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TEMPORARY STABILIZATION SPECIFICATION IMPROVEMENTS

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A report of the findings of
ICT-R27-126
Temporary Stabilization Specification Improvements

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16. Abstract

Seed variety performance data for establishing temporary vegetative cover was collected at four Illinois locations at four planting seasons. Current Illinois Department of Transportation (IDOT) standard specifications call for a mixture of perennial rye and spring oats for temporary vegetative cover, with no variation for time of year or site conditions. That mixture has demonstrated some success; however, for every location and time of year, this study identified at least one seed variety that demonstrated performance superior to the specified mix. Temporary seeding specifications currently employed by nearby states were reviewed and compared with Illinois' specifications. In addition to seed variety, the effectiveness of seed bed preparation using a power rake and the effectiveness of straw-mat and loose wheat-straw mulching methods were investigated.

Based on the observed results, the research team has proposed modifying temporary seeding recommendations to reflect seeding date and site location. Adoption of these research-based temporary seeding specifications will likely result in improved temporary vegetative cover establishment, reduced erosion, and improved water quality.

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DISCLAIMER

EXECUTIVE SUMMARY

The objective of this project was to improve the performance of temporary seeding operations conducted during construction activities in Illinois. Empirical data on the performance of promising seed varieties for temporary vegetative cover establishment at different Illinois locations and times of year were collected. The research team has proposed modified temporary seeding recommendations that reflect seeding date and site location. Adoption of these research-based temporary seeding specifications will likely result in improved temporary vegetative cover establishment, reduced erosion, and improved water quality.

Temporary seeding specifications currently employed by nearby states were reviewed and compared to Illinois' specifications. Test plots of promising seed varieties were sown throughout the year on geographically representative sites with simulated construction site conditions. In addition to seed variety, the effectiveness of seed bed preparation using a power rake, and the effectiveness of straw-mat and loose wheat-straw mulching methods were investigated. Test plots were monitored for germination, growth, and percentage cover.

The nature of transportation construction work dictates that temporary turf-establishment efforts often encounter difficult seeding conditions because of time of year and soil conditions. Current Illinois Department of Transportation (IDOT) standard specifications list a mixture of perennial rye and spring oats for temporary vegetative cover, with no variation for time of year or site conditions. This mixture has demonstrated some success; however, for every location and time of year, this study identified at least one seed variety that demonstrated performance superior to the currently specified mix.

Our general recommendation for improving the current standard specifications includes specifying of season- and location-specific seed varieties, skipping the use of a power rake for seed bed preparation, and using loose wheat-straw mulch anchored by a specialized straw disk or roller.

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ABBREVIATIONS

ANOVA	Analysis of variance
BMP	Best management practice
CRP	Conservation Reserve Program
DSLR	Digital single-lens reflex
ICT	Illinois Center for Transportation
IDOT	Illinois Department of Transportation
IEPA	Illinois Environmental Protection Agency
MoDNR	Missouri Department of Natural Resources
MoHTC	Missouri Highways and Transportation Commission
NPDES	National Pollutant Discharge Elimination System
SIUE	Southern Illinois University Edwardsville
SWPPP	Storm Water Pollution Prevention Plan
TRP	Technical Review Panel

CHAPTER 1 INTRODUCTION

Storm water discharges associated with construction activities in Illinois are regulated by the provisions of the Clean Water Act, as detailed by the Illinois Environmental Protection Agency's (IEPA) National Pollutant Discharge Elimination System (NPDES) General Permit No. ILR-10, effective 1 August 2013 through 31 July 2018. Part IV, D. 2. B., of the General Permit provides guidance on required stabilization practices, including stabilization of disturbed areas where construction activities have temporarily ceased. Stabilization efforts are required to start within one working day of the cessation of earth-disturbing activity if earth-disturbing activities are not anticipated to resume within 14 days. Stabilization practices may include seeding, mulching, geotextiles, and sodding. In many cases, storm water pollution prevention plans (SWPPPs) specify the use of temporary seeding as the primary stabilization method to be applied where construction has temporarily ceased.

IDOT's *Standard Specifications for Road and Bridge Construction* (IDOT 2012) provides contractually binding details for methods and materials to be employed for IDOT-funded projects. Although these standards were developed by and for IDOT, they are also nearly universally incorporated into the contractual specifications of private construction projects in Illinois. As a result, the vast majority of construction related temporary seeding activities in Illinois are implemented as specified by IDOT.

Table 1 of Section 250.07 of the IDOT road and bridge manual lists seed varieties to be used for a variety of applications. The temporary turf specification states that a mixture of perennial ryegrass (*Lolium perenne*)[1] and spring oats (*Avena sativa*) should be applied at a rate of 50 and 64 pounds, respectively, per acre. The table referred to notes that alternate seed varieties may be used with the approval of the engineer. This study was undertaken to determine if other seed varieties provide superior temporary cover and to provide the engineer with guidance for appropriately selecting seed varieties.

Time of year and geographic location are primary variables often considered by agronomists when selecting appropriate seed varieties. Construction projects may start, finish, and temporarily cease land-disturbing activities at any time of year. To address the possibility that temporary seeding specifications should be adjusted for time of year, this study undertook test plantings covering four seasons: late fall, dead of winter, early spring, and midsummer. Illinois extends over 5.5 degrees of latitude, a distance of 380 miles north to south. This geographic extent produces a significant range of frost dates, average temperatures, precipitation, growing degree days, and daylight length across Illinois, affecting the performance of seed varieties. To evaluate seed variety performance related to location within Illinois, this study undertook test plantings at four geographically representative sites, ranging from extreme southern Illinois to within 44 miles of the Wisconsin border.

Tillage and mulching techniques may affect the success of temporary seeding efforts. This study compared the performance of rough-tilled soils, simulating the condition of disturbed soils, where the only tillage preparation consists of back dragging with a dozer blade, and the performance on finely tilled soils prepared with the use of a power rake normally used for tilling soil prior to final seeding or sodding operations. The common mulching techniques—surface-applied wheat-straw mulch and stapled straw mats—were evaluated as part of this study.

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[1] Common name and scientific name associations will be shown when a variety is first mentioned in this report. Subsequent reference to that variety will be by common name only.

This project provides data on the performance of alternative seed mixes, seed bed preparation methods, and mulching methods that may improve compliance with the Clean Water Act and the provisions of the NPDES General Permit. Adoption of improved temporary seeding specifications identified by this study could result in improved temporary vegetative cover establishment, reduced erosion, and improved water quality.

CHAPTER 2 REGIONAL TEMPORARY SEEDING PRACTICES

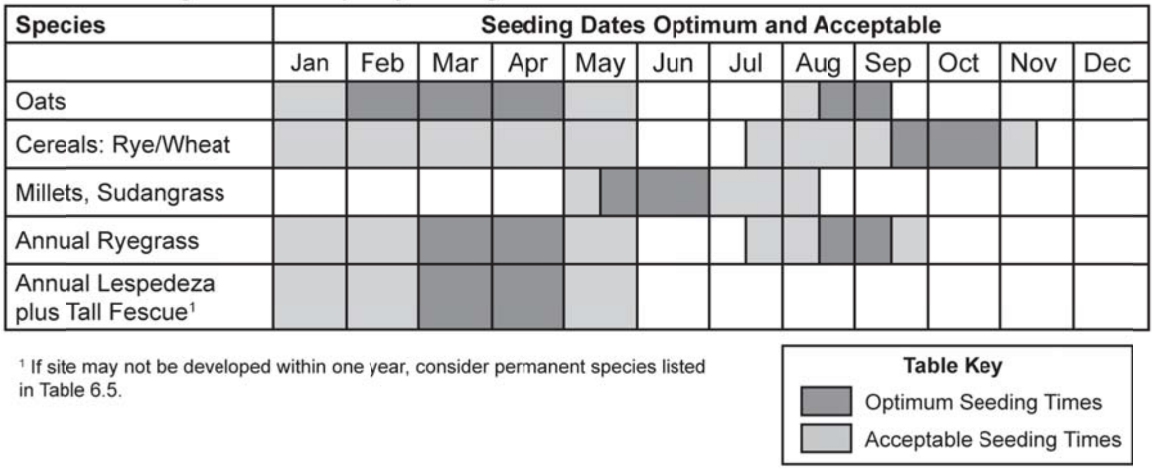
Illinois is bordered on the north by Wisconsin, on the west by Iowa and Missouri, and on the south and east by Kentucky and Indiana. We investigated the temporary seeding specifications of these surrounding states to compare their approaches with Illinois' temporary seeding specification and to identify promising seed varieties for field testing.

Wisconsin's standard specifications include nine different permanent seed mixtures, to be selected primarily based on soil type (*Standard Specification*, Section 630, Seeding; Wisconsin DOT 2014). Additional permanent seed mixtures are specified for wet conditions, steep slopes, areas subjected to heavy road salt, native plant reestablishment, and urban turf areas. For temporary seeding, Wisconsin's standards specify oats for seeding dates ranging from last frost until 1 September. Temporary seeding operations occurring after 1 September may use either winter wheat (*Triticum aestivum*) or cereal rye (*Secale cereale)*. One of these three cereal type varieties should make up 60% of the temporary seed mixture; the remaining 40% of the temporary seed mixture should be the permanent seed mix appropriate for the soil type. Winter wheat, cereal rye, and oats were all tested during the field trial portion of this study.

Iowa's *Standard Specifications for Highway Construction*, Section 2601 (Iowa DOT 2012) provides gudiance for tempoary seeding, based on time of year and whether the site is in a rural or urban setting. The Iowa guidelines allow the elimination of tillage operations for temporary seeding operations, particularly on difficult to access areas and stockpiles. The seed mixture specified for temporary seeding in urban settings includes Kentucky bluegrass (*Poa pratensis*), perrenial ryegrass, and creeping red fescue (*Festuca rubra*) at a rate of 122, 35, and 18 pounds per acre, respectively. No deviation is provided for time of year for temporary seeding in urban settings. The seed mixture specified for rural temporary seeding operations is composed of a mixture of oats and Canadian wildrye (*Elymus canadensis*), to be applied at a rate of 50 and 5 pounds per acre, respectively, from 1 March through 31 October. For rural temporary seeding operations conducted from 1 November through 28 February, the seeding rate should be increased to 62 pounds per acre for oats and 7 pounds per acre for Canadian wildrye. Canadian wildrye and creeping red fescue (as a component of a fescue turf mix) were evaluated during the field trial portion of this study.

Standard specifications from the Missouri Highways and Transportation Commission (MoHTC) direct seed specifiers to currently applicable Missouri Department of Natural Resources's (MoDNR) guidelines for selecting seed varities (MoHTC Standard Specifications, Section 805). MoDNR suggests that the project engineer follow guidelines provided in their publication *Protecting Water Quality: A Field Guide to Erosion, Sediment, and Storm Water Best Management Practices for Development Sites in Missouri*. Depending on the time of year, this document recommends the following varieties: oats, winter wheat and cereal rye, millet or sudangrass (*Sorghum* spp.), annual ryegrass (*Lolium multiflorum*), or a mix of annual lespedezaplus (*Kummerowia stipulacea*) and tall fescue (*Festuca arundinacea*). Table 6.4 of that document, shown below, provides optimum and acceptable seeding dates for each variety. The field trial portion of this study included Sudex, a commercially available sudangrass hybrid, annual rye grass, and Kentucky 31, a common, commercially availble variant of tall fescue.

Table 6.4 Seeding Dates for Temporary Seeding



Species	Seeding Dates Optimum and Acceptable											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oats												
Cereals: Rye/Wheat												
Millets, Sudangrass												
Annual Ryegrass												
Annual Lespedeza plus Tall Fescue[1]												

[1] If site may not be developed within one year, consider permanent species listed in Table 6.5.

Kentucky supplements its standard specifications with a manual titled *Technical Specifications for BMPs.* Section 4.4 of that document, “Soil Stabilization” provides details for temporary seeding operations. For seeding operations occurring from 1 November through 28 February, a mixture of winter wheat, annual rye, tall fescue, and perennial rye at a rate of 120, 120, 120, and 40 pounds, respectively, per acre is specified. For seeding operations occurring during the period 1 March through 31 October, the same mixture and rates are called for; and an additional 120 pounds per acre of oats are specified. All of the varieties specified by the Kentucky standards were evaluated during the field trial portion of this study.

Indiana’s standard specifictions, *Indiana Standard Specifications, 2012,* details a spring mix and a fall mix. The spring mix consists of oats at a rate of 150 pounds per acre, to be used for operations performed between 1 January and 15 June. The fall mix is comprised of winter wheat applied at a rate of 150 pounds per acre, to be used for seeding dates ranging from 1 September through 31 December. Mulch alone should be applied for temporary stabilization occurring from 16 June through 31 August. Both oats and winter wheat were evaluated during the field trial portion of our study.

Unlike Illinois, every surrounding state makes at least some adjustment to temporary seeding specifications because of time of year. These adjustments range from Iowa’s simple adjustment of seeding rate and Indiana’s switch from oats to winter wheat to Missouri’s comparitively complex, five-variety/12-month matrix. Although no bordering state makes any adjustment for geographic location within the state, Wisconsin’s specifications do take into consideration the soil type and topographical attributes of the site. When bordering state specifications mention mulch in relation to temporary seeding, they refer to wheat straw and universally require that the straw be anchored by mechanical punching with disks or rollers designed for that purpose. No surrounding state specifies straw blankets or other more elaborate mulch systems for temporary seeding operations. Seed bed preparation specifications for temporary seeding operations were generally found to be less stringent than those for permanent seeding; and in many cases, Iowa for example, special tillage could be eliminated entirely, provided that the soil is not compacted or crusted over. As a result of our review of specifications in nearby states, we are confident that we have identified seed varieties that deserve comparative field testing in Illinois. We are further encouraged that considerations given to seeding dates by nearby states justified the multiple-season testing provided by our study. Surrounding state temporary seeding recommendations are summarized in Table 1.

Table 1. Current Temporary Seeding Specifications for Illinois and Surrounding States

State	**General directions**	**Seed mix**	**Mulching**	**Source**
Missouri	Seeding and mulching shall be per current MoDNR standards.	Varies as specified by five-mix/12-month matrix	—	*Protecting Water Quality: A Field Guide to Erosion, Sediment, and Storm Water Best Management Practices for Development Sites in Missouri (MoDNR 2012)*
Iowa	Select rural or urban mix.	Mixture of oats and Canadian wildrye; increase seeding rate for seeding dates between 1 November and 28 February	—	Iowa Department of Transportation (2012)
Indiana	Seed may be drilled or mixed with water.	Seed mix "T" for temporary cover at construction sites 1 January–15 June: Oats at 150 lb./acre 16 June–31 August: Mulch alone 1 September–30 December: Winter wheat at 150 lb./acre	—	*Indiana Standard Specification* (2012)
Kentucky	Follow guidelines of current technical specifications for BMP document.	1 March–31 October: perennial rye, annual rye, tall fescue, wheat. 1 November–28 February: add oats to above mix.	—	Kentucky Department of Transportation*, Technical Specifictions for BMPs* (2014)
Wisconsin	Select temporary mix based on time of year and soil type.	Use oats in spring and summer, winter wheat or rye in fall in combination with soil-appropriate permanent seed mix.	—	Wisconsin Department of Transportation, *Standard Specification* (2014)
Illinois	Type 7 seeding mix should be sown by a hydraulic seeder or grass drill. Hand broadcasting will be allowed.	Perennial ryegrass 50 lb./acre (55 kg/ha) Mixture oats, spring 64 lb./acre (70 kg/ha)	Hand or machine application of straw mulch at the rate of 4.5 metric ton/ha (2 ton/acre). Placing and stabilizing straw at the rate of 4.5 metric ton/ha (2 ton/acre) over seeded areas.	Illinois Department of Transportation, *Standard Specifications for Road and Bridge Construction* (2012)

CHAPTER 3 METHODS

3.1 SITE LOCATIONS

The current specification for temporary vegetative cover establishment provides the same guidelines for the entire state. However, geographic and climatic differences throughout the state could affect the results with the current method. For example, northern Illinois has an annual average temperature of 48°F and an average annual precipitation of 33 inches. Southern Illinois has an annual average temperature of 58°F and an average annual precipitation of 43 inches (Illinois Climate Network 2014). The USDA plant hardiness zone map (Figure 1), a predictor of plant success based on average low temperatures, describes five hardiness zones within Illinois (Agricultural Research Service U.S. Department of Agriculture 2012). It is reasonable to conclude from climate data that plants could perform differently in different regions throughout the state. Variety test plots were established at four sites representing the major regions of Illinois:

1. Dixon Springs research farm, 25 miles south of Harrisburg at latitude 37.5 degrees north, in plant hardiness zone 6b.
2. Orr research farm, between Quincy and Jacksonville at latitude 39.75 degrees north, at the transition from hardiness zones 6a to 5b.
3. Northern Illinois research center, west of Aurora at latitude 41.8 degrees north, in hardiness zone 5b.
4. SIUE campus at latitude 38.75 degrees north, on the border of hardiness zones 6a and 6b.

Sites 1 through 3 represent southern, central, and northern Illinois, while site 4 represents southwestern Illinois, the region with the largest concentration of construction activity in downstate Illinois (IDOT, personal communication, June 2012).

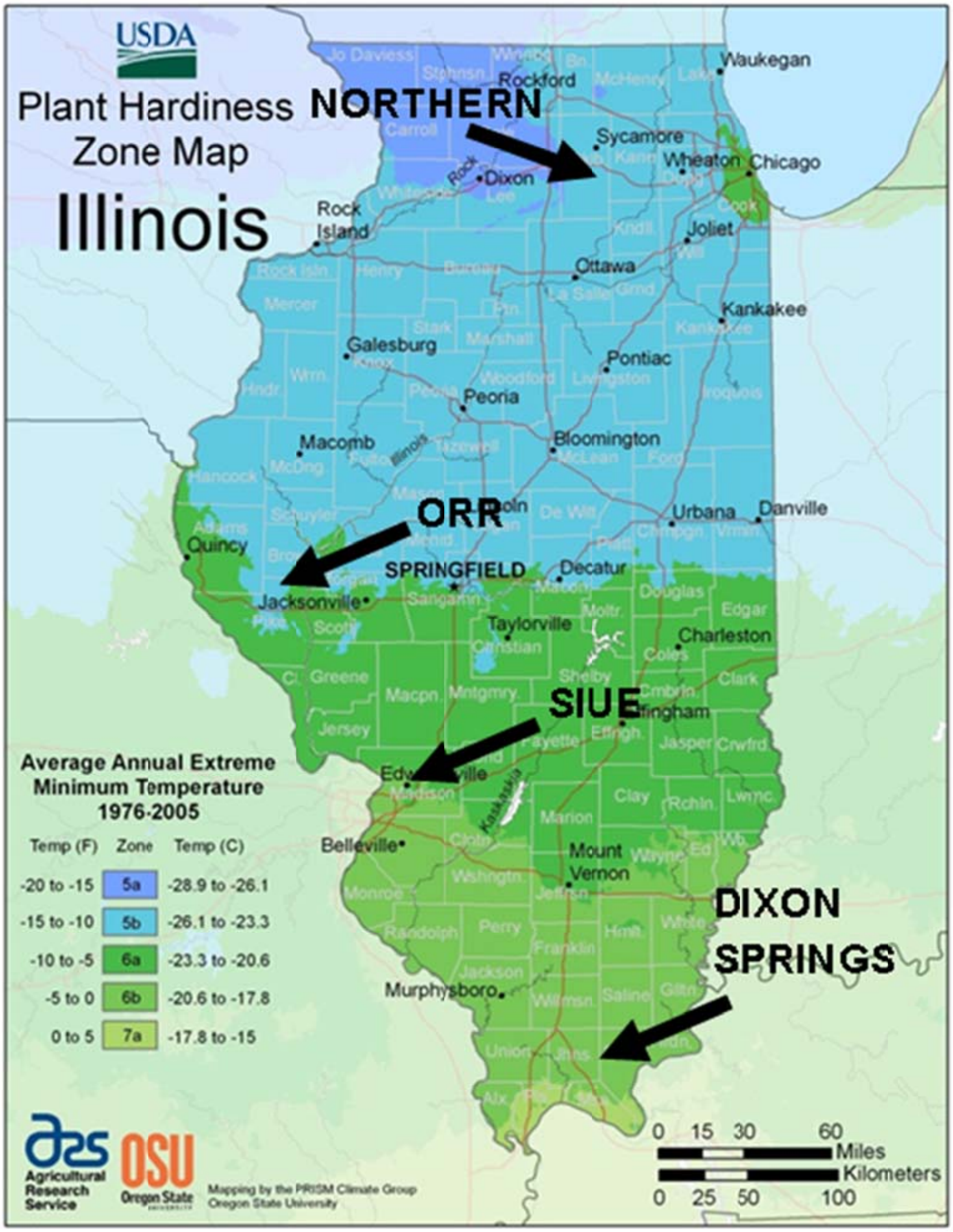


Figure 1. Map of USDA hardiness zones in Illinois (adapted from Agricultural Research Service, U.S. Department of Agriculture 2012). Arrows indicate locations of field sites.

