradiata* (Somu) (green)	1	
11.	*Polemonium acutiflorum* (Poac) (tan)	1	
12.	Henderson Ridge rf (gray)	2	
13.	*Artemisia tilesii* (Arti) (pink)	2	
14.	'Tundra' bg (blue)	2	
15.	'Service' bg (ylw)	2	Some powdery mildew on leaves
16.	*Anemone narcissiflora* (Anna) (purple)	n/a	No germination
17.	'Alyeska' pg (red)	2	
18.	'Kenai' pg (green)	4	
19.	'Norcoast' hg (tan)	2	Some powdery mildew on leaves
20.	'Nortran' hg (gray)	1	
21.	'Sourdough' (blue)	4	Some powdery mildew on leaves
22.	'Arctared' rf (white)	3	Some powdery mildew on leaves
23.	'Gruening' bg (pink)	1	
24.	*Festuca altaica* (Feal) (ylw)	5	Some powdery mildew on leaves
25.	*Eriophorum angustifolium* (only 3 cells)	n/a	No germination

Appendix 2: Soil Analysis Data

Report Number:
R06087-0196
Acount Number:
56002

A&L Eastern Labortories, Inc.

7621 Whitepine Road Richmond, Virginia 23237 (804) 743-9401
Fax No. (804) 271-6446 Email: office@al-labs-eastern.com

TO: PALMER SOIL & WATER CONSERVATION DISTRICT
259 S ALASKA ST
PALMER, AK 99645

RE: RED DOG SOIL

CURTIS DUNKIN

Date Received: 3/27/06 Date Reported: 03/30/2006

REPORT OF ANALYSIS

LAB NO.	SAMPLE ID	ANALYSIS	RESULT	UNIT	METHOD
10282	K	Total Kjeldahl Nitrogen	2410	mg/kg	MSA Part 2 (1982) pp 599-6
		Ammonia-N	1.30	mg/kg	EPA 350.1
		Lead	1020	mg/kg	SW 846-6010B
		Molybdenum	7	mg/kg	SW 846-6010B
		Silver	< 5	mg/kg	SW 846-6010B
		Organic Nitrogen	2410	mg/kg	
10283	S	Total Kjeldahl Nitrogen	1970	mg/kg	MSA Part 2 (1982) pp 599-6
		Ammonia-N	2.20	mg/kg	EPA 350.1
		Lead	99	mg/kg	SW 846-6010B
		Molybdenum	17	mg/kg	SW 846-6010B
		Silver	8	mg/kg	SW 846-6010B
		Organic Nitrogen	1970	mg/kg	
		Sand	17	%	Bouyoucos 1962
		Silt	37	%	Bouyoucos 1962
		Clay	46	%	Bouyoucos 1962
		Soil Textural Class	Clay		Bouyoucus 1962
10284	O	Total Kjeldahl Nitrogen	2060	mg/kg	MSA Part 2 (1982) pp 599-6
		Ammonia-N	4.30	mg/kg	EPA 350.1
		Lead	245	mg/kg	SW 846-6010B
		Molybdenum	8	mg/kg	SW 846-6010B
		Silver	6	mg/kg	SW 846-6010B
		Organic Nitrogen	2060	mg/kg	

ALE-MISC

Paul Chu, Ph.D.

Report Number:
R06087-0196

Account Number:
56002

A&L Eastern Laboratories, Inc.

7621 Whitepine Road Richmond, Virginia 23237 (804) 743-9401
Fax No (804) 271-6446 Email: office@al-labs-eastern.com

Send To: PALMER SOIL & WATER CONSERVATION DISTRICT
259 S ALASKA ST
PALMER, AK 99645

Grower: RED DOG SOIL

Submitted By: CURTIS DUNKIN

Farm I D:

Field I D:

SOIL ANALYSIS REPORT

Page: 1 **Date Received:** 3/27/2006 **Date of Analysis:** 3/28/2006 **Date of Report:** 3/30/2006