The SIUE site is located on the former site of the operating engineers training and proving grounds approximately 0.25 mile northwest of the SIUE campus core. The operating engineers' proving ground has been used for erosion-control blanket demonstrations and sediment-control basin studies and as a training area for heavy equipment earthwork operations. As a result of these training activities, the site exhibits compaction and low organic matter characteristics that duplicate conditions found on typical heavy civil construction projects (Grinter, M., personal communication, 1 October 2012).

Planting site slopes range from nearly flat at Northern to an estimated average slope of 3% at Orr, SIUE, and Dixon Springs.

3.2 EXPERIMENTAL DESIGN

3.2.1 Treatments

3.2.1.1 Seed Varieties

Seed selections were based on recommendations from DOT standard specifications for the states surrounding Illinois; from the Elsbury, Missouri, NRCS plant materials center plant releases (USDA NRCS 2000, USDA NRCS Northeast Plant Materials Program 2002, Bruckerhoff 2003, Casey 2012); the USDA Plants database (USDA NRCS 2014); and recommendations from previous studies. Some current research suggests that native plants may be a viable option for quickly establishing vegetative cover. For this reason, we included a number of native species to compare to the nonnative plants more commonly used for temporary seeding. In addition to these native plants, we compared seed varieties used by surrounding states for temporary seeding, the current Illinois temporary turf specification, and a number of turf-producing plants and cover crops commonly used in Illinois. To evaluate the seed varieties most likely to be successful in each season, two different seed lists were developed, one for the fall and winter plantings and one for the spring and summer plantings. The seed varieties we selected for testing are listed and justified in Table 2, Part 1. Cost, seeding rate, and plant densities for selected varieties are listed in Table 2, Part 2.

As indicated in the treatment design diagrams (Appendix A), ten seed selections were evaluated per planting. In all but one case, the selections were the same, within a season, across all four sites but varied from season to season to select seeds that were likely to be successful. Because of the delay of the winter planting in the early months of 2013 and seed availability, the SIUE spring planting differed in seed selection from the other sites by including winter wheat, Canada wildrye, and barley in place of sudex, buffalograss, and Bermudagrass.

Seeds were applied to the site with a 6-foot-wide Gerber 72-GDP drop seeder (Figure 2) pulled by a three point hitch equipped tractor (Figure 3). The aperture of the seeder opening was determined by rotating the wheel of the seeder through 40 revolutions, driving the seed agitator and expelling seed from the seed-aperture holes, simulating seeding 1,000 square feet. The weight of the seed expelled from the seed apertures was then measured against the target recommended seeding rate. Adjustments to the aperture were made until the target rate was reached. The appropriate aperture opening was measured in millimeters to replicate the correct opening size for all subsequent seeding of that variety. This process was repeated for all seed varieties.

Table 2, Part 1. Seed Variety Justification and Seasons of Use

Seed Varieties	Justification	Fall/ Winter	Spring/ Summer
95/5 Sports Turf Mix	A six-species fescue and bluegrass mix sold by Belleville Seed. Turf mixes have the potential to provide quick turf, stabilizing soil.	X	X
Annual Rye (*Lolium perenne* L. ssp. *multiflorum*(Lam.) Husnot)	A cool-season grass that is common in the area and recommended by Tennessee, Ohio, and Wisconsin for construction seeding.	X	X
Barley (*Hordeum vulgare* L.)	A cool season–tolerant grass and a common cover crop.	X	
Bermudagrass (*Cynodon dactylon*(L.) Pers.)	A widely naturalized and common turf grass, Bermudagrass has potential to provide quick turf and stability.		X
Buffalograss (*Bouteloua dactyloides*(Nutt.) J.T. Columbus)	Widely recommended as a native turf grass, buffalograss has potential to be a quick and hearty soil stabilizer.		X
Canada Wildrye (*Elymus canadensis* L.)	A native cool-season grass described by the NRCS as a plant with exceptional seedling vigor and rapid establishment, making it ideal for erosion-control seeding.	X	
Cereal Rye (*Secale cereale* L.)	A common cool-season crop; recommended by Missouri, Iowa, and Wisconsin for roadside seeding.	X	X
CRP IL CP2 Mix	A common and cost-effective native seed mix widely available in Illinois, making it more likely to be adopted by contractors than a hard-to-procure custom blend. It contains side oats grama (*Bouteloua curtipendula* (Michx.) Torr.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), partridge pea (*Chamaecrista fasciculate* (Michx.) Greene), purple prairie clover (*Dalea purpurea* Vent.), and round-headed bush clover (*Lespedeza capitata* Michx.).	X	X
Fawn Tall Fescue (*Festuca arundinacea* (Schreb.) Dumort., nom. cons.)	A common cover crop used in the Illinois area. Fescues are recommended by Ohio for construction seeding. Endophyte-free seeds were used.	X	X
Oats (*Avena sativa* L.)	Commonly recommended by Midwest states, including Missouri, Iowa, Indiana, Wisconsin, and Tennessee, for use in roadside seeding	X	X

Table continues next page

Seed Varieties	Justification	Fall/ Winter	Spring/ Summer
Perennial Rye/Oats (*Lolium perenne* L., *Avena sativa* L.)	Current seed mix prescribed by the Illinois DOT. Used as a control.	X	X
Sorghum Sudangrass (Sudex) (*Sorghum bicolor* (L.) Moench ssp. *Drummondii*)	A common cover crop with excellent germination rates.		X (Summer Only)
Winter Wheat (*Triticum aestivum* L.)	A common winter cover crop and recommended by Indiana and Wisconsin for use in roadside seeding.	X	X (Spring Only)

Table 2, Part 2. Seed Variety Cost

Variety	Pounds per Acre	Seed Cost per Pound	Seed Cost per Acre	Seeds per Pound	Plants per Square Foot at 95% Germination
Winter Wheat	100	$0.27	$27.00	12,000	26
Cereal Rye	100	$0.43	$43.00	18,080	39
Spring Oats	100	$0.28	$28.00	12,700	28
Annual Ryegrass	150	$0.90	$135.00	224,000	733
Barley	100	$0.36	$36.00	13,600	30
Tall Fescue	150	$1.25	$187.50	226,800	742
Canada Wildrye	80	$14.00	$1,120.00	115,000	201
95/5 Sports Turf Mix	150	$1.57	$235.50	200,000	654
Sudex	35	$1.50	$52.50	14,000	11
Bermudagrass (hulled)	80	$8.00	$640.00	2,000,000	3,489
Buffalograss	80	$18.00	$1,440.00	40,000	70
CRP IL CP2 Quail Mix	10	$39.17	$391.70	326,167	71
Side Oats Grama	3.33		$0.00	579,000	42
Little Bluestem	3.33		$0.00	255,000	19
Partridge Pea	1.66		$0.00	62,000	2
Purple Prairie Clover	0.83		$0.00	300,000	5
Round-Headed Bush Clover	0.83		$0.00	154,000	3
Perennial Rye/Oats	114	$0.93	$105.42	151,867	378
Perennial Rye	50	$1.75	$87.50	330,000	360
Spring Oats	64	$0.28	$17.92	12,700	18
				Mix Total	**378**

Figure 2. Drop seeder.

Figure 3. Equipment transport. Power rake, drop seeder, tractor, and tiller loaded for transport to remote planting site.

Canada wildrye, CRP (Conservation Reserve Program), and Bermudagrass proved to be either too light or too fine to be distributed by the drop seeder. For these species, we calculated the exact weight of seed for each 6-foot x 6-foot plot; and they were applied to the plot by hand seeding. In addition, hand seeding was used for all seed varieties during the winter plantings in 2014 because of the difficulty in using a tractor during muddy and icy field conditions. Seeding rates are given in Table 3.

Table 3. Seeding Rates

Seed Variety	**lb/acre**	**kg/ha**
Winter Wheat	100	112.1
Cereal Rye	100	112.1
Spring Oats	100	112.1
Annual Ryegrass	150	168.2
Barley	100	112.1
Fawn Tall Fescue	150	168.2
Canada Wildrye	80	89.7
Perennial Ryegrass/Oats Mixture	114	127.8
Perennial Ryegrass	50	56.1
Spring Oats	64	71.8
95/5 Sports Turf	150	168.2
CRP IL CP2 Quail Mix	6	6.7
Side Oats Grama	2	2.2
Little Bluestem	2	2.2
Partridge Pea	1	1.1
Purple Prairie Clover	0.5	0.6
Round-Headed Bush Clover	0.5	0.6
Bermudagrass (Hulled)	80	89.7
Buffalograss	80	89.7
Sorghum Sudangrass (Sudex)	35	39.2

3.2.1.2 Soil-Preparation Treatments

In the fall, spring, and summer plantings, each seed variety selected was sown in test beds at each location that simulated two pre-seeding soil-preparation methods. The first method emulated typical, minimal temporary-seeding soil preparations. This treatment consisted of roughly tilling the soil with a tandem disk (Figure 4). Rough-tilling operations were conducted no more than 3 days prior to seeding. Rough tilling creates an uneven soil surface with non-uniform soil clumps, mimicking the often less than ideal planting conditions of construction sites. The second method, selected to test more uniform seed bed preparation, consisted of passing a Work Saver power landscape rake over the rough-tilled soil to even out the terrain and create a uniform environment for germination. Power landscape raking was performed on the day of planting at all sites (Figure 5).

Figure 4. Soil preparation. Tandem disc for primary tillage and rough-tillage preparation.

Figure 5. Power rake for fine seed bed preparation.

3.2.1.3 Mulching

In addition to differences in seed bed preparation, each variety was tested with three mulching treatments during the fall, spring, and summer plantings: no mulch, loose wheat straw purchased from area farmers, and straw mat purchased from Nu-Way Supply. No mulch and loose straw represented typical practices used in the industry, and straw mats were evaluated to determine if they could yield benefits greater than their additional cost. The loose-straw treatment consisted of hand spreading dry wheat straw across two rows on the long axis of each block (Figure 6), one on the rough-tilled half and one on the fine-tilled half. One-half bale was used per row, resulting in one full bale per block, an amount equivalent to 1.25 tons/acre, an amount sufficient to provide 100% cover but less than the 2.0 tons/acre specified in the IDOT manual. The mat treatment consisted of pressed straw mat rolls, 6 feet wide. Mats were rolled out along two rows per block, one on the rough-tilled half of the block and one on the fine-tilled side. Mats were secured to the ground using metal blanket staples following the manufacturer’s recommendations. The no-mulch treatment area was left bare as our control.

Figure 6. Spreading straw mulch, with straw mats, and no-mulch areas visible.

The mulching treatment was applied immediately following seeding. The experimental design resulted in three replicate sets of six plots per variety, representing every combination of variety, seed bed preparation, and mulch method.

3.2.2 Randomized Block Design

The experimental design at each site for each season's planting consisted of three randomized blocks, each measuring 60 feet x 36 feet (Figure 7). Within each block, every combination of seed bed preparation, mulching, and seed variety was represented. The use of a blocked design allowed the isolation of any large-scale effects on germination and growth because of variation in soil properties, slope, and other site factors, so that they did not confound the treatment comparisons.

Appendix A shows the layout of the blocks for each seasonal planting at each of the four sites and includes detailed diagrams for each block, indicating the randomized arrangement of each treatment combination.

Half of each block, along the long axis, was randomly assigned each of the two soil-preparation treatments. The three mulching treatments were applied along the long axis, within each of the soil preparation treatments, with the order of the mulching treatments randomized in each case. The ten seed varieties were sown at right angles to the soil preparation and mulching treatments, with the order of varieties randomized in each block. As a result, each of the 60 possible combinations of seed bed preparation, mulching, and seed variety is represented in each block by a 6-foot x 6-foot plot (Appendix A).

Figure 7. Planted site showing randomized block design.

Each site was initially prepared by removing existing vegetation, if any, by tilling; staking out test plots; and conducting soil tests. Soil samples were collected by combining several shovelfuls, from different locations within each plot, of the soil's upper layer (0- to 6-inch depth), mixing the soil, and then extracting approximately 8 cubic inches to form a representative sample. Samples were sent to SGS soils laboratory and tested for pH, available phosphorus (P), available potassium (K), percent organic matter, and particle size to evaluate soil differences between sites.

3.2.3 Plantings

Because of the variability in plant species' ability to provide suitable cover in differing seasons, it is important to evaluate which seed varieties and mixtures perform best when planted at different times throughout the year. This study included plantings in all four seasons.

The fall planting occurred from mid-October through early December 2012, when we established the first round of experiments at all four sites. The late-fall period was selected to mimic the typical cessation of construction activities that occurs at this time of year on many projects.

The winter planting was planned to occur from January through early March 2013; we planned to visit each of the sites to conduct another set of seeding operations. However, this early-season seeding could not be conducted, as repeated winter storms prohibited planned winter-tillage operations. This late-winter seeding date was designed to simulate a construction project that was not able to install temporary seeding effectively because of frozen conditions and is now attempting to establish cover. A modified replicated split-block design was implemented in January of 2014, testing ten seed varieties, without prior winter tillage and no mulching treatment. Planting methods were modified to reflect the difficulties of seeding in frozen conditions. Soil-preparation treatments and the straw-mat mulching treatment were eliminated because of their impossibility in frozen conditions. All seed varieties were hand seeded because of the difficulty of using tractors in winter conditions. Appendix B shows the modified site plan for the winter plantings.

The spring planting occurred in May 2013. This mid-spring date was selected to emulate a construction project that began early in the construction season and then proceeded far enough that a portion of the site requires temporary seeding.

The summer planting occurred from mid-July through mid-August, 2013. This seeding time was selected to evaluate midsummer seeding dates that often occur on construction sites. At the Orr site, the summer experiments were planted on the same ground where the fall experiments were planted, because of field space limitations. Field staff at the Orr site treated the existing vegetation with glyphosate herbicide before mowing and removing standing vegetation. This procedure reduced the possibility of a significant increase in organic matter although it did not eliminate possible changes to the volunteer seed bank resulting from the fall experiments.

3.3 DATA COLLECTION AND ANALYSIS

Because the determination of the most successful seed variety is based primarily on the amount of vegetative cover, a photography-based methodology was chosen to provide a standardized quantitative method of determining vegetative cover based on foliar projective cover (Roderick 1999), as opposed to the commonly used field methods of visual estimation or point intercept (Elzinga et al. 1998). Adobe Photoshop was chosen for photography analysis because of its wide availability and our team's familiarity with it.

Each plot was evaluated by sampling vegetative cover in a 2.7-square-foot quadrat centered in each 6-foot x 6-foot plot, avoiding edge effects. Quadrats were digitally photographed individually from above, using a fixed-position tripod 1-m high with a leveled camera positioned straight down. Photographs were taken using a Pentax DSLR camera at an 18mm focal length. The distance from the end of the camera lens to the ground was 90 cm. Figure 8 shows the camera and tripod/quadrat.

Figure 8. The camera tripod/quadrat.

Automatic exposure and autofocus were used to provide the best quality images under changing light conditions in the field. We attempted to use flash to normalize light conditions on all plots but found that at close range the flash caused the photographs to be overexposed and unsuitable for this type of analysis. Using Adobe Photoshop, we measured total vegetative cover from these photographs by determining the percentage of green pixels within the frame. Green pixels were isolated by color selection and then thresholding the color value to exclude indirectly reflected green light not associated with vegetation. The threshold was set at a fixed level of 20; however, in the case of very fine grasses or very bright light conditions, 20 often excluded upwards of 10% of the green pixels. In this case, level 5 color threshold was applied to the photos. This portion of the analysis was a judgment call by the person doing the photo analysis and shows that, although this method is a more quantitative method of vegetation analysis, there is still a human element of estimation. While we were on site, a visual estimate of approximate percent cover was also recorded to compare to and validate image analysis cover values.

Differences in vegetative cover among seed varieties, seed bed preparation methods, and mulching methods at each location and at each seeding date were tested using a blocked, three-way analysis of variance (ANOVA) followed by post-hoc Tukey-Kramer tests applied to the least-squares means. The analysis allowed the identification of the best combinations of seed variety, preparation method, and mulching method at each site and in each season. An alpha level of $P = 0.05$ was used for all statistical tests, with the null hypothesis of no effect being rejected when $P \le 0.05$. Data were collected for spring and summer approximately one month after the planting date. In the case of fall and winter plantings (which showed no germination at one month), data was collected during April 2013 and May 2014, respectively, when measurable vegetative cover was present.

CHAPTER 4 RESULTS

4.1 SOIL ANALYSIS

Soil testing revealed that all sites were suitable for seed germination, having neither extreme pH levels nor a large proportion of sand. Organic matter was low at the Dixon Springs and SIUE sites, as is typical for construction sites. Orr and Northern had higher but not extreme levels of organic matter. Results are summarized in Table 4.

Table 4. Soil Analysis Summary

Field Site	Aspect	Slope	Water pH	P lb./acre	K lb./acre	% Organic Matter	% Sand	% Silt	% Clay	Soil Classification
Dixon Springs	East	~ 3%	6.9	29	246	1.7	15	80	5	Silt
SIUE	North	~ 2%	8.4	50	210	1.6	25	62.5	12.5	Silt Loam
Northern	East	~ 0-1%	6.2	58	286	3.2	35	40	25	Loam
Orr	South	~ 0-1%	7.5	64	386	2.8	30	60	10	Silt Loam

4.2 VEGETATIVE COVER ANALYSIS

Analyzing the data using visual estimates showed generally the same results as when analyzing the data using image-analysis methods (Figure 9). The biggest difference between cover-analysis methods was found to be in detecting differences among seed varieties. Because of rounding when performing visual estimates, in several instances there was no significant difference between the best and the second-best performers. As indicated in Figure 9, the image-analysis cover values were much less likely to be a rounded number and therefore provided a more accurate measure when evaluating fine differences between treatments.

Processing and analyzing each image took between one to two minutes per plot, whereas a visual estimate took only a few seconds. A trained data collector could accurately approximate image-analysis values, but it takes a fair amount of experience and time to become proficient. Additionally, when working on projects with multiple persons visually estimating cover, their individual estimations could vary significantly. Image analysis provides a standardized vegetative-cover analysis that is beneficial when there are multiple data collectors covering large plot arrays or long-term experiments with cover estimates taken years apart.

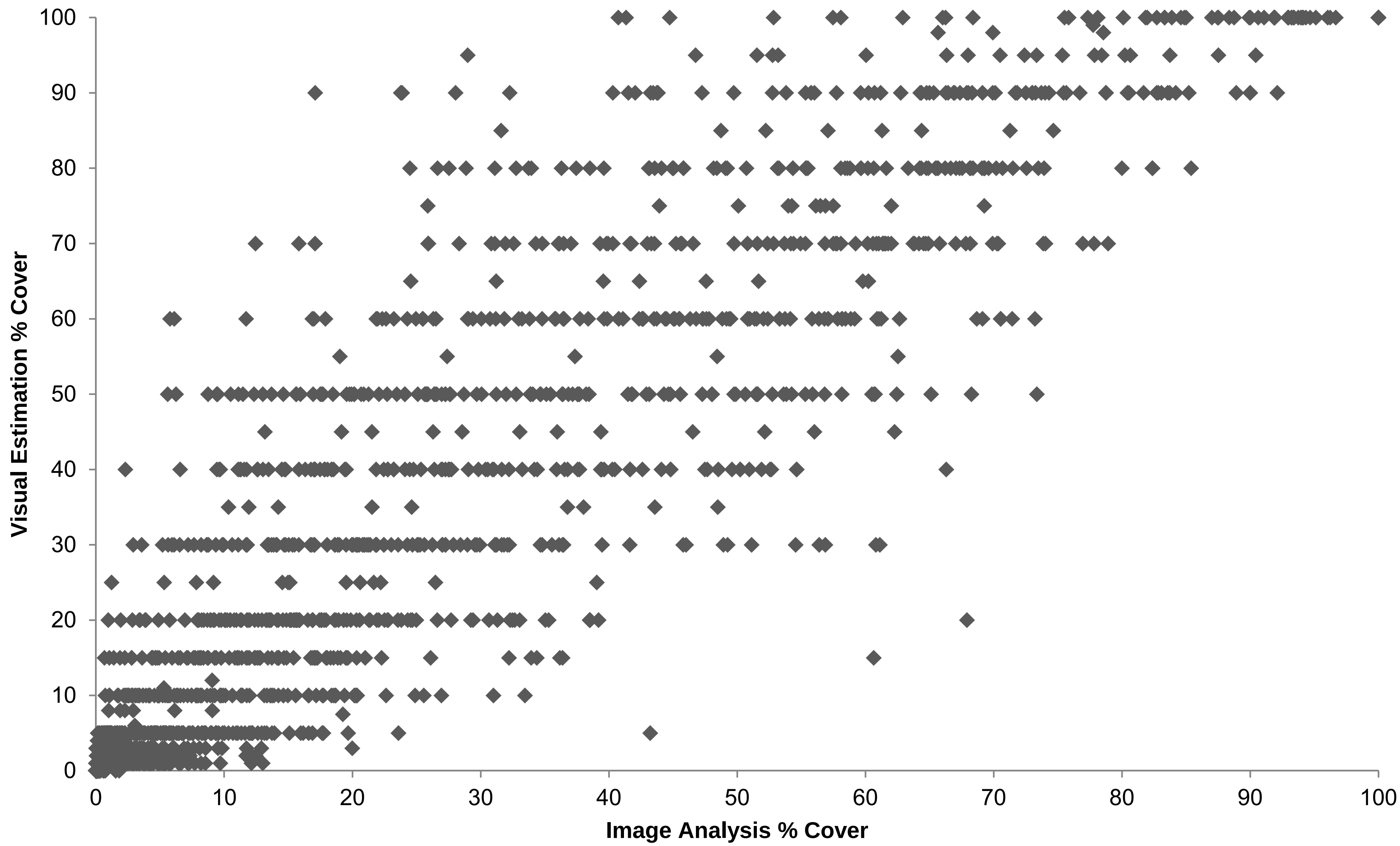


Figure 9. Comparison of cover values. A comparison of visual estimates of cover and image-analysis cover values for all plots from all plantings at all sites. Visual estimations were more likely to be a multiple of ten than the image-analysis values. (Correlation coefficient = 0.91)

4.3 SITE AND SEASON RESULTS

All treatments were analyzed for their effect on percent vegetative cover, based on foliar protective cover (Roderick 1999) using image-analysis techniques described above. Block values were significant in eight out of eleven plantings, justifying the randomized block design (Appendix C).