Analytical Method(s):
Mehlich III

Sample Number	Lab Number	Organic Matter			Phosphorus				Potassium		Magnesium		Calcium		Sodium		pH		Acidity	C.E.C.
		%	ENR lbs/A	Rate	Available ppm	Rate	Reserve ppm	Rate	K ppm	Rate	MG ppm	Rate	CA ppm	Rate	NA ppm	Rate	Soil pH	Buffer Index	H meq/100g	meq/100g
K	10282	1.5	11	L	31	M			57	VL	350	VL	9100	VH			7.1			48.6
S	10283	1.7	75	L	15	L			46	VL	70	L	360	L			4.5	6.6	3.5	6.0
O	10284	2.5	80	L	14	L			46	VL	275	H	1140	L			5.0	6.4	5.6	13.7

Sample Number	Percent Base Saturation					Nitrate		Sulfur		Zinc		Manganese		Iron		Copper		Boron		Soluble Salts		Chloride		Aluminum	
	K %	Mg %	Ca %	Na %	H %	NO3-N ppm	Rate	SO4-S ppm	Rate	ZN ppm	Rate	MN ppm	Rate	FE ppm	Rate	CU ppm	Rate	B ppm	Rate	ms/cm	Rate	CL ppm	Rate	AL ppm	Rate
K	0.3	6.0	93.7			5	L	6083	VH	431.3	VH	51	VH	830	VH	16.5	VH	0.6	M						
S	2.0	9.8	30.2		58.0	13	M	95	VH	13.8	VH	36	H	276	VH	10.4	VH	0.4	L						
O	0.9	16.7	41.5		40.9	10	M	31	H	17.0	VH	70	VH	321	VH	13.2	VH	0.4	L						

Values on this report represent the plant available nutrients in the soil.
Rating after each value: VL (Very Low), L (Low), M (Medium), H (High), VH (Very High).
ENR - Estimated Nitrogen Release. C.E.C. - Cation Exchange Capacity.

Explanation of symbols: % (percent), ppm (parts per million), lbs/A (pounds per acre), ms/cm (milli-mhos per centimeter), meq/100g (milli-equivalent per 100 grams).
Conversions: ppm x 2 = lbs/A, Soluble Salts ms/cm x 640 = ppm.

This report applies to the sample(s) tested. Samples are retained a maximum of thirty days after testing. Soil Analysis prepared by A & L EASTERN LABORATORIES, INC.

by: Paul Chu, Ph.D.

Report Number:
R06115-0128
Acount Number:
56002

A&L Eastern Labortories, Inc.

7621 Whitepine Road Richmond, Virginia 23237 (804) 743-9401
Fax No. (804) 271-6446 Email: office@al-labs-eastern.com

TO: PALMER SOIL & WATER CONSERVATION DISTRICT
259 S ALASKA ST
PALMER, AK 99645

RE: PALMER SOIL & WATER CONSURTIS DUNKIN DISTRICT

Date Received: 4/24/06 Date Reported: 04/26/2006

REPORT OF ANALYSIS

LAB NO.	SAMPLE ID	ANALYSIS	RESULT	UNIT	METHOD
18923	0	Sand	46	%	Bouyoucos 1962
		Silt	32	%	Bouyoucos 1962
		Clay	22	%	Bouyoucos 1962
		Soil Textural Class	Loam		Bouyoucus 1962
18924	K	Sand	58	%	Bouyoucos 1962
		Silt	38	%	Bouyoucos 1962
		Clay	4	%	Bouyoucos 1962
		Soil Textural Class	Sandy Loam		Bouyoucus 1962

ALE-MISC

Paul Chu, Ph.D.

Red Dog Soil Lab Tests Total Dissolved Salts March, 2006

Date Tested	Dilution	Sample	pH 20 min	pH 24 hrs	tds 20 min	tds 24 hrs	EC 24 hrs (670)	EC Agronomic Range
3/22-23/06	1:1 Paste	O	5.2	4.95	61 ppm	67 ppm	0.1 dS/m	Very Low
3/22-23/06	1:1 Paste	S	4.6	4.47	57 ppm	73 ppm	0.11 dS/m	Very Low
3/22-23/06	1:1 Paste	K	7.28	7.1	1880 ppm	2000 ppm	2.99 dS/m	Very High

Plant Mat. C: Submitted by Don R.
Tested by PSWCD CSD

Appendix 3: Photographs 7/12/06

See Table 4 and Figures 1 and 2 for Photo Interpretation

Table 4 – Photo Identification of Species with Tag Color

Sp.#	Name (Abbreviation)	Tag Color
1……	*Tripleurospermum maritima* ‘Kotzebue’	green
2……	*Trisetum spicatum* ‘Nelchina’	blue
3……	*Poa glauca* ‘Nome’	tan
4……	*Elymus macrourus* ‘Solomon’	pink
5……	‘Teller’ alpine bluegrass	yellow
6……....	‘Twenty-Mile’ boreal yarrow	orange
7……....	‘Wainwright’ slender wheatgrass	white
8……....	*Hordeum brachyantherum* ‘Lowell Point’	red
9……..	*Solidago decumbens* (Sode)	purple
10……	*Solidago multiradiata* (Somu)	green
11……	*Polemonium acutiflorum* (Poac)	tan
12……	‘Henderson Ridge’ red fescue	gray
13……	*Artemisia tilesii* (Arti)	pink
14……	‘Tundra’ glaucous bluegrass	blue
15……	‘Service’ big bluegrass	yellow
16……	*Anemone narcissiflora* (Anna)	purple
17……	‘Alyeska’ polargrass	red
18……	‘Kenai’ polargrass	green
19……	‘Norcoast’ Bering hairgrass	tan
20……	‘Nortran’ tufted hairgrass	gray
21……	‘Sourdough’ bluejoint	blue
22……	‘Arctared’ red fescue	white
23……	‘Gruening’ alpine bluegrass	pink
24……	*Festuca altaica* (Feal)	yellow
25……	*Eriophorum angustifolium*	(3 cells, separate small tray)

Tripleurospermum maritima (green tag)	*Tripleurospermum maritima*	*Trisetum spicatum* (lt. blue tag)
Poa glauca (tan tag)	*Poa glauca*	*Trisetum spicatum*
'Teller' alpine bluegrass (yellow tag)	*Elymus macrourus* (pink tag)	*Elymus macrourus*
'Teller' alpine bluegrass	[Empty]	[Empty]

Fig.1: Key to species in photos taken 7/12/06 – on the left side of each soil grouping. Top row is in the background. Bottom row = foreground. The four pots on the extreme right of the photo are not included.