4.3.1 SIUE

4.3.1.1 SIUE Fall

Mulching treatments and seed varieties showed significant effects on vegetative cover. ANOVA results are summarized in Appendix C, Table C1. Annual ryegrass (mean = 15.36 ± SE = 1.38) and wheat (12.1 ± 1.38) provide the best cover but are not significantly different from one another (Figure 10). Mulching provides a significant benefit, but there was no statistical difference between straw (6.3 ± 0.85) and mat (8.3 ± 0.85) (Figure 11). Soil preparation showed no effect. The combined effects of straw or mat mulch with either annual ryegrass or wheat provided the greatest vegetative cover (Table 5). Canada wildrye and CRP were excluded from this analysis because they failed to germinate.

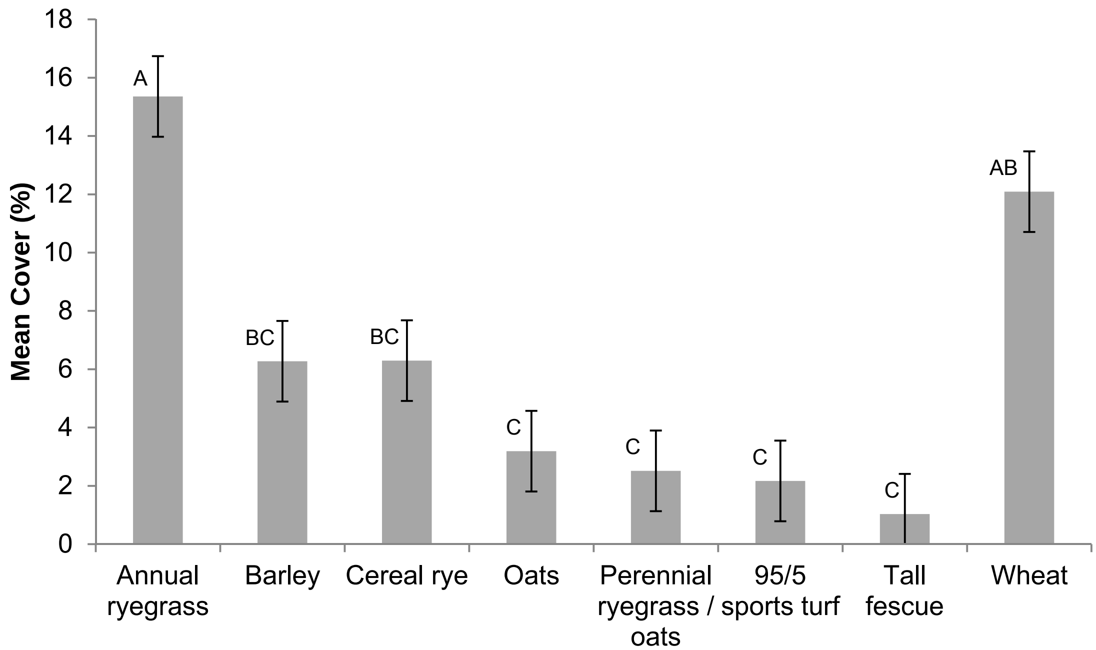


Figure 10. SIUE fall planting seed-variety effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

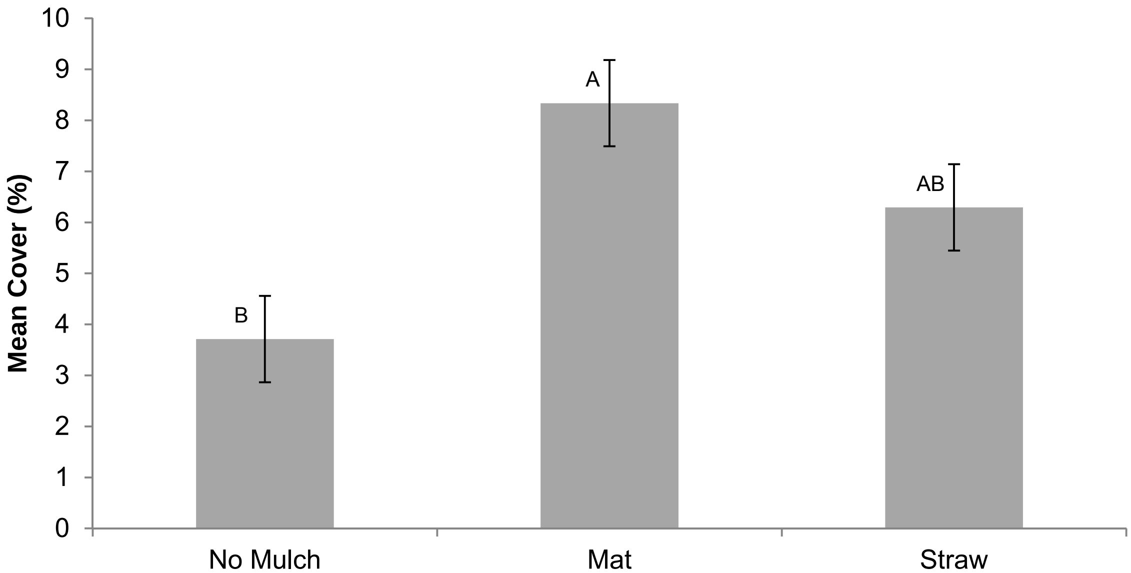


Figure 11. SIUE fall planting mulching effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 5. SIUE Fall Planting Combined Effects of Mulching and Seed-Variety Treatments

	Mulch		
Seed Variety	**None**	**Mat**	**Straw**
Annual Ryegrass	13.0	**17.6**	**15.5**
Barley	3.9	8.5	6.5
Cereal Rye	3.9	8.5	6.5
Oats	0.8	5.4	3.4
Perennial Ryegrass/Oats	0.1	4.7	2.7
95/5 Sports Turf	0	4.4	2.3
Tall Fescue	0	3.3	1.2
Winter Wheat	9.7	**14.3**	**12.3**

These values represent the additive effects of the two treatments. Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

4.3.1.2 SIUE Winter

Winter plantings at SIUE showed no significant advantage between seed varieties or mulch treatments. The relatively high vegetative cover values can be attributed to the extensive weed cover at the site. Weed species included *Poa annua* and *Bromus* species. Sports turf, tall fescue, and annual ryegrass were the only seed varieties that germinated and survived to compete with the weedy ground cover (Table 6).

Table 6. SIUE Winter Planting Vegetative Cover Mean Values by Seed Mix

Seed Variety	Mean % Vegetative Cover
Annual Ryegrass	32.25
Barley	34.72
Bermudagrass	30.38
Canada Wildrye	32.62
Cereal Rye	33.48
Oats	26.52
Perennial Ryegrass/Oats	38.03
95/5 Sports Turf	30.83
Tall Fescue	41.66
Wheat	49.37

Tukey-Kramer tests found no difference among means.
Standard error of each mean is 7.30.

4.3.1.3 SIUE Spring

Mulching method, soil preparation, and seed variety all showed significant effects on vegetative cover. ANOVA results are summarized in Appendix C, Table C3. Seed variety and soil preparation showed an interaction effect, meaning that their combined effect differs from that which would be expected if their individual effects were added. Annual ryegrass under the rough-soil-preparation treatment showed the greatest vegetative cover (38.7 ± 2.24) and was significantly greater than the other high-performing seed-variety and soil-preparation treatments (Figure 12).

Mat mulching treatment showed the greatest vegetative cover (18.2 ± 0.87) and was significantly higher than straw and no-mulch treatments (Figure 13). The greatest vegetative cover was from the additive effects of annual ryegrass seeded over a rough soil preparation and covered by mat mulch (Tables 7 and 8).

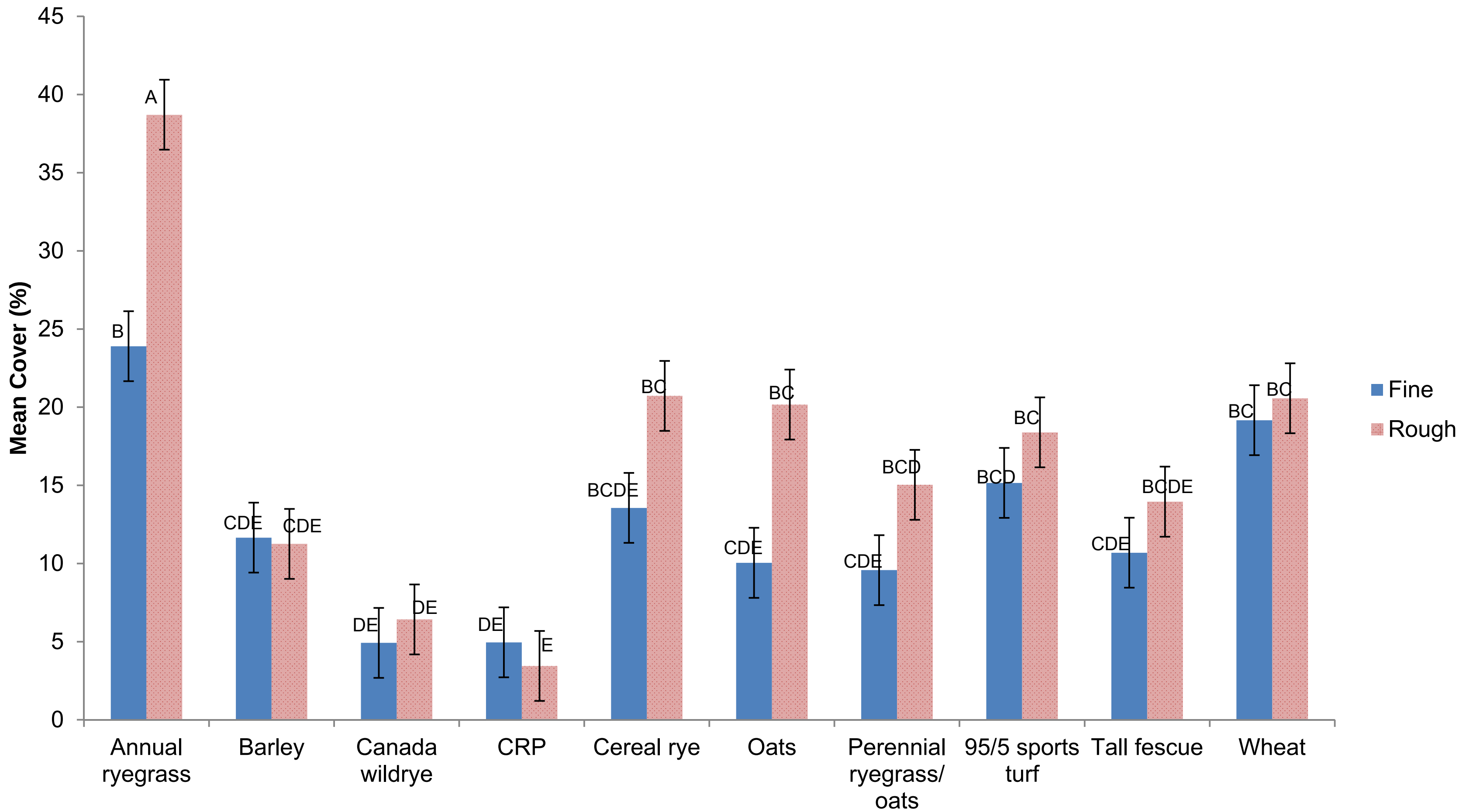


Figure 12. SIUE spring planting seed-variety and soil-preparation effects. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

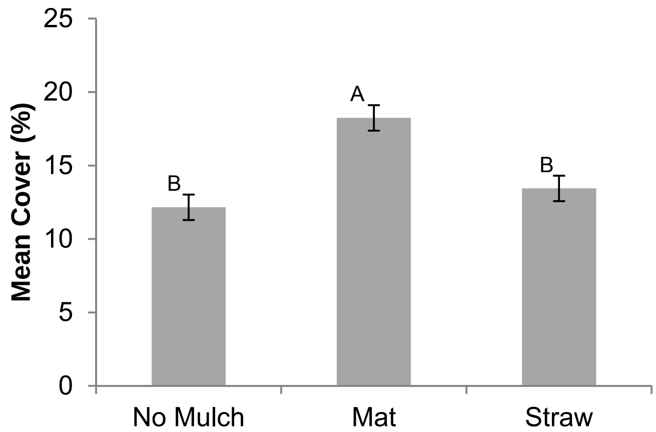


Figure 13. SIUE spring planting mulching effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 7. SIUE Spring Planting Interaction Effect Between Seed Variety and Soil Preparation.

Seed Variety	Soil Preparation	Mean % Vegetative Cover
Annual Ryegrass	Fine	23.90
	Rough	**38.71**
Barley	Fine	11.66
	Rough	11.26
Canada Wildrye	Fine	4.92
	Rough	6.42
CRP	Fine	4.96
	Rough	3.44
Cereal Rye	Fine	13.56
	Rough	20.72
Oats	Fine	10.04
	Rough	20.17
Perennial Ryegrass/Oats	Fine	9.58
	Rough	15.03
95/5 Sports Turf	Fine	15.16
	Rough	18.39
Tall Fescue	Fine	10.69
	Rough	13.96
Wheat	Fine	19.17
	Rough	20.57

The bolded values represent the interaction of the two treatments that yielded the greatest vegetative cover. Standard error of each mean is 2.24.

Table 8. SIUE Spring Planting Joint Effects of Mulching Treatment and the Seed Variety

	Mulch		
Seed Variety	**None**	**Mat**	**Straw**
Annual Ryegrass	28.8	**34.9**	**30.1**
Bermudagrass	9.0	15.1	10.3
Buffalograss	3.2	9.3	4.5
CRP	1.7	7.8	3.0
Cereal Rye	14.7	20.8	16.0
Oats	12.6	18.7	13.9
Perennial Ryegrass/Oats	9.8	15.9	11.1
95/5 Sports Turf	14.3	20.4	15.6
Sudex	9.9	16.0	11.2
Tall Fescue	17.4	23.5	18.7

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

4.3.1.4 SIUE Summer

Mulch and seed variety showed significant effects on vegetative cover. ANOVA results are summarized in Appendix C, Table C3. Mat (8.3 ± 0.91) and straw (6.06 ± 0.91) mulch showed the highest cover but did not differ significantly from each other (Figure 14). Annual ryegrass (19.1 ± 1.65) and sudex (16.3 ± 1.65) showed significantly higher vegetative cover than other seed varieties but did not significantly differ from each other (Figure 15). Soil-preparation treatment had no significant effect. Greatest vegetative cover was achieved by either sudex or annual ryegrass in combination with either mat or straw mulch (Table 9).

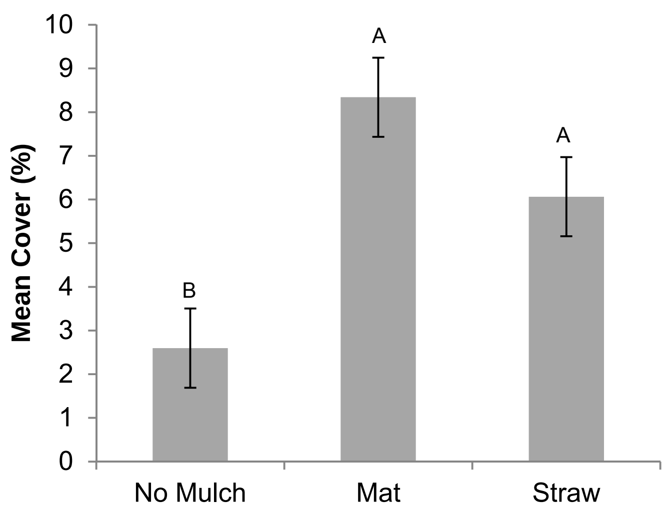


Figure 14. SIUE summer planting mulching effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

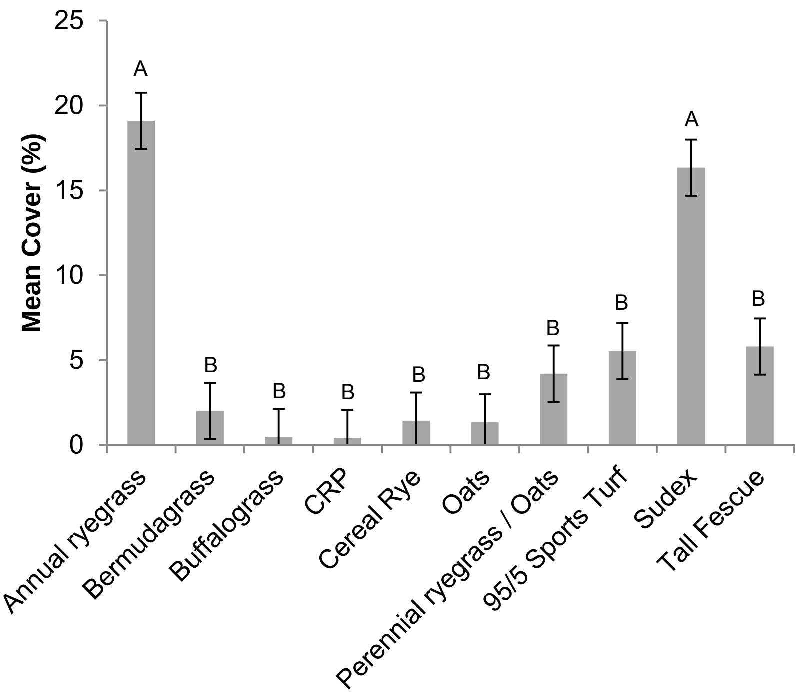


Figure 15. SIUE summer planting seed-variety effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 9. SIUE Summer Planting Combined Effects of Mulching and Seed-Variety Treatments (These values represent the additive effects of the two treatments.)

	Mulch		
Seed Variety	**None**	**Mat**	**Straw**
Annual Ryegrass	16.0	**21.7**	**19.5**
Bermudagrass	0	4.7	2.5
Buffalograss	0	3.2	0.88
CRP	0	3.1	0.8
Cereal rye	0	4.1	1.8
Oats	0	4.0	1.7
Perennial Ryegrass/Oats	1.2	6.9	4.6
95/5 Sports Turf	2.5	8.2	5.9
Sudex	13.3	19.0	16.7
Tall fescue	2.7	8.5	6.2

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

4.3.2 Orr

4.3.2.1 Orr Fall

Only three seed varieties had germinated at our initial data collection, therefore all other seed varieties were excluded from analysis. Seed variety showed an effect, and soil preparation and mulch showed an interaction effect. ANOVA results are summarized in Appendix C, Table C5. Cover between the seed varieties did not significantly differ; wheat (1.02 ± 0.17), cereal rye (0.85 ± 0.17), and barley (0.80 ± 0.17) did not significantly differ (Figure 16). No seed variety produced significant cover at one month. Soil preparation and mulch showed an interaction effect. The combinations of rough soil preparation and either straw (2.10 ± 0.24) or mat (1.17 ± 0.24) had the greatest vegetative cover (Table 10).

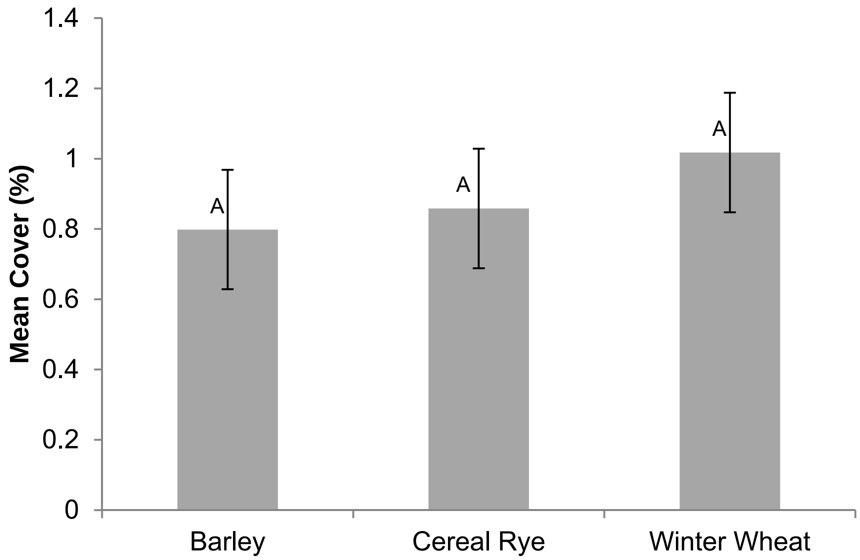


Figure 16. Orr fall planting seed-variety effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 10. Orr Fall Planting Interaction Effect Between Soil Preparation and Mulching Treatment

Soil Preparation	Mulch	Mean % Vegetative Cover
Fine	Bare	0.55
Fine	Mat	0.61
Fine	Straw	0.41
Rough	Bare	0.52
Rough	Mat	**1.17**
Rough	Straw	**2.10**

The bolded values show the combination of treatments that yielded the greatest vegetative cover. Standard error of each mean is 0.24.

4.3.2.2 Orr Winter

Winter plantings at Orr showed no statistically significant advantage between seed varieties or mulch treatments (Table 11); however, annual rye achieved a level of performance that was visually and measurably greater than the other tested varieties. Although there were fewer weeds at Orr than at SIUE, weed cover was significant in all plots. Bermudagrass, wheat, and oats failed to germinate.

Table 11. Orr Winter Planting Vegetative Cover Mean Values

Seed Variety	**Mean % Vegetative Cover**
Annual Ryegrass	**58.98**
Barley	32.15
Bermudagrass	17.21
Canada wildrye	31.54
Cereal rye	16.93
Oats	34.70
Perennial Ryegrass/Oats	18.35
95/5 Sports Turf	22.69
Tall Fescue	23.88
Wheat	16.82

Standard error of each mean is 9.13.

4.3.2.3 Orr Spring

Soil preparation and seed variety showed an effect on vegetative cover. Mulch showed no effect. ANOVA results are summarized in Appendix C, Table C7. Rough soil preparation (44.2 ± 1.1) had a significantly higher vegetative cover than fine soil preparation (35.50 ± 1.1) (Figure 17). Annual ryegrass (76.4 ± 2.46) showed the greatest vegetative cover of all the seed varieties (Figure 18). Greatest vegetative cover can be expected by combining annual ryegrass with a rough soil-preparation treatment (Table 12).

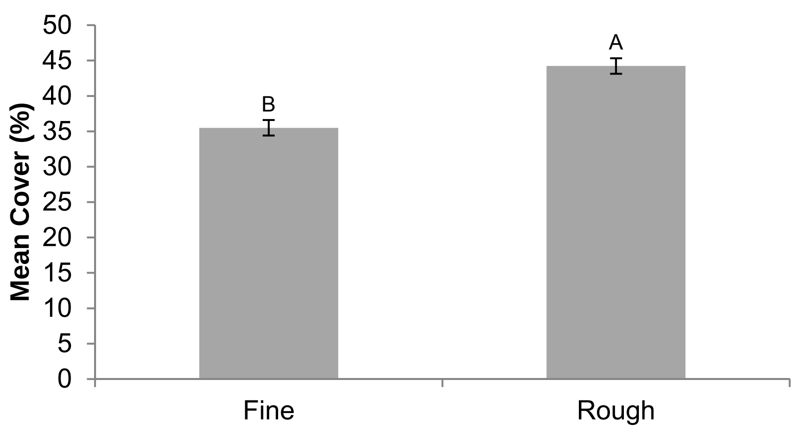


Figure 17. Orr spring planting soil-preparation effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

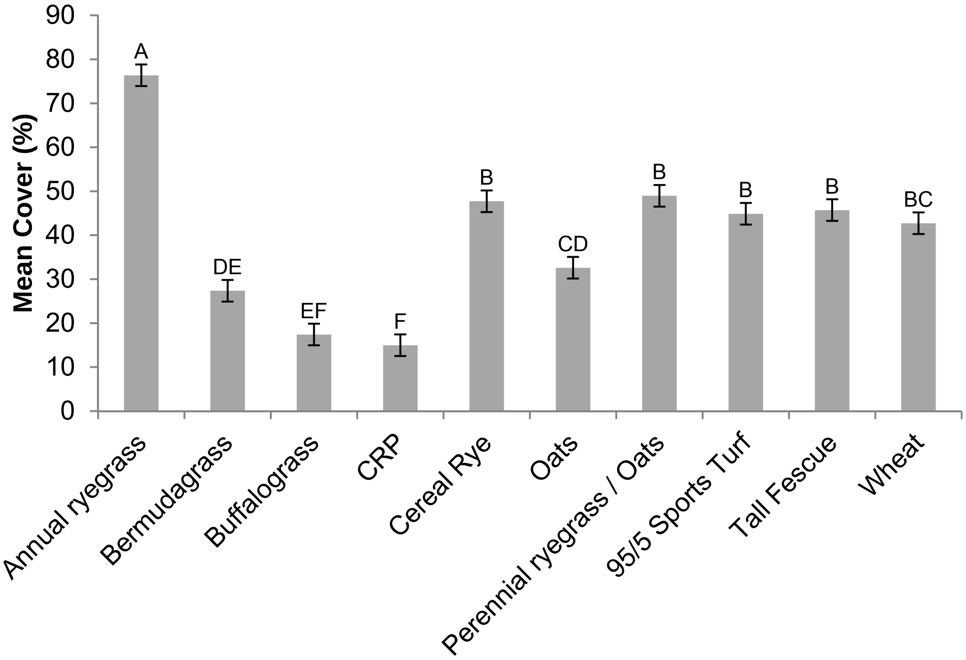


Figure 18. Orr spring planting seed-variety effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 12. Orr Spring Planting Combined Effects of Seed Variety and Soil Preparation
(These values represent the additive effects of the two treatments.)

	Soil Prep	
Seed Variety	**Fine**	**Rough**
Annual Ryegrass	72.0	**80.7**
Bermudagrass	23.0	31.7
Buffalograss	13.0	21.8
CRP	10.6	19.3
Cereal Rye	43.4	52.1
Oats	28.2	37.0
Perennial Ryegrass/Oats	44.6	53.3
95/5 Sports Turf	40.5	49.2
Sudex	41.3	50.1
Tall Fescue	38.4	47.1

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

4.3.2.4 Orr Summer

There was a significant interaction between soil preparation and mulch and between seed variety and mulch. ANOVA results are summarized in Appendix C, Table C8. All soil-preparation and mulch combinations were equivalent except fine and no mulch, which performed worse than the other combinations (Figure 19). Annual ryegrass under straw (66.4 ± 3.74) and mat (59.6 ± 3.74) showed the greatest vegetative cover and did not differ significantly from each other (Figure 20). Some of the low-performing seed varieties had more significant differences in mulching treatments. However, even with no mulch, annual rye outperformed the other seed varieties. Greatest vegetative cover is expected from annual ryegrass combined with rough soil preparation treatment under either straw or mat (Tables 13 and 14).

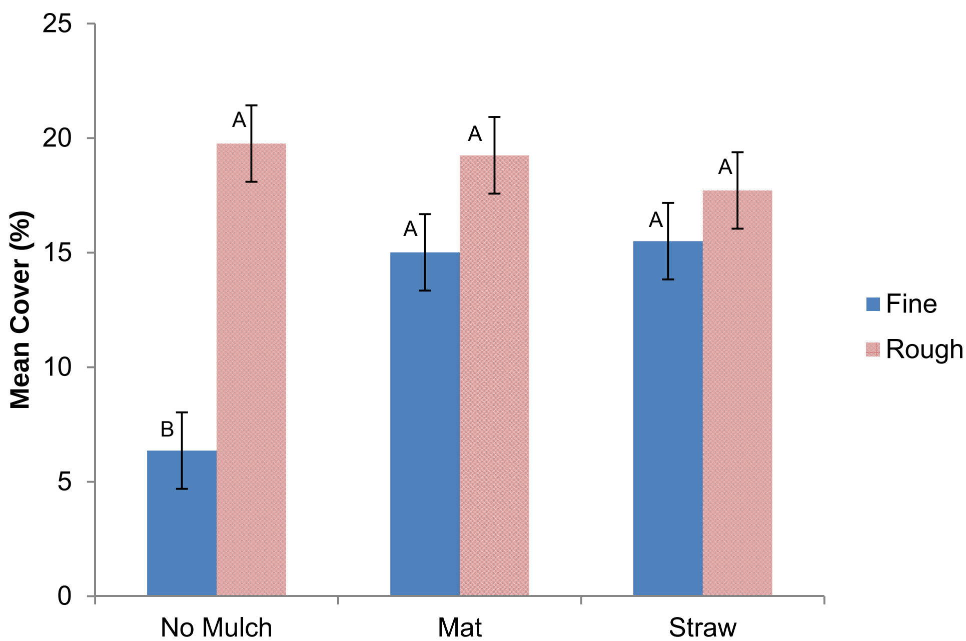


Figure 19. Orr summer planting soil-preparation and mulch interaction effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

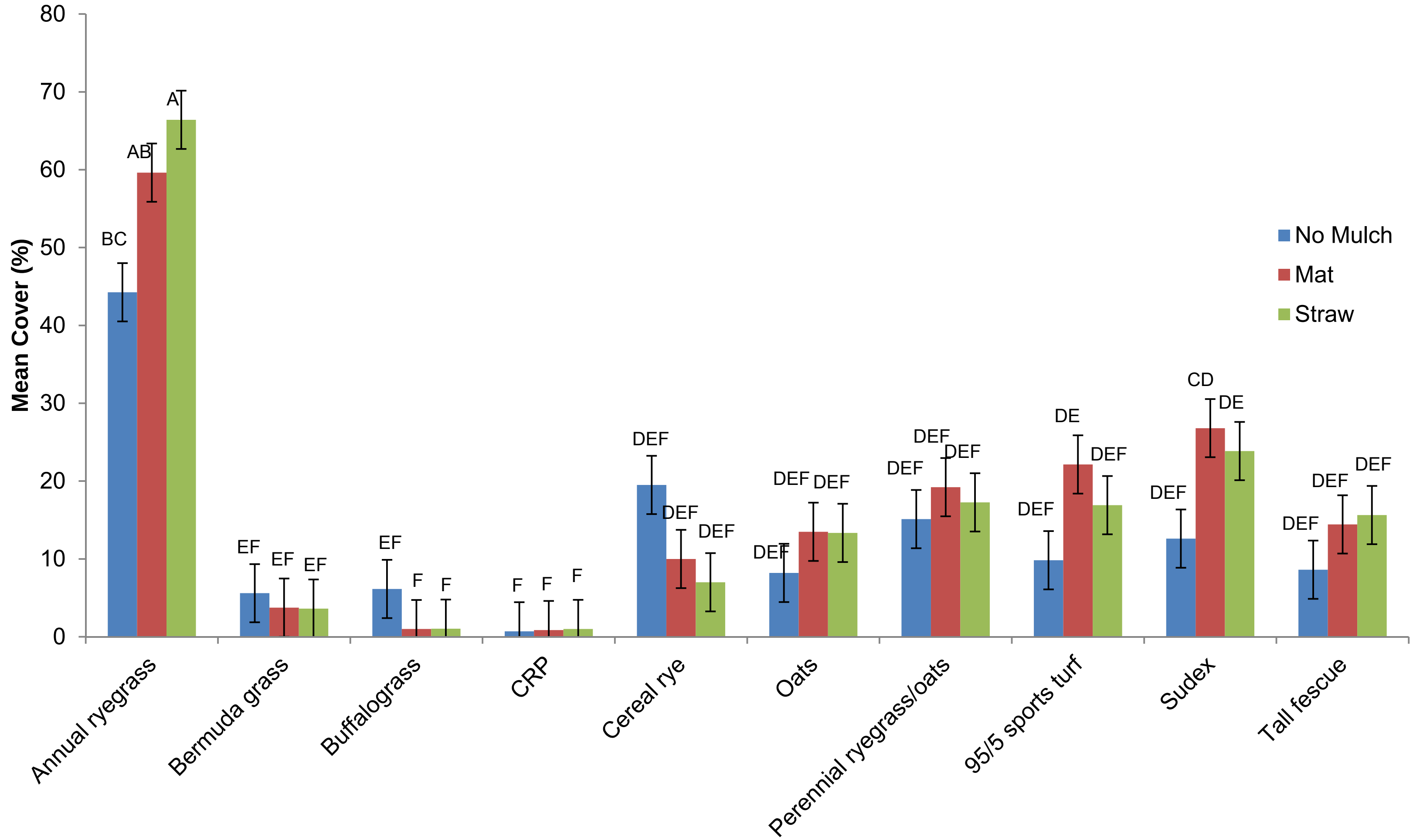


Figure 20. Orr summer planting interaction effect of seed variety and mulch. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 13. Orr Summer Planting Additive Effect Between Seed Variety and Soil Preparation

	Soil Preparation	
Seed Variety	**Fine**	**Rough**
Annual Ryegrass	53.5	60.1
Bermudagrass	1.0	7.6
Buffalograss	0	6.0
CRP	0	4.2
Cereal Rye	8.9	15.5
Oats	8.4	15.0
Perennial Ryegrass/Oats	13.9	20.5
95/5 Sports Turf	13.0	19.6
Sudex	**100.0**	24.4
Tall Fescue	9.6	16.2

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

Table 14. Orr Summer Planting Interaction Means Between Seed Variety and Mulch

Seed Variety	**Mulch**	**Mean % Vegetative Cover**
Annual Ryegrass	Bare	44.25
	Mat	**59.63**
	Straw	**66.42**
Bermudagrass	Bare	5.60
	Mat	3.75
	Straw	3.63
Buffalograss	Bare	6.15
	Mat	1.00
	Straw	1.04
CRP	Bare	0.70
	Mat	0.86

Table continues next page

Seed Variety	Mulch	Mean % Vegetative Cover
	Straw	1.00
Cereal Rye	Bare	19.51
	Mat	9.99
	Straw	7.01
Oats	Bare	8.21
	Mat	13.49
	Straw	13.35
Perennial Ryegrass/ Oats	Bare	15.12
	Mat	19.22
	Straw	17.27
95/5 Sports Turf	Bare	9.84
	Mat	22.14
	Straw	16.90
Sudex	Bare	12.61
	Mat	26.80
	Straw	23.86
Tall Fescue	Bare	8.61
	Mat	14.44
	Straw	15.63

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 3.74.

4.3.3 Dixon Springs

4.3.3.1Dixon Springs Fall

Soil preparation and mulch, as well as seed variety and mulch, showed significant interaction effects. ANOVA results are summarized in Appendix C, Table C9. Only the lowest-performing soil-preparation and mulch combination, fine and no mulch (3.46 ± 0.52) showed a significant difference from the others, performing half as well (Figure 21). Cereal rye under mat (28.2 ± 1.16) and straw (23.3 ± 1.16) yielded the greatest vegetative cover (Figure 22). Greatest vegetative cover can be expected from cereal rye under rough or fine soil preparation and straw or mat mulch.

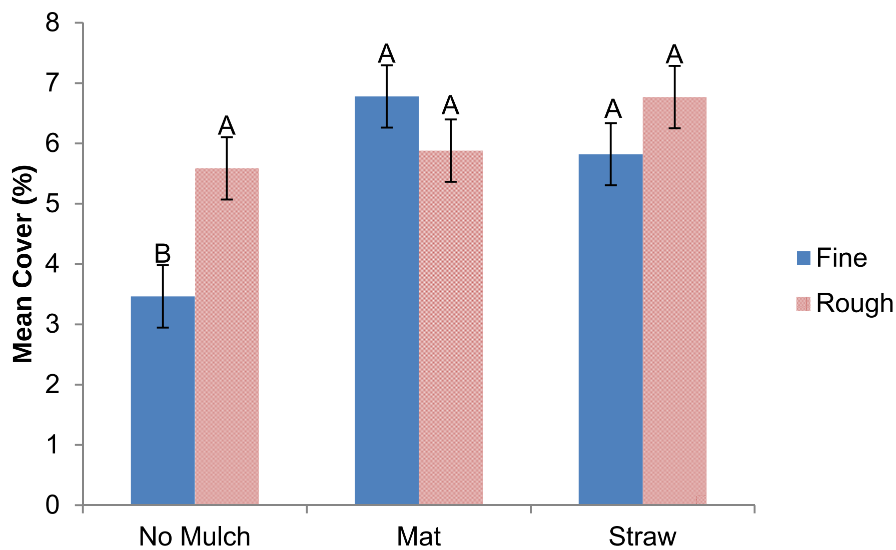


Figure 21. Dixon Springs fall planting interaction effect of soil preparation and mulch. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

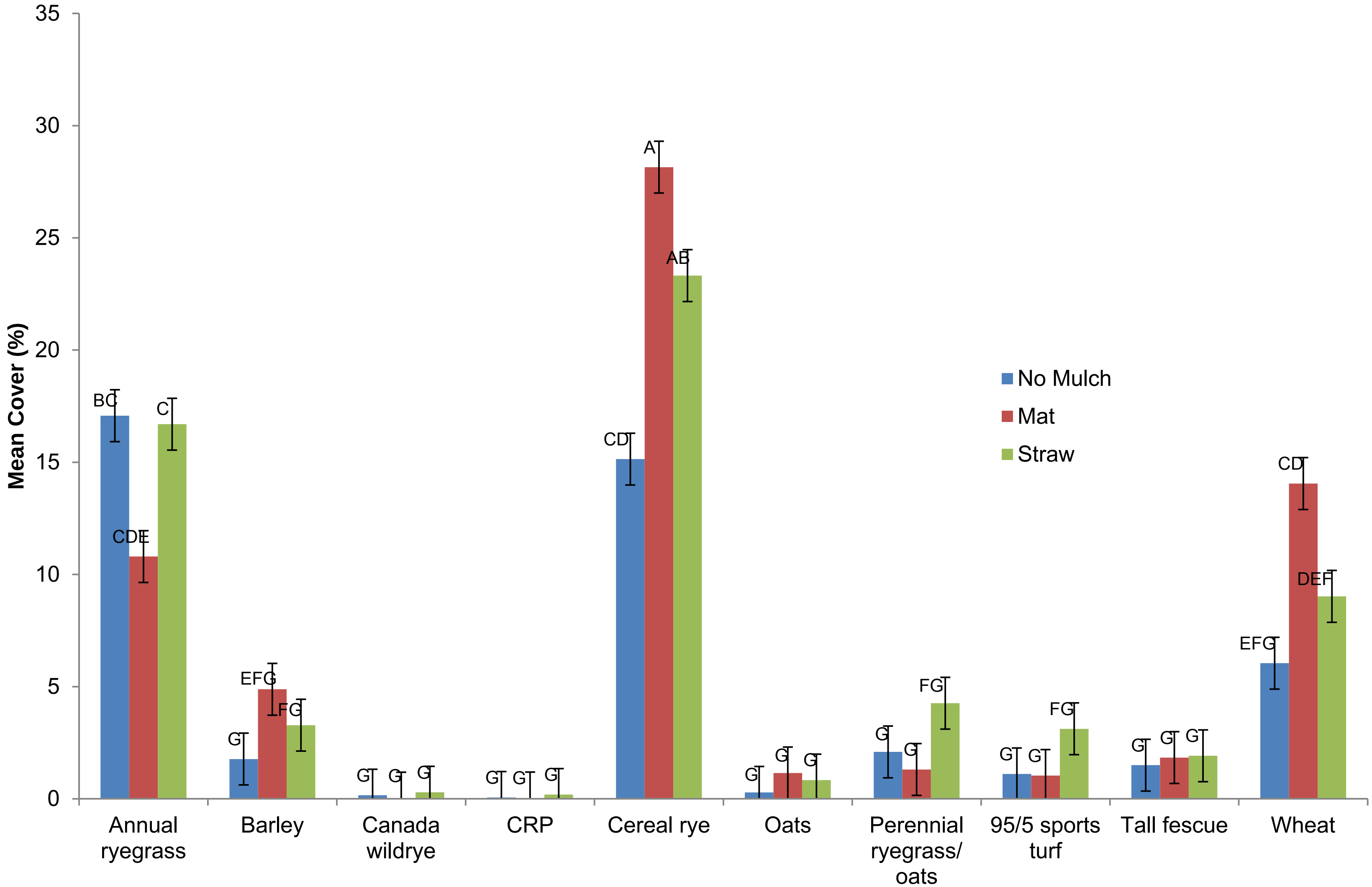


Figure 22. Dixon Springs fall planting interaction effect of seed variety and mulch. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

4.3.3.2 Dixon Springs Winter

Seed variety showed a significant effect in the winter planting at Dixon Springs (Table 15). Annual ryegrass has significantly greater vegetative cover than all other seed varieties. Mulching treatment did not show any significant effect. This result is due in part to the high winds on the seeding date that made application of loose-straw mulch largely ineffective.

Table 15. Dixon Springs Winter Planting Vegetative Cover Mean Values

Seed Variety	**Mean % Vegetative Cover**
Annual Ryegrass	**12.33**
Barley	0.51
Bermudagrass	0.57
Canada Wildrye	0.49
Cereal Rye	0.22
Oats	0.10
Perennial Ryegrass/Oats	0.82
95/5 Sports Turf	2.44
Tall Fescue	1.61
Wheat	2.54

Bolded values represent significantly greater cover values. Standard error of each mean is 1.19.