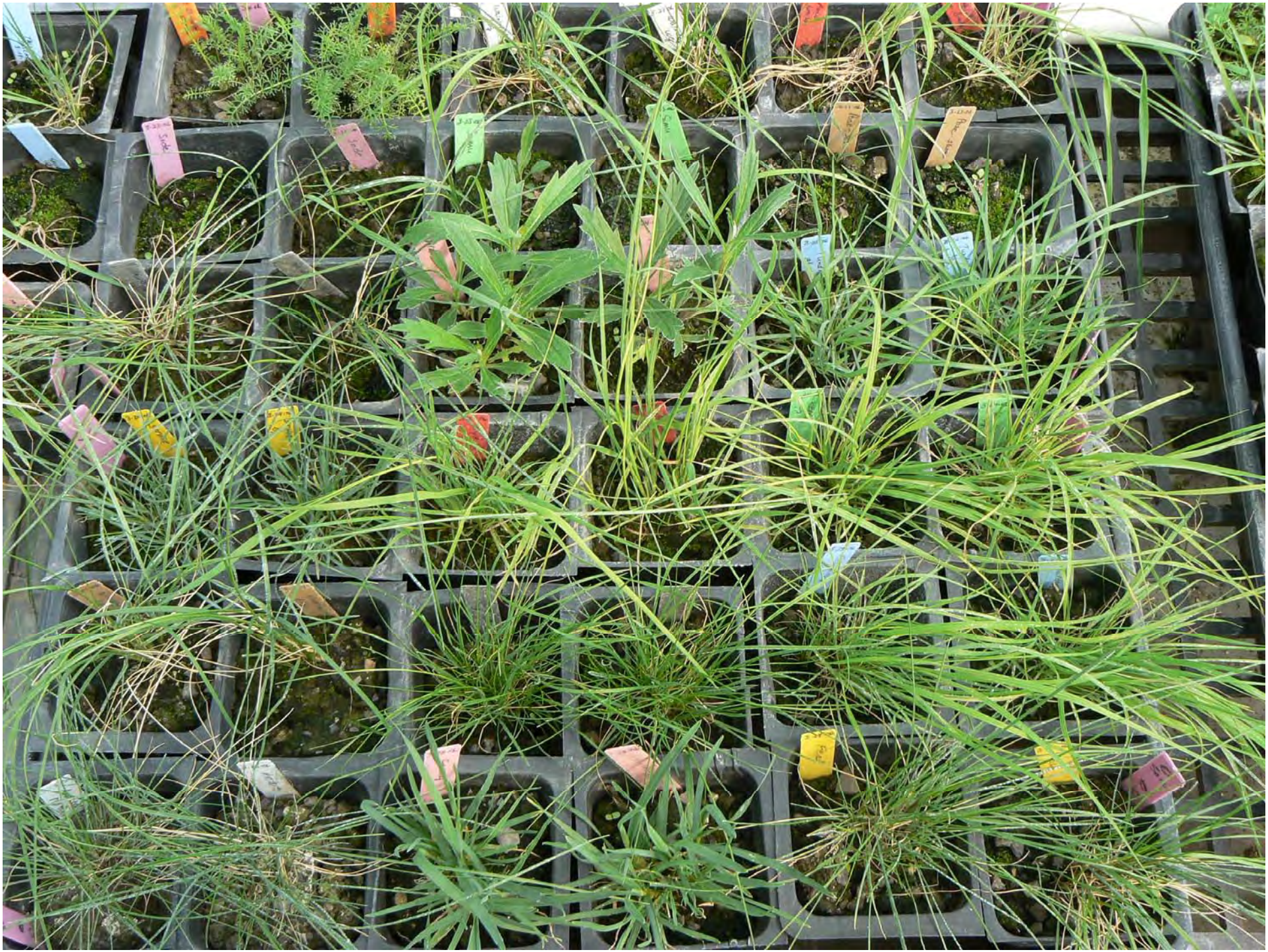
20-Mile yarrow (orange tag)	20-Mile yarrow	Wainwright wheatgrass (white tag)	Wainwright wheatgrass	Lowell Point meadow barley (red tag)	Lowell Point meadow barley
Solidago decumbens (purple tag)	*Solidago decumbens*	*Solidago multiradiata* (green tag)	*Solidago multiradiata*	*Polemonium acutiflorum* (tan tag)	*Polemonium acutiflorum*
Henderson Ridge red fescue (gray tag)	Henderson Ridge red fescue	*Artemisia tilesii* (pink tag)	*Artemisia tilesii*	Tundra big bluegrass (blue tag)	Tundra big bluegrass
Service big bluegrass (yellow tag)	Service big bluegrass	Alyeska polargrass (red tag)	Alyeska polargrass	Kenai polargrass (green tag)	Kenai polargrass
Norcoast Bering hairgrass (tan tag)	Norcoast Bering hairgrass	Nortran tufted hairgrass (gray tag)	Nortran tufted hairgrass	Sourdough bluejoint (blue tag)	Sourdough bluejoint
Arctared red fescue (white tag)	Arctared red fescue	Gruening alpine bluegrass (pink tag)	Gruening alpine bluegrass	*Festuca altaica* (yellow tag)	*Festuca altaica*

Fig 2: Key to species in photos taken 7/12/06 – on the right side of each soil grouping. Top row is in the background; bottom row = foreground.