4.3.3.3 Dixon Springs Spring

Seed variety showed an interaction effect with soil preparation and an interaction with mulch treatments. ANOVA results are summarized in Appendix C, Table C11. Annual ryegrass had the greatest vegetative cover of all the seed varieties and did not differ between rough soil preparation (83.1± 3.59) and fine soil preparation (91.2 ± 3.59) (Figure 23). Under mulching treatments, annual ryegrass had the highest cover under all mulching treatments (straw = 89.11 ± 4.4, mat = 85.1 ± 4.4, no mulch = 87.2 ± 4.4). These values also did not differ from Bermudagrass under no mulch (71.1 ± 4.4) and tall fescue under straw (69.0 ± 4.4) (Figure 24). Greatest vegetative cover can be expected from annual ryegrass under both rough or fine soil preparation and any mulching method (Tables 16 and 17).

Table 16. Dixon Springs Spring Planting Interaction Means Between Seed Variety and Mulch

Seed Variety	Mulch	Mean % Vegetative Cover
Annual Ryegrass	Bare	**87.24**
	Mat	**85.14**
	Straw	**89.11**
Bermudagrass	Bare	**71.07**
	Mat	42.82
	Straw	60.73
Buffalograss	Bare	39.05
	Mat	35.52
	Straw	46.25
CRP	Bare	25.29
	Mat	26.67
	Straw	41.88
Cereal Rye	Bare	44.32
	Mat	49.52
	Straw	62.19
Oats	Bare	31.97
	Mat	34.25
	Straw	52.42
Perennial Ryegrass/Oats	Bare	52.76
	Mat	50.18
	Straw	57.79
95/5 Sports Turf	Bare	58.55
	Mat	57.55
	Straw	59.14
Tall Fescue	Bare	54.79
	Mat	57.61
	Straw	69.04
Wheat	Bare	25.76
	Mat	38.90
	Straw	49.61

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 4.40.

Table 17. Dixon Springs Spring Planting Interaction Means Between Seed Variety and Soil Preparation

Seed Variety	Soil Preparation	Mean % Vegetative Cover
Annual Ryegrass	Fine	**91.22**
	Rough	**83.11**
Bermudagrass	Fine	69.87
	Rough	46.55
Buffalograss	Fine	58.32
	Rough	22.23
CRP	Fine	46.05
	Rough	16.51
Cereal Rye	Fine	64.60
	Rough	39.42
Oats	Fine	47.02
	Rough	32.07
Perennial Ryegrass/Oats	Fine	63.62
	Rough	43.54
95/5 Sports Turf	Fine	68.90
	Rough	47.94
Tall Fescue	Fine	67.39
	Rough	53.58
Wheat	Fine	49.65
	Rough	26.53

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.
Standard error of each mean is 3.59.

4.3.3.4 Dixon Springs Summer

There were two major problems with the summer planting at Dixon Springs. One, a neighboring corn crop was planted too close to our experiment and either encroached or shaded out part of all three blocks under the rough soil-preparation treatment. Therefore, the soil-preparation method was excluded from this analysis. Both mulch and seed variety had an effect on cover. ANOVA results are summarized in Appendix C, Table C12.

Two, the Dixon Springs site had a large number of weeds that quickly and aggressively took over the plots. Seed varieties that were particularly slow to germinate, Buffalograss and CRP, for example, were particularly susceptible to encroachment by field weeds, which inflated their cover values and made it appear that they generated more cover than they actually did. These field weeds included green foxtail (*Setaria vividis* L.), crabgrass (*Digitaria* sp.), pink smartweed (*Polygonum pensylvanicum* L.), and yellow nut sedge (*Cyperus esculentus* L.).

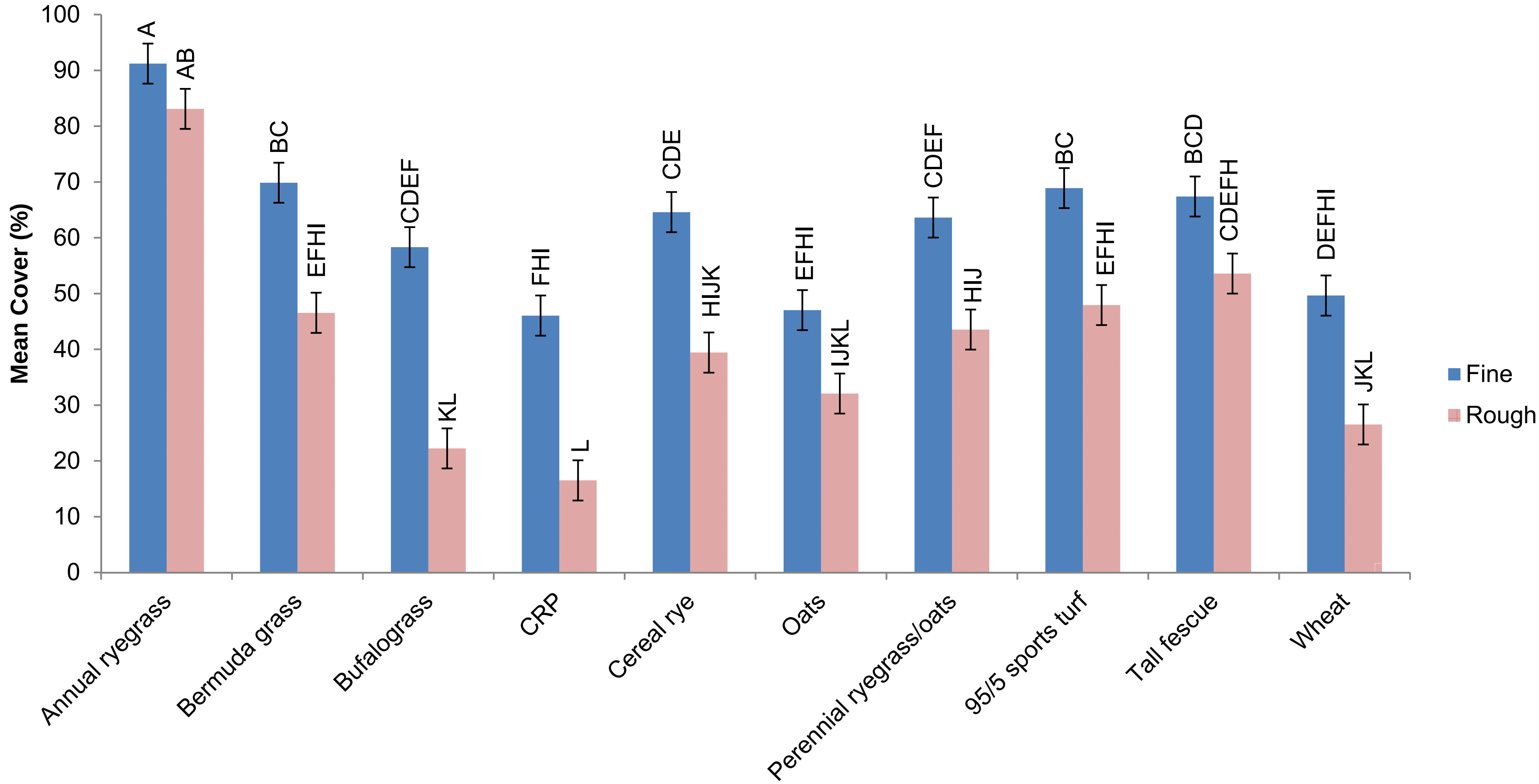


Figure 23. Dixon Springs spring planting interaction effect of seed variety and soil preparation. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

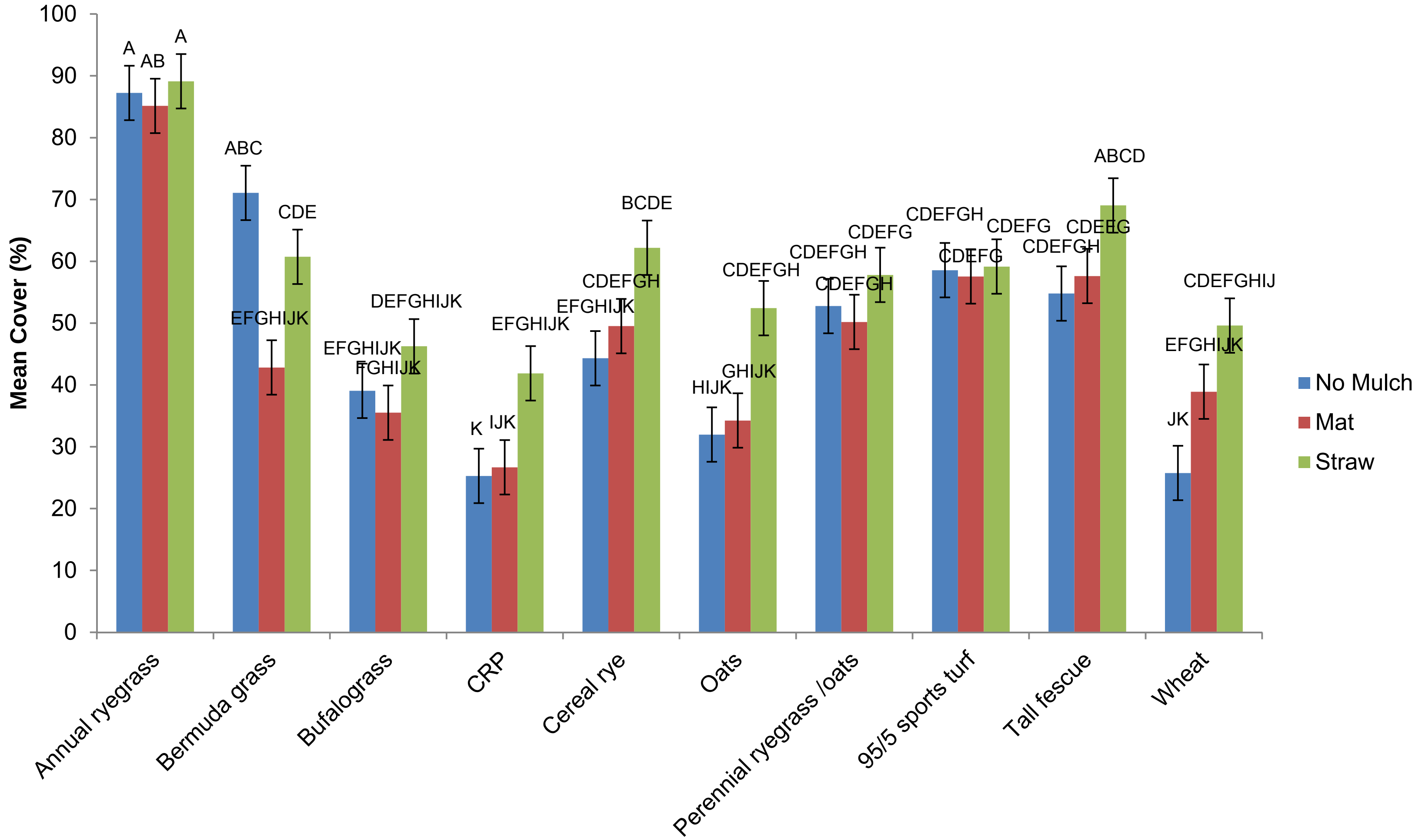


Figure 24. Dixon Springs spring planting interaction effect between seed variety and mulch effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Because of the hot, dry conditions following summer seeding at Dixon Springs, a number of the seed varieties sprouted and died before establishing cover—including annual ryegrass, which was a high performer at other sites planted in the same season. During a year with wetter conditions, these results could vary significantly. For instance, annual ryegrass could be expected to have higher vegetative cover, based on its performance at other sites during the summer growing season.

Straw (63.3 ± 2.3) and no mulch (65.9 ± 2.3) showed significantly higher vegetative cover than mat but did not differ from each other (Figure 25).

Sudex grew so vigorously at this site that it was too tall for our camera tripod quadrat. Visual estimation was used for analysis in this case and was near 100% in all plots. Sudex had the greatest vegetative cover of all the seed varieties (95.6 ± 4.2) (Figure 26). Greatest vegetative cover can be achieved by combining sudex seeding with either no mulch or straw (Table 18).

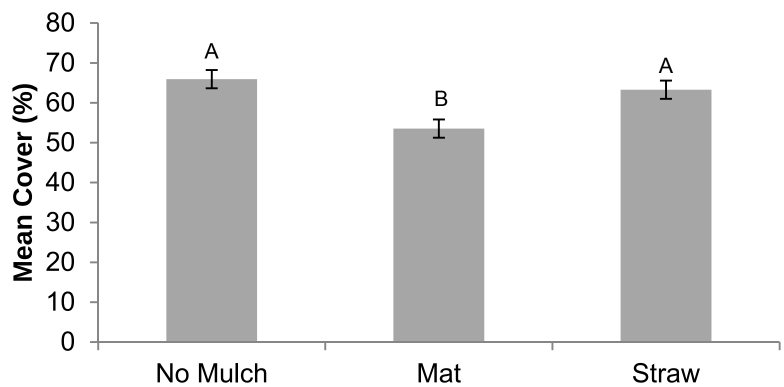


Figure 25. Dixon Springs summer planting mulch effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

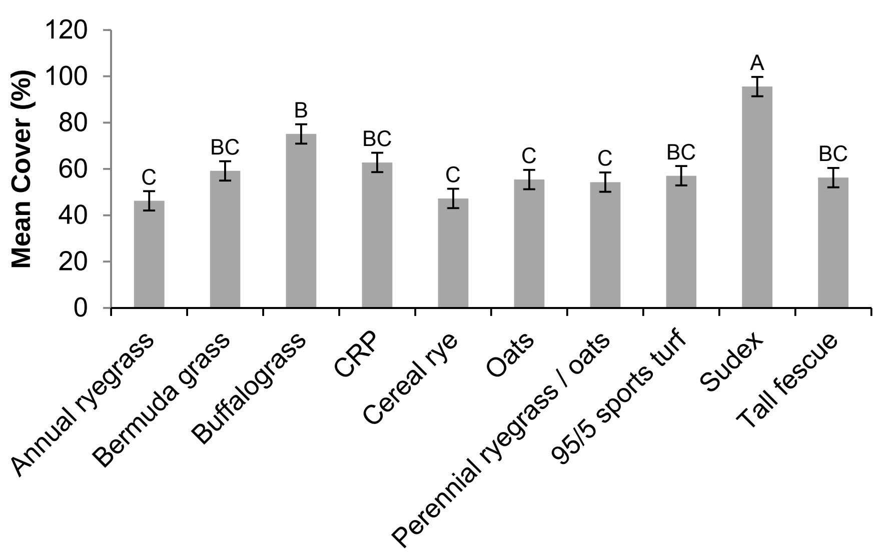


Figure 26. Dixon Springs summer planting seed-variety effect. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

Table 18. Dixon Springs Summer Planting Combined Effects of Seed Variety and Mulch (These values represent the additive effects of the two treatments.)

	Mulch		
Seed Variety	**None**	**Mat**	**Straw**
Annual Ryegrass	51.3	38.9	48.6
Bermudagrass	64.2	51.8	61.6
Buffalograss	80.1	67.7	77.5
CRP	67.8	55.4	65.2
Cereal Rye	52.2	39.9	49.6
Oats	60.4	48.1	57.8
Perennial Ryegrass/Oats	59.3	46.9	56.7
95/5 Sports Turf	62.1	49.7	59.4
Sudex	**100.0**	88.2	**97.9**
Tall Fescue	61.3	48.9	58.7

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover.

4.3.4 Northern

4.3.4.1 Northern Fall

Due to an extended period of precipitation, the fall seeding plots at the Northern site were flooded and continually inundated for approximately 3 days. Most mulching treatments were washed away from their intended locations. The flooding and surface storm water flow also eliminated the difference in soil structure between fine- and rough-tilled areas. The result was an incomplete data set from our Northern fall-seeding effort (Figure 27).

Figure 27. Flood damage at the northern field site. Our plots were to the left of this overflowing drainage ditch. (Photo by Russ Higgins, U of I Northern Agricultural Research Center.)

Two data-collection trips were conducted to document Northern's fall planting plot performance. The first trip was conducted on 16 May 2013, when emerged plants were only a few inches tall. The second trip occurred on 19 June 2013, at which time the cereal grain varieties had headed out and the remaining emerged varieties were nearing the vegetative cover maximum extent. During each trip, two different views of each variety in each planting block were recorded. A visual analysis of each variety strip was undertaken to rank the apparent effectiveness of each variety.

An on-site visual analysis of plots during the 16 May visit and a post visit viewing of variety photographs indicate that three varieties—tall fescue, 95/5 sports turf, and annual rye—exhibited superior initial performance over the other varieties. Among these three, tall fescue exhibited the best visually evident emergence and percent cover, significantly outperforming the currently specified perennial rye/oats mixture (Figure 28).

Figure 28. 16 May 2013 Northern field site. Perennial ryegrass/oats on the left, tall fescue on the right.

On-site and photographic visual analysis of the fall-planted plots on 19 June 2013 revealed that several varieties had grown substantially over the previous 34 days. Cereal rye, annual ryegrass, 95/5 sports turf, and tall fescue all exhibited 100% or nearly 100% coverage. Cereal rye grew the tallest, followed by annual rye. Although tall fescue did not achieve the height of the other well-performing varieties, it did exhibit the best evident plant density. The currently specified perennial rye/oats mixture also exhibited substantial growth over this period but did not achieve 100% coverage or the vegetative growth of the best-performing varieties.

Although not supported by automated photographic data extraction or statistical analysis, our visual evaluation of Northern's fall planting indicate the best early-performing variety is tall fescue; and that although other varieties achieve excellent growth and coverage later in the growing season, tall fescue remains on an equal footing with them (Figures 29 and 30). The currently specified perennial rye/oats mixture was not among the top-performing varieties for either early emergence or maturing phase stage of growth.

Figure 29. 19 June 2013 Northern field site. Cereal rye on the left, perennial ryegrass/oats on the right.

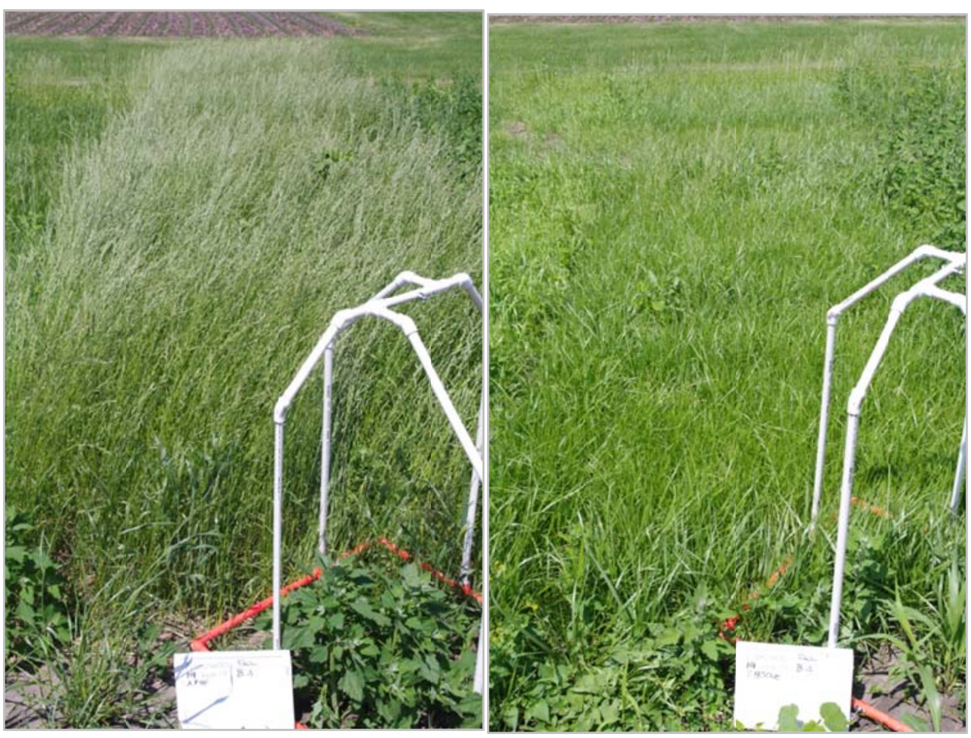


Figure 30. 19 June 2013 Northern field site. Annual ryegrass on the left, tall fescue on the right.

4.3.4.2 Northern Winter

Seed variety showed a significant effect in the winter planting at Northern (Table 19). Annual ryegrass and winter wheat had significantly greater vegetative covers than all other seed varieties but did not significantly differ from each other. Mulching treatments were not tested at Northern because seeding was onto about four inches of snow and deeply frozen underlying soil (Figure 31). Straw mat could not be stapled in place, and loose straw would have quickly been displaced by wind.

Figure 31. Northern winter seeding.

Table 19. Northern Winter Planting Vegetative Cover Mean Values

Seed Variety	Mean % Vegetative Cover
Annual Ryegrass	**5.44**
Barley	0.34
Bermudagrass	0.05
Canada Wildrye	0.15
Cereal Rye	0.03
Oats	0.28
Perennial Ryegrass/Oats	0.08
95/5 Sports Turf	0.27
Tall Fescue	0.14
Wheat	**0.86**

Bolded values represent significantly greater cover values.
Standard error of each mean is 0.92.

4.3.4.3 Northern Spring

Seed variety showed an interaction effect with soil-preparation treatments and an interaction with mulch treatments (Tables 20 and 21). ANOVA results are summarized in Appendix C, Table C14. Annual ryegrass under either rough (87.9 ± 2.9) or fine soil preparation (92.32 ± 2.9) and under any mulching treatment (straw = 91.3 ± 3.6, mat = 86.9 ± 3.6, no mulch = 92.4 ± 3.6) yielded the greatest vegetative cover (Figures 32 and 33).

Table 20. Northern Spring Planting Interaction Means Between Seed Variety and Mulch

Seed Variety	Mulch	Mean % Vegetative Cover
Annual Ryegrass	Bare	**92.43**
	Mat	**86.85**
	Straw	**91.13**
Bermudagrass	Bare	27.87
	Mat	3.17
	Straw	16.89
Buffalograss	Bare	10.09
	Mat	1.69
	Straw	4.58
CRP	Bare	6.97
	Mat	1.93
	Straw	5.86
Cereal Rye	Bare	54.80
	Mat	59.49
	Straw	59.81
Oats	Bare	17.84
	Mat	43.61
	Straw	26.62
Perennial ryegrass/oats	Bare	48.07
	Mat	51.46
	Straw	57.45
95/5 sports turf	Bare	26.94
	Mat	26.88
	Straw	30.73
Tall fescue	Bare	40.59
	Mat	43.92
	Straw	50.21
Wheat	Bare	42.38
	Mat	62.05
	Straw	55.60

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 3.58.

Table 21. Northern Spring Planting Interaction Means Between Seed Variety and Soil Preparation

Seed Variety	Soil Preparation	Mean % Vegetative Cover
Annual Ryegrass	Fine	**92.32**
	Rough	**87.96**
Bermudagrass	Fine	24.80
	Rough	7.15
Buffalograss	Fine	7.83
	Rough	3.08
CRP	Fine	8.36
	Rough	1.48
Cereal Rye	Fine	61.32
	Rough	54.75
Oats	Fine	24.64
	Rough	34.06
Perennial Ryegrass/Oats	Fine	54.99
	Rough	49.67
95/5 Sports Turf	Fine	28.31
	Rough	28.06
Tall Fescue	Fine	45.13
	Rough	44.68
Wheat	Fine	51.51
	Rough	55.17

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 2.92.

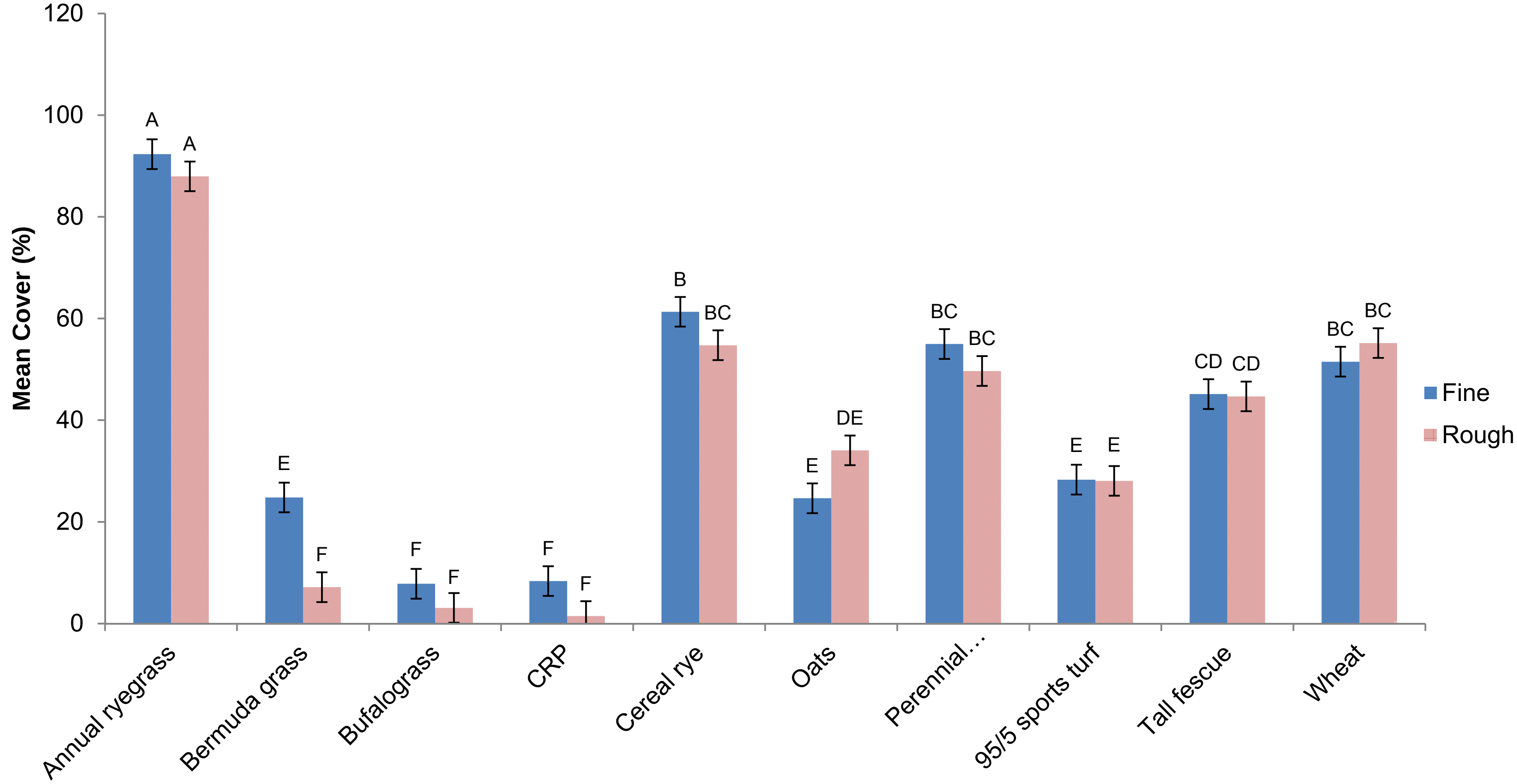


Figure 32. Northern spring planting interaction effect between seed variety and soil preparation. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

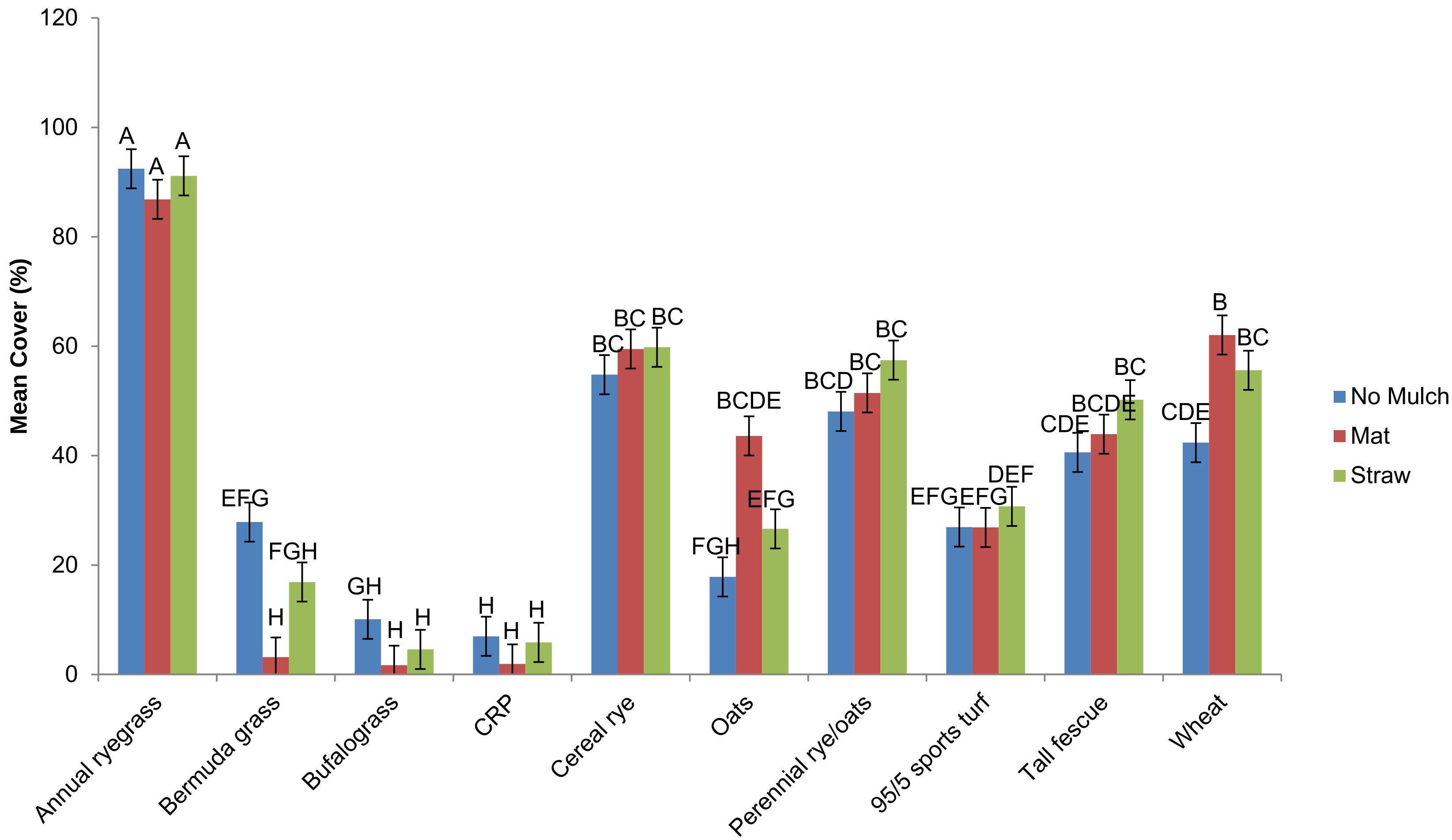


Figure 33. Northern spring planting interaction effect between seed variety and mulch. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

4.3.4.4 Northern Summer

Seed variety showed an interaction effect with soil-preparation treatments and an interaction with mulch treatments (Tables 22 and 23). ANOVA results are summarized in Appendix C, Table C15. Under rough soil preparation, the two high-performing seed varieties, sudex (44.0 ± 3.18) and annual ryegrass (31.2 ± 3.18), showed the highest cover but did not significantly differ from each other (Figure 34). Sudex under straw (48.2 ± 3.9) and mat (41.0 ± 3.9), as well as annual ryegrass under straw (38.5 ± 3.9) and mat (40.3 ± 3.9), yielded the greatest vegetative cover and did not significantly differ from each other or from Bermudagrass (31.6 ± 3.9) and cereal rye (27.386 ± 3.9) under straw mulch (Figure 35).

Greatest vegetative cover at the northern site in the summer can be expected from sudex or annual ryegrass, under rough soil preparation and straw or straw mulch.

Table 22. Northern Summer Planting Interaction Means Between Seed Variety and Soil Preparation

Seed Variety	Soil Preparation	Mean % Vegetative Cover
Annual Ryegrass	Fine	25.93
	Rough	**31.22**
Bermudagrass	Fine	22.50
	Rough	15.97
Buffalograss	Fine	2.56
	Rough	4.25
CRP	Fine	3.89
	Rough	7.46
Cereal Rye	Fine	14.97
	Rough	22.80
Oats	Fine	6.08
	Rough	16.09
Perennial Ryegrass/Oats	Fine	12.36
	Rough	25.54
95/5 Sports Turf	Fine	11.96
	Rough	12.95
Sudex	Fine	22.27
	Rough	**44.01**
Tall Fescue	Fine	8.06
	Rough	11.13

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 3.18.

Table 23. Northern Summer Planting Interaction Means Between Seed Variety and Mulch

Seed Variety	**Mulch**	**Mean % Vegetative Cover**
Annual Ryegrass	Bare	6.93
	Mat	**40.32**
	Straw	**38.47**
Bermudagrass	Bare	7.90
	Mat	18.18
	Straw	**31.63**
Buffalograss	Bare	1.59
	Mat	3.10
	Straw	5.54
CRP	Bare	4.03
	Mat	3.43
	Straw	9.57
Cereal Rye	Bare	6.26
	Mat	23.00
	Straw	**27.39**
Oats	Bare	6.62
	Mat	12.49
	Straw	14.15
Perennial Ryegrass/Oats	Bare	6.33
	Mat	26.59
	Straw	23.93
95/5 Sports Turf	Bare	4.58
	Mat	15.55
	Straw	17.23
Sudex	Bare	10.21
	Mat	**41.01**
	Straw	**48.18**
Tall Fescue	Bare	5.70
	Mat	9.56
	Straw	13.52

Bolded values represent the combinations of treatments that yielded the greatest vegetative cover. Standard error of each mean is 3.90.

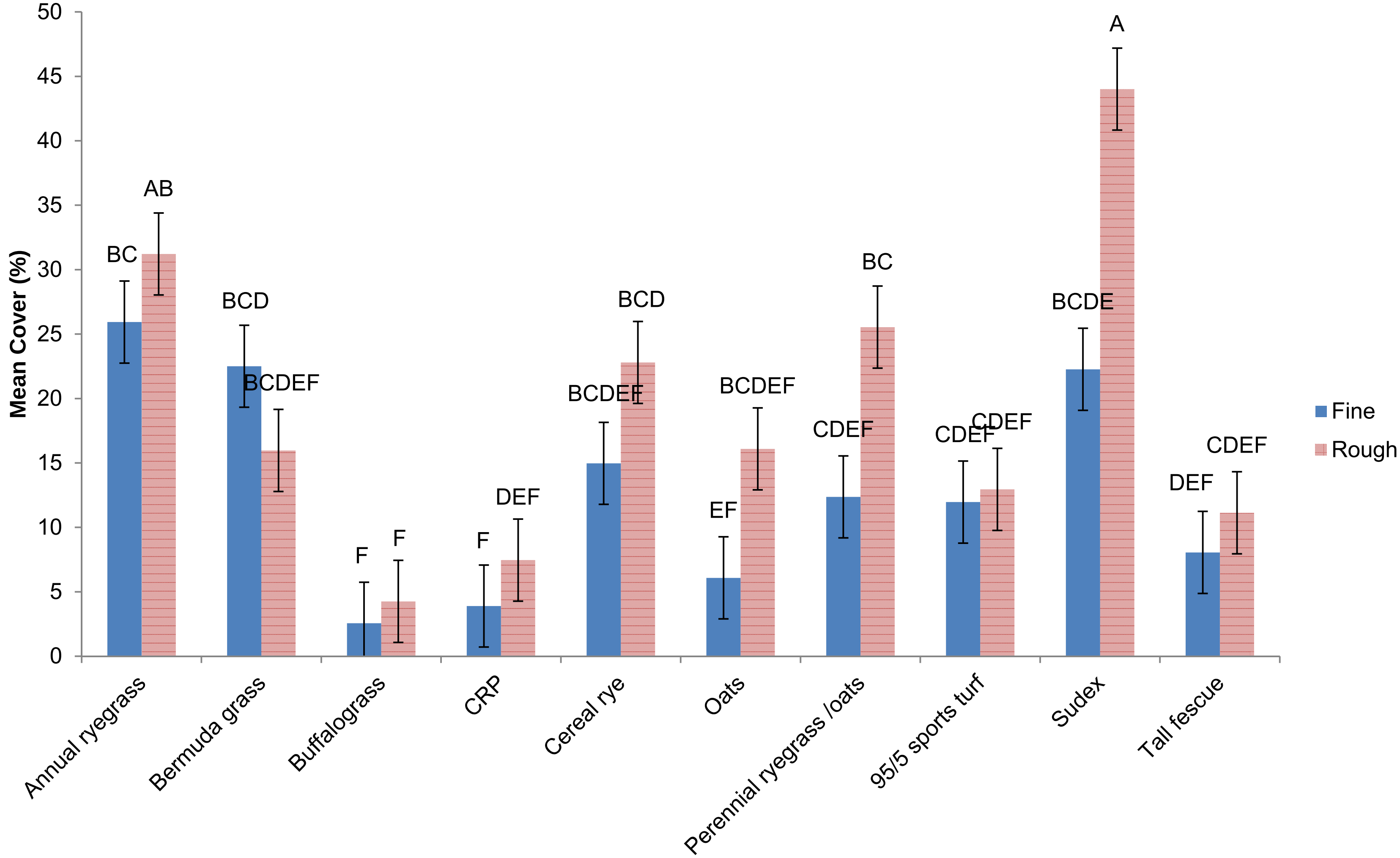


Figure 34. Northern summer planting interaction effect between seed variety and soil preparation. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

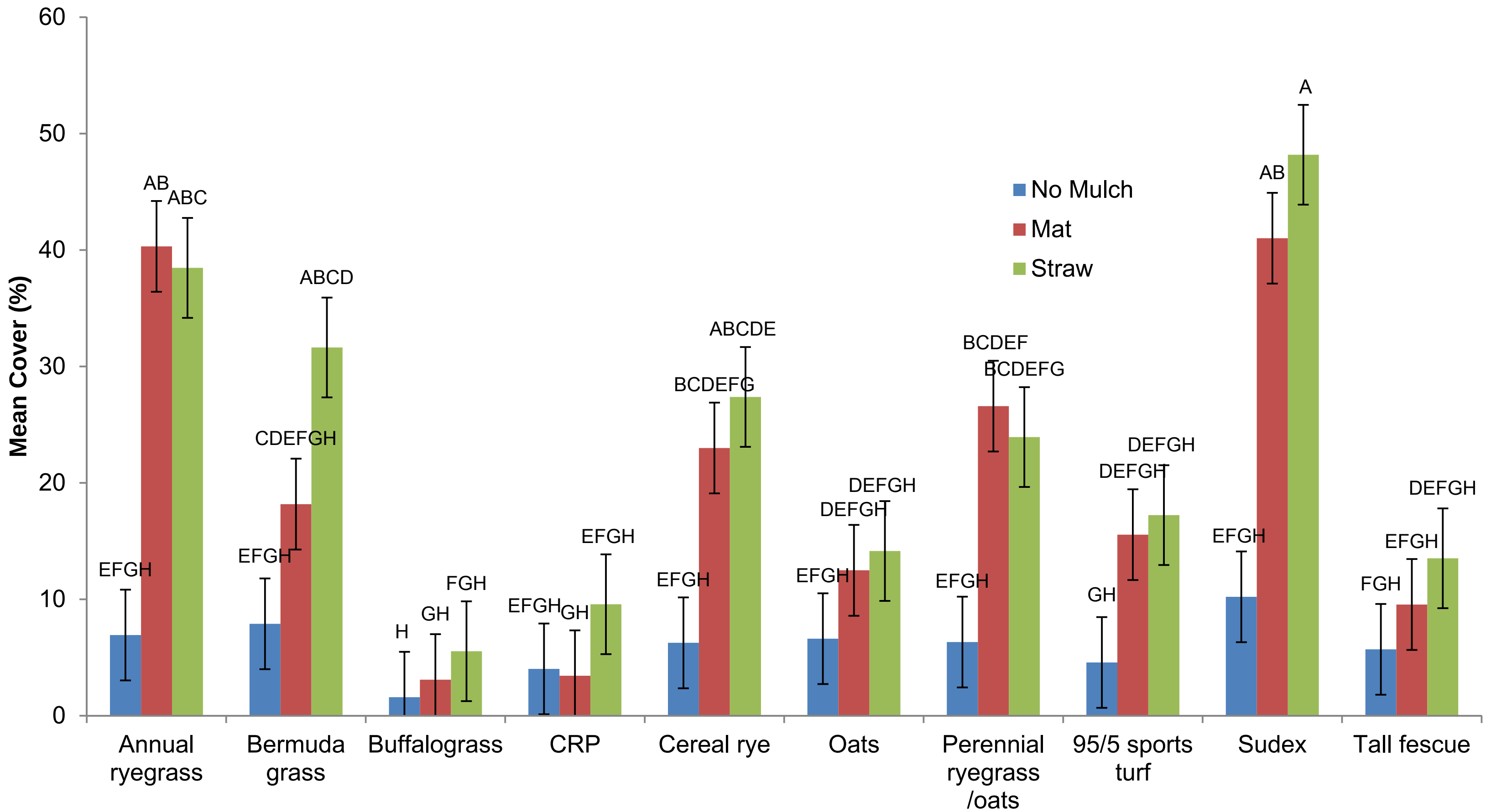


Figure 35. Northern summer planting interaction effect between seed variety and mulch. Error bars represent standard errors. Means that share a letter are not significantly different, based on Tukey-Kramer tests with α = 0.05.