Photograph: Soil K - left side

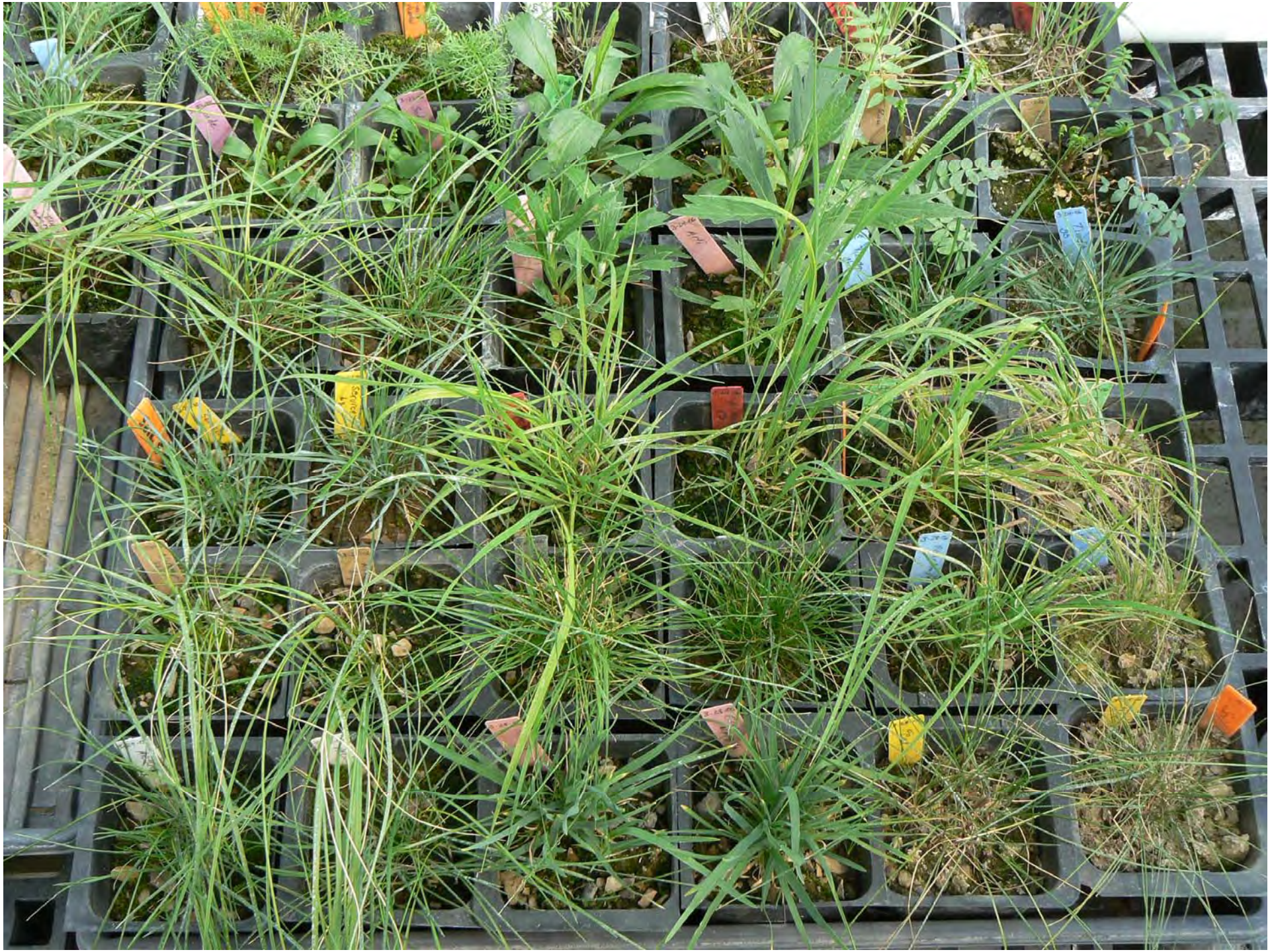
Photograph: Soil K - right side

Photograph: Soil O - left side



Photograph: Soil O - right side

Photograph: Soil S - left side



Photograph: Soil S - right side