CHAPTER 5 ANALYSIS

5.1 MULCHING

Although the results indicate that both loose straw and straw mats may increase plant performance, loose straw is recommended as it is a less expensive and quicker to install than straw mat. A straw mat takes at least two people to install effectively, while loose straw can easily be applied by one person. Straw is also a more cost-effective mulching treatment than straw mat (Jin and Englande Jr. 2009). In southwestern Illinois, high-quality wheat straw can be purchased for approximately $3 per 40-pound square bale. Straw costs when applied at a rate of 1.25 tons/acre (the rate used in this study) are currently $181.50 per acre, as opposed to $1,938 per acre for straw mat material (Nu-Way Products, personal communication, 2014). Labor hours associated with loose straw are also less than those associated with straw mat, 10 man-hours per acre for loose straw (hand spreading only, no anchoring) per our study, as opposed to 48 man-hours per acre for straw mat (The Korte Company cost history data base, personal communication 2014). We did not test soil-anchoring of loose straw, as our plots were too small to use soil-anchoring equipment. However, observations in this study showed that either muddy conditions during mulching operations or rainfall prior to a wind event served to anchor the loose straw before it was displaced by the wind. At a few sites, wind displaced most of the loose straw within a day of placement.

Another consideration when determining what mulch to use is the slope of the site. The study sites had slopes ranging from 0% to 3%; therefore, the recommendations from this study are best suited to sites that have similar slopes. Straw mat may be effective enough on extremely steep areas to justify its use. Loose straw applied near roadways may be subject to displacement due to air turbulence caused by traffic. In some cases, a combination of straw mat and loose straw mulch may be the best option (Illinois Department of Transportation 2010, Bhattarai et al. 2011).

5.2 SOIL PREPARATION

A smooth, firm, finely tilled seedbed is nearly universally recommended as a precursor for grass seed establishment. This study employed a commercially available power rake, identical to those used by landscaping contractors, to create a prepared seed bed on one-half of the plot areas. The other half of the plot area was left in a minimally tilled condition created with a single pass with a tandem disk. The rough-tilled areas were characterized by an uneven surface and soil clods ranging up to five inches in size. The fine-tilled areas were smooth, even, and had soil particles no larger than 0.5 inch. The hypothesis was that seed varieties would exhibit improved performance on finely tilled areas because of improved soil/seed contact and more uniform moisture conditions. However, at almost all of the study sites, the fine-tillage preparation had a negative effect. The landscape power rake, although successful in creating a more uniform seed bed, reduced the number of under-clod voids and the variety of cracks and small spaces in the soil surface that could aid seed by increasing contact with soil, by providing a more suitable germination climate, or by protecting against seed predation. These results do not mean that fine-tillage operations currently specified for permanent seeding operations should be abandoned. Permanent seeding efforts include subsequent operations to place seed at the appropriate depth and apply specifically designed compactive effort to maximize seed/soil contact and promote germination. Unlike permanent seeding operations using specially designed turf-seed planters, temporary seeding efforts are usually limited to surface broadcast-seeding methods. This study indicated that minimal, rough tillage should be recommended for temporary stabilization efforts that employ broadcast surface-seeding techniques.

5.3 SEED VARIETIES RECOMMENDED BY THIS STUDY

The current specification of a perennial ryegrass and oats mixture never yielded the greatest vegetative cover or close to the highest cover, indicating that the current specification for temporary stabilization could be measurably improved by simply changing the seed-variety specification.

At the majority of the study sites, annual ryegrass was the best-performing seed variety during at least one season. Annual ryegrass (*Lolium perenne* ssp. *multiflorum,* also known as Italian ryegrass) is a common nonnative cool-season grass that is recommended by Kentucky, Missouri, Ohio, Tennessee, and Wisconsin for construction seeding. Annual ryegrass (originally cultivated in Europe) is commonly planted on erosion-control projects because of its strong germination, vigorous growth, and deep-spreading root system (USDA NRCS Northeast Plant Materials Program 2002). Ideal for temporary seeding because of its annual growth cycle, annual ryegrass planted as a soil stabilizer can be easily removed or tilled under at the recommencement of construction activities. However, at the Northern field site, when our plot area was tilled to make way for another experiment, the soil preparation stimulated annual ryegrass regrowth in the area where it previously had been seeded. The annual ryegrass had been allowed to go to seed and had not been treated with herbicide before the plot was tilled. At the Orr site, plots were mowed and sprayed with glyphosate prior to tilling and did not show the same vigorous regrowth.

Across the globe, introduced annual ryegrass is showing a strong ability to develop glyphosate-resistant strains. In New Zealand, a 2013 study showed four vineyard populations of annual ryegrass previously exposed to glyphosate that were ten times more resistant to glyphosate than populations that had not been exposed to the herbicide. One population was 30 times more resistant (Ghanizadeh et al. 2013). A study from Japan also reports wild populations of annual ryegrass showed up to 78% survival rates after application of glyphosate (Niinomi et al. 2013). These are the first confirmed glyphosate-resistant plants found in both New Zealand and Japan. Studies in Oregon and Washington have indicated wild populations of annual ryegrass resistant to multiple herbicides (Liu et al. 2013), and the International Survey of Herbicide Resistant Weeds indicates many recorded instances of annual ryegrass developing herbicide resistance (Heap 2014). Because of its known tendency to establish as an agricultural weed, it would be prudent to do more research into how annual ryegrass behaves in agricultural fields and the potential for spread into agricultural land.

Annual ryegrass is not currently considered a noxious weed in Illinois. Annual ryegrass's ability to spread is of concern to the USDA and other land-management agencies although it has not yet proven to be a problem in natural areas within Illinois. Kentucky lists annual ryegrass as an invasive plant of low risk, and California considers it a noxious weed. Research has shown that annual ryegrass outcompetes and creates thick mats of dead vegetation in vernal pools in the central valley of California, excluding the rare and endemic plants found therein (Gerhardt and Collinge 2007; Faist, A., University of Colorado Boulder, personal communication, 31 March 2014). For this reason, we recommend annual ryegrass with a word of caution, as it has been shown to be invasive in other parts of the country. Annual ryegrass is already recorded in 32 counties in Illinois (USDA and NRCS 2014), so its use by IDOT would not constitute introduction; however, it should be monitored and used only as a temporary soil-stabilization method. Studies should be done to determine effective ways of reducing annual ryegrass spread and seed production. Land managers in California have had success reducing seed production through regular mowing (Mackenzie 2004).

To avoid the problems often posed by nonnative plants, a number of native plants were tested in hopes of finding an alternative to introduced species. The native seeds tested in this study were unable to establish significant cover or rapid growth. None of the native seed varieties tested was able to establish quickly enough to be considered for recommendation for temporary soil stabilization. It is possible that the study methods were not sufficient to establish the native plants for this purpose. Seeding rates were based on existing permanent-seeding recommendations and were lower than those of the higher-performing seed varieties. Additional research should be performed to determine if increasing the seeding rate, changing the seeding method, or changing the mulching method could improve the establishment of vegetative cover among the native species evaluated. It is possible seed predation by granivores was a factor in the failure of the native-seed varieties to germinate. Changes in mulching methods could provide some protection from seed predations; however, plant biomass and litter have been shown to increase seed predation in some cases, as they provide cover for granivores (Reader 1991).

An additional native species that warrants investigation is Cave-In-Rock switchgrass (*Panicum virgatum*), a vigorous perennial warm-season grass. Used on its own or in combination with one of the successful cool-season grasses, it could provide effective year-round ground cover (USDA NRCS 1973).

Sudex, also called sorghum sudangrass, a warm-season hybrid (*Sorghum bicolor x S. bicolor* var. *sudanese*), was one of the top performers during the summer season at SIUE, Northern, and Dixon Springs. A large-leaved plant, Sudex produced plots with high vegetative cover with relatively low plant density. In some cases Sudex grew to be 5.5 feet tall. A downside to vegetation this high and dense is that it is more difficult to remove than a low-growing turf grass. However, Sudex has been shown to be an effective weed suppressor both through shading and allelopathy (Razzaq et al. 2012). A 2011 study showed that native plants established on plots that had been previously seeded with Sudex as a cover crop had more biomass and greater diversity than plots previously seeded with wheat, a common restoration nurse crop (Milchunas et al. 2011). Further studies could find that using sudex as a temporary ground cover may reduce unwanted weeds and increase the effectiveness of the subsequent permanent seeding. Sudex seed may be difficult to obtain, as its use as livestock fodder has declined along with the cattle production in general in Illinois. It is likely that milo, pearl millet, and other varieties of *Sorghum* spp. could be substituted when Sudex seed is not available.

5.4 WINTER PLANTING

Seed plots planted after early December did not germinate until the onset of the following growing season. Temporary seeding operations are not recommended for sites when construction activity halts after approximately Thanksgiving and activities are scheduled to resume before the first week of March, as no significant germination or growth of any variety can be expected during this period. However, for sites that cease ground-disturbing activities in late fall and are not scheduled to resume operations until after mid-March, temporary seeding using dormant-seeding techniques should be employed immediately following the cessation of land-disturbing activities. Dormant seeding allows seeds to take immediate advantage of favorable weather and soil conditions. This study indicated that dormant seeding can be successful even when conducted on snow pack and hard-frozen soils. Winter-seeded annual ryegrass was the first to germinate and clearly provided the best cover at Dixon Springs, Northern, and Orr. Weed pressure, primarily from meadow grass (*Poa annua*) and brome (*Bromus* sp.), interfered with the ability to accurately evaluate winter-seeding variety performance at the SIUE site. Nonetheless previous observations of dormant-seeded annual ryegrass in the vicinity of SIUE indicate that annual ryegrass would likely be the best-performing variety in the southwest region of Illinois.

5.5 ADDITIONAL RESEARCH

Because of this study's experimental design, treatments were tested on small, uniform plots of land. Repeating tests on a larger scale could increase the reliability of recommended temporary turf performance on larger areas, differing soil types and steeper slopes, and in different weather conditions. This study took place in years that had above-average precipitation (43.8 inches, 3.6 inches above average) and below-average temperatures (50.8°F, 1.4°F below average) (Illinois Climate Network 2014). It is possible that drought or unusually hot or cold years could have an impact on the performance of recommended seed varieties.

CHAPTER 6 CONCLUSION AND RECOMMENDATIONS

This study found that the current temporary turf specification used by the Illinois Department of Transportation is not the most effective temporary stabilization method. The currently prescribed mixture of perennial ryegrass and oats was not a top performer at any of the test sites in any season. Treatment combinations yielding the greatest vegetative cover are summarized in Table 24. No single variety performed equally well at all sites and in all seasons. To better stabilize soils on construction sites in Illinois, one can use the results of this study to develop regionally and seasonally tailored specifications. The recommendations based on the findings of this study could further be improved and validated by testing the most effective treatments of this study on a larger scale, repeating the experiment with additional seed varieties on a greater range of planting dates, and altering the tested treatments (i.e., changing seeding rates/methods). Based on the results of this study, specific recommendations are as follow.

6.1 RECOMMENDATION 1, STATEWIDE, ALL SITES WITH SHORT CESSATION

On sites where land-disturbing activities are scheduled to cease for at least 14 days but no more than 30 days, temporary soil stabilization should consist of loose straw only, applied at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored immediately following cessation of land-disturbing activities.

6.2 RECOMMENDATION 2, STATEWIDE, ALL WINTER-PERIOD-ONLY CESSATION SITES

On sites where land-disturbing activities are scheduled to cease after Thanksgiving and resume again before 1 March, temporary soil stabilization should consist of loose straw only, at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored immediately following cessation of land-disturbing activities.

6.3 RECOMMENDATION 3, STATEWIDE, ALL WINTER-PERIOD-CESSATION AND SPRING-OR-LATER-RESUMPTION SITES

On sites where land-disturbing activities are scheduled to cease after Thanksgiving and resume after 1 March, temporary soil stabilization should consist of a dormant seeding, immediately following cessation of land-disturbing activities, with annual ryegrass at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.4 RECOMMENDATION 4, STATEWIDE, ALL SPRING-CESSATION SITES

On sites where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 1 March until 15 June, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with annual ryegrass at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.5 RECOMMENDATION 5, CENTRAL AND NORTHERN SITES, SUMMER CESSATION

On sites north of Rend Lake where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 16 June until 15 August, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with annual ryegrass at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.6 RECOMMENDATION 6, SOUTHERN SITES, SUMMER CESSATION

On sites south of Rend Lake where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 16 June until 15 August, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with Sudex at a rate of 35 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.7 RECOMMENDATION 7, STATEWIDE, EARLY-FALL-CESSATION SITES

On sites where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 15 August until 1 October, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with annual ryegrass at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.8 RECOMMENDATION 8, NORTHERN SITES, LATE-FALL-CESSATION SITES

On sites north of Bloomington, Illinois, where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 1 October until Thanksgiving, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with tall fescue at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

6.9 RECOMMENDATION 9, CENTRAL AND SOUTHERN SITES, LATE-FALL CESSATION SITES

On sites south of Bloomington, Illinois, where land-disturbing activities are scheduled to cease temporarily for more than 30 days beginning on dates ranging from 1 October until Thanksgiving, temporary soil stabilization should consist of seeding, immediately following the cessation of land-disturbing activities, with annual ryegrass at a rate of 150 pounds per acre and the application of loose straw at a rate of at least 1.25 tons per acre. Loose straw should be soil-anchored.

Table 24. Summary of Experimental Results by Region and Season*

Site	Region	USDA Zone	Treatment	Fall	Cover (%)	Spring	Cover (%)	Summer	Cover (%)	Winter	Cover (%)
Northern	North of I-80	5a 5b	Seed variety:	Tall fescue**	60	Annual ryegrass	92.3	Annual ryegrass or Sudex	48.4	Annual ryegrass	5.4
			Soil preparation:	No result		No effect		Rough		NA	
			Mulch:	No result		No effect		Straw or mat		NA	
Orr	North of I-72 South of I-80	5b	Seed variety:	Wheat, Barley, or Cereal rye	2.2	Annual ryegrass	80.7	Annual ryegrass	69.7	Annual ryegrass	58.8
			Soil preparation:	Rough		Rough		Rough		NA	
			Mulch:	Straw or mat		No effect		Straw or mat		No effect	
SIUE	North of I-64 South of I-72	6a	Seed variety:	Annual ryegrass or Wheat	17.6	Annual ryegrass	42.3	Annual ryegrass or Sudex	21.7	Annual ryegrass ****	38
			Soil preparation:	No effect		Rough		No effect		NA	
			Mulch:	Straw or mat		Mat		Straw or mat		No effect	
Dixon Springs	South of I-64	6b 7a	Seed variety:	Cereal rye	28.2	Annual ryegrass	89.1	Sudex	100	Annual ryegrass	12.33
			Soil preparation:	No effect		No effect		***		NA	
			Mulch:	Straw or mat		No effect		No mulch or straw		No effect	

*This table shows the combination of treatments that yielded the greatest vegetative cover at each site in each season. The highest observed mean vegetative cover is listed in the cover [%] column. **Data affected by flooding. ***No data because of plot encroachment by corn. ****Based on previous observations.

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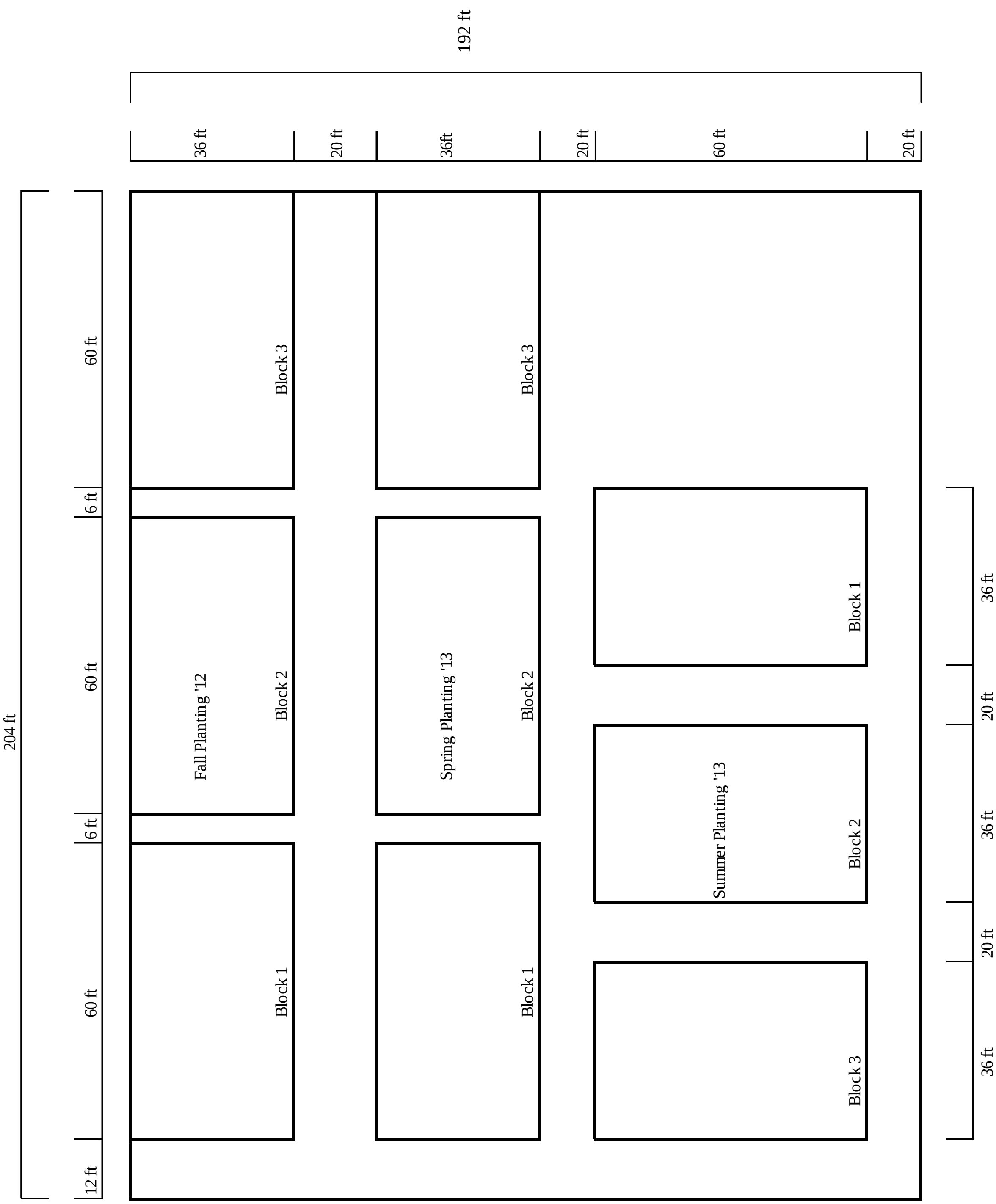
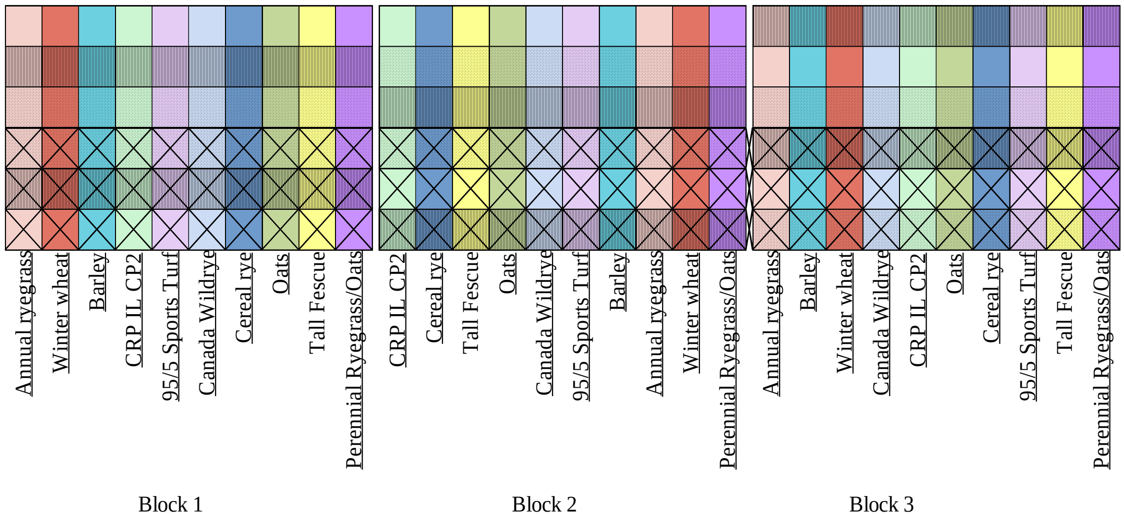
APPENDIX A PLOT DESIGN

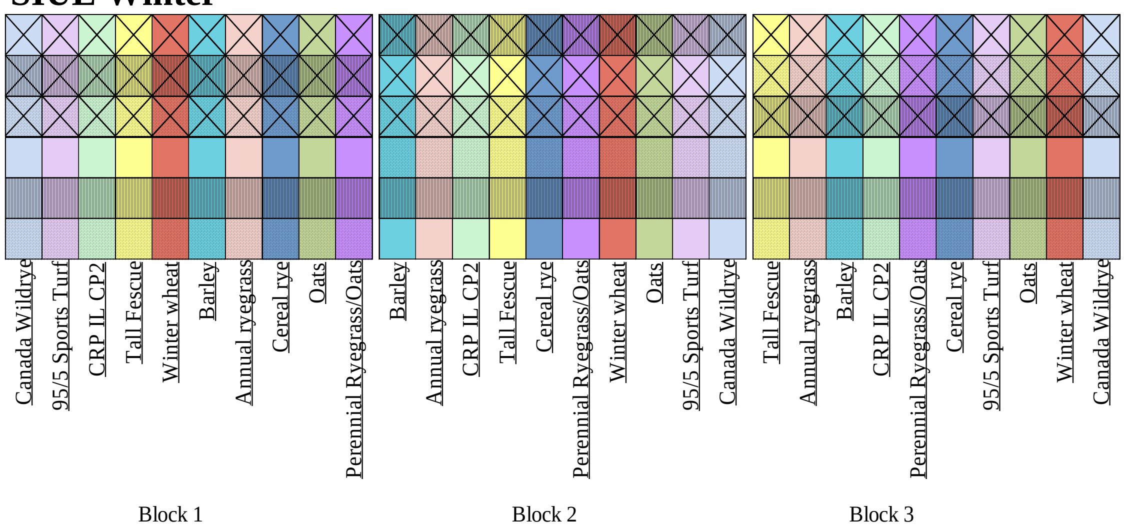
SIUE PLOT DESIGN



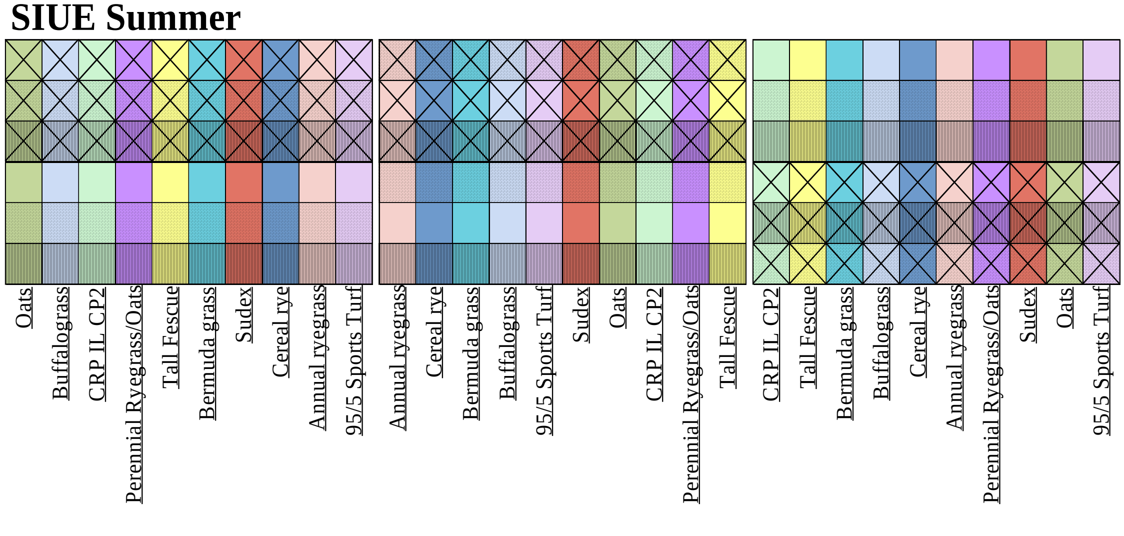
SIUE Fall

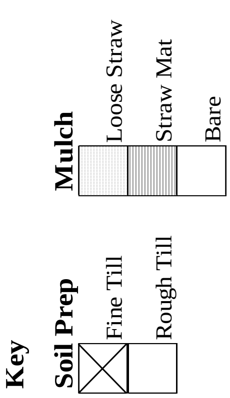


SIUE Winter

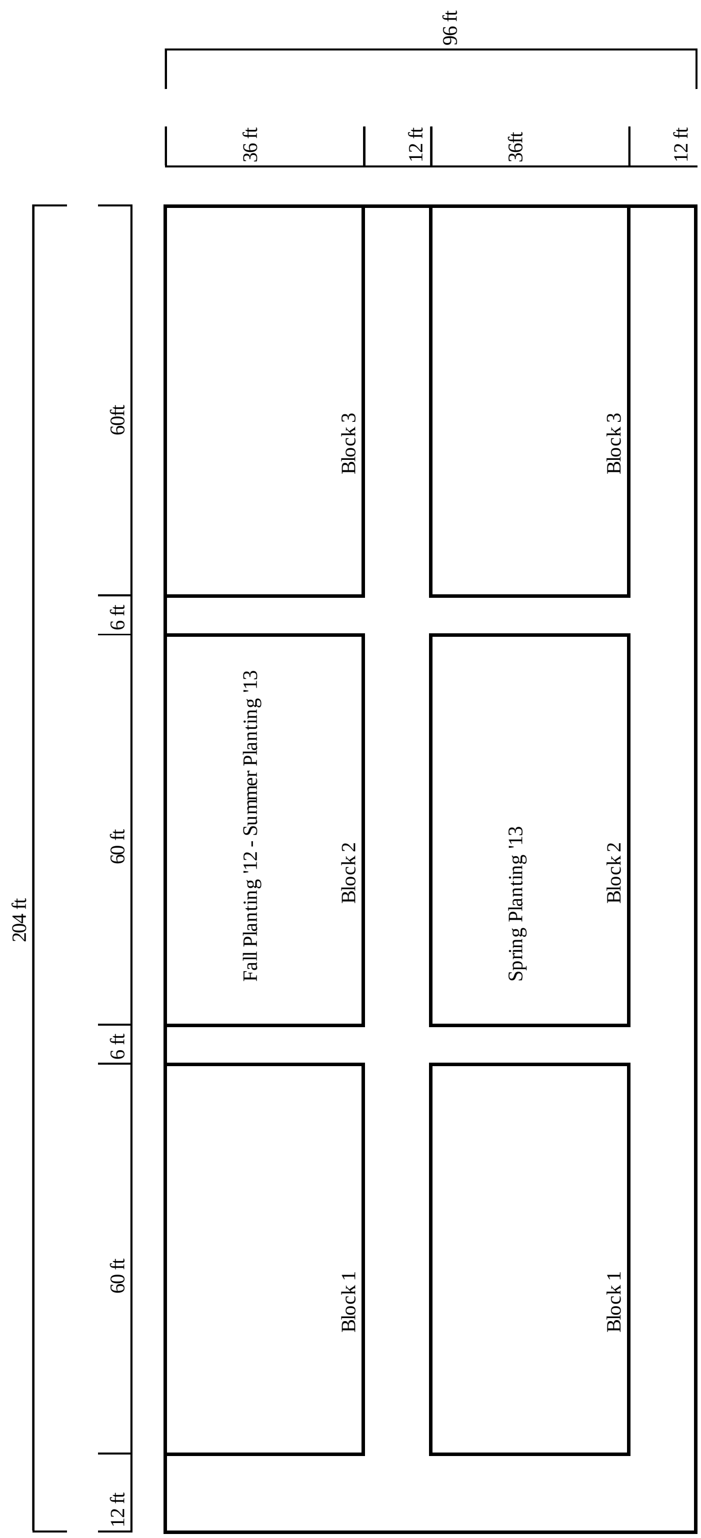


SIUE Summer





ORR PLOT DESIGN



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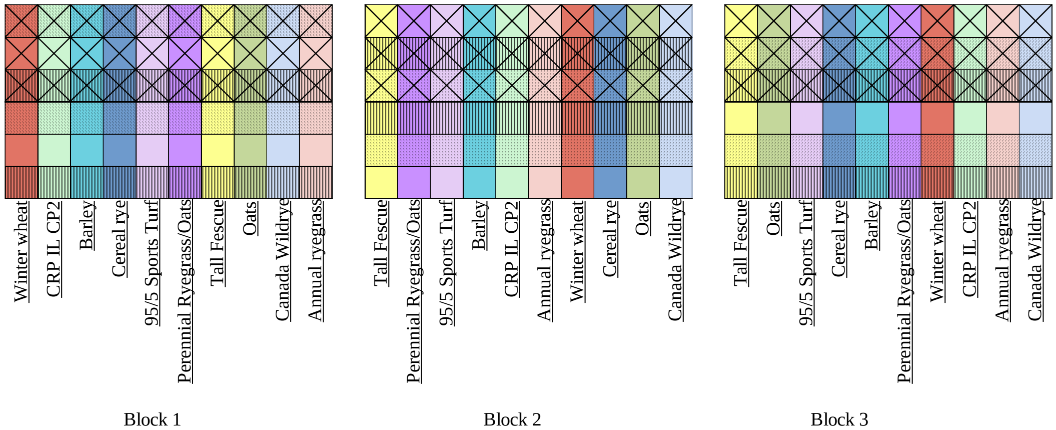
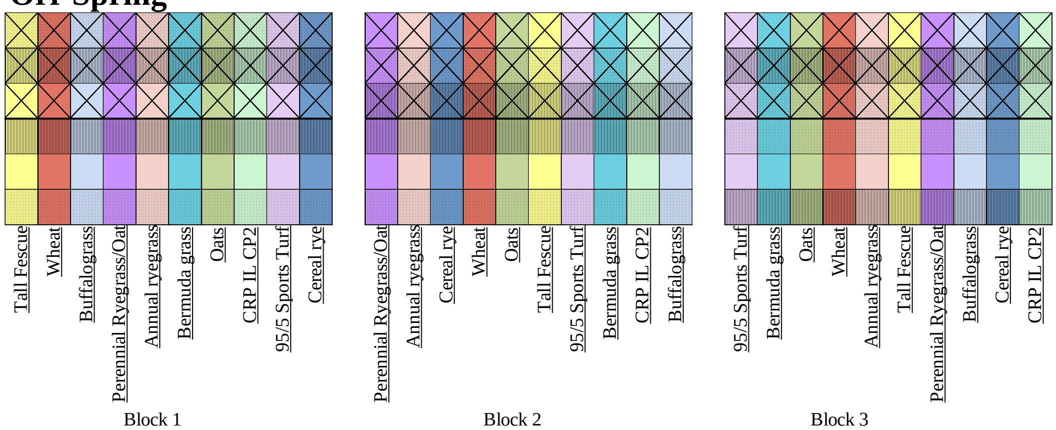


Orr Spring



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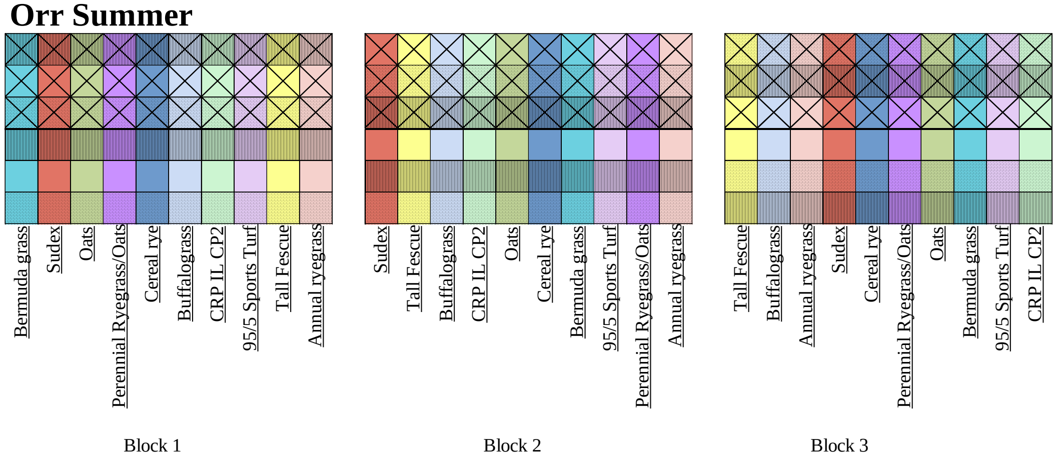
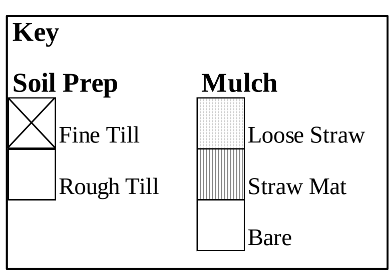
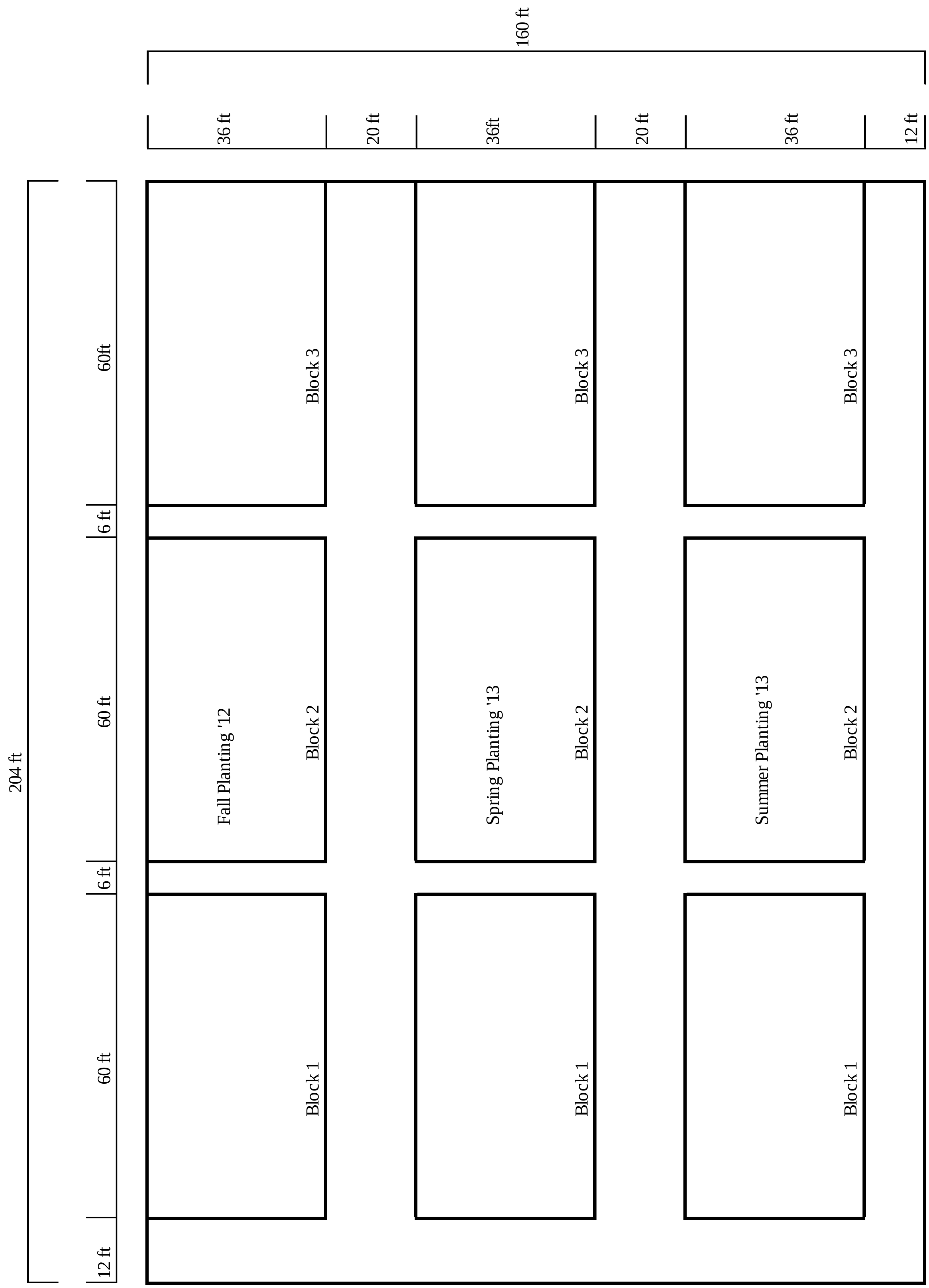
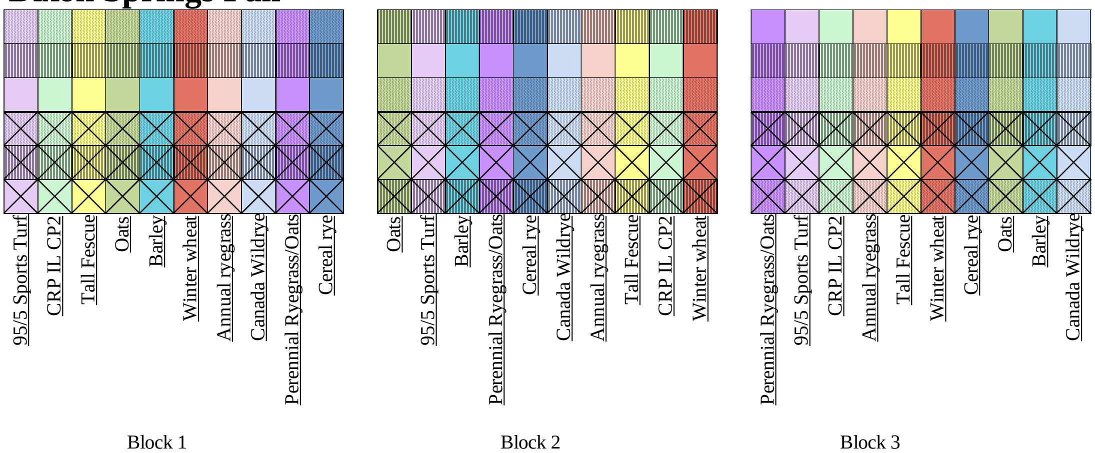




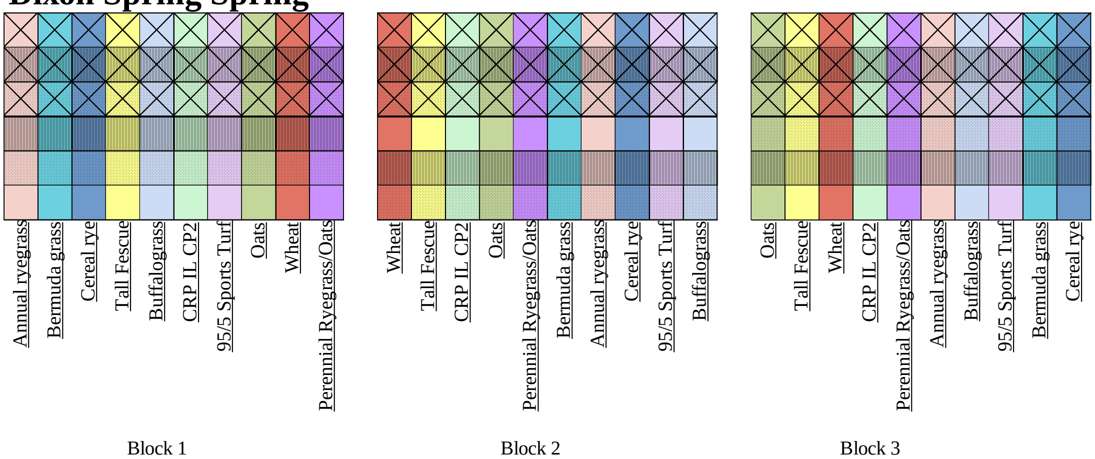
DIXON SPRINGS PLOT DESIGN



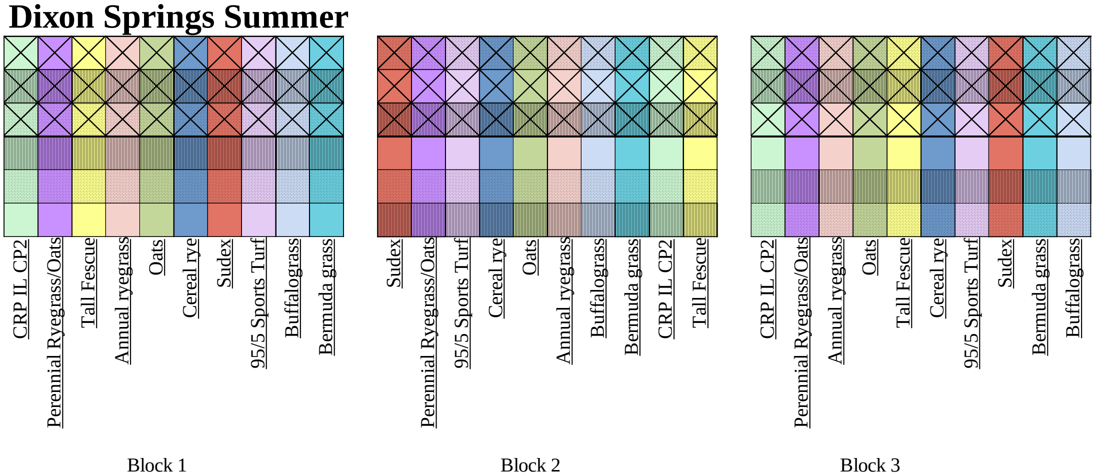
Dixon Springs Fall

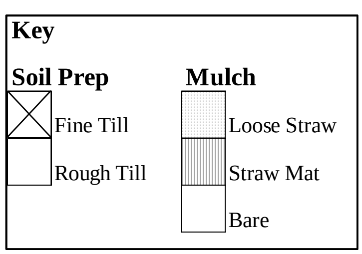


Dixon Spring Spring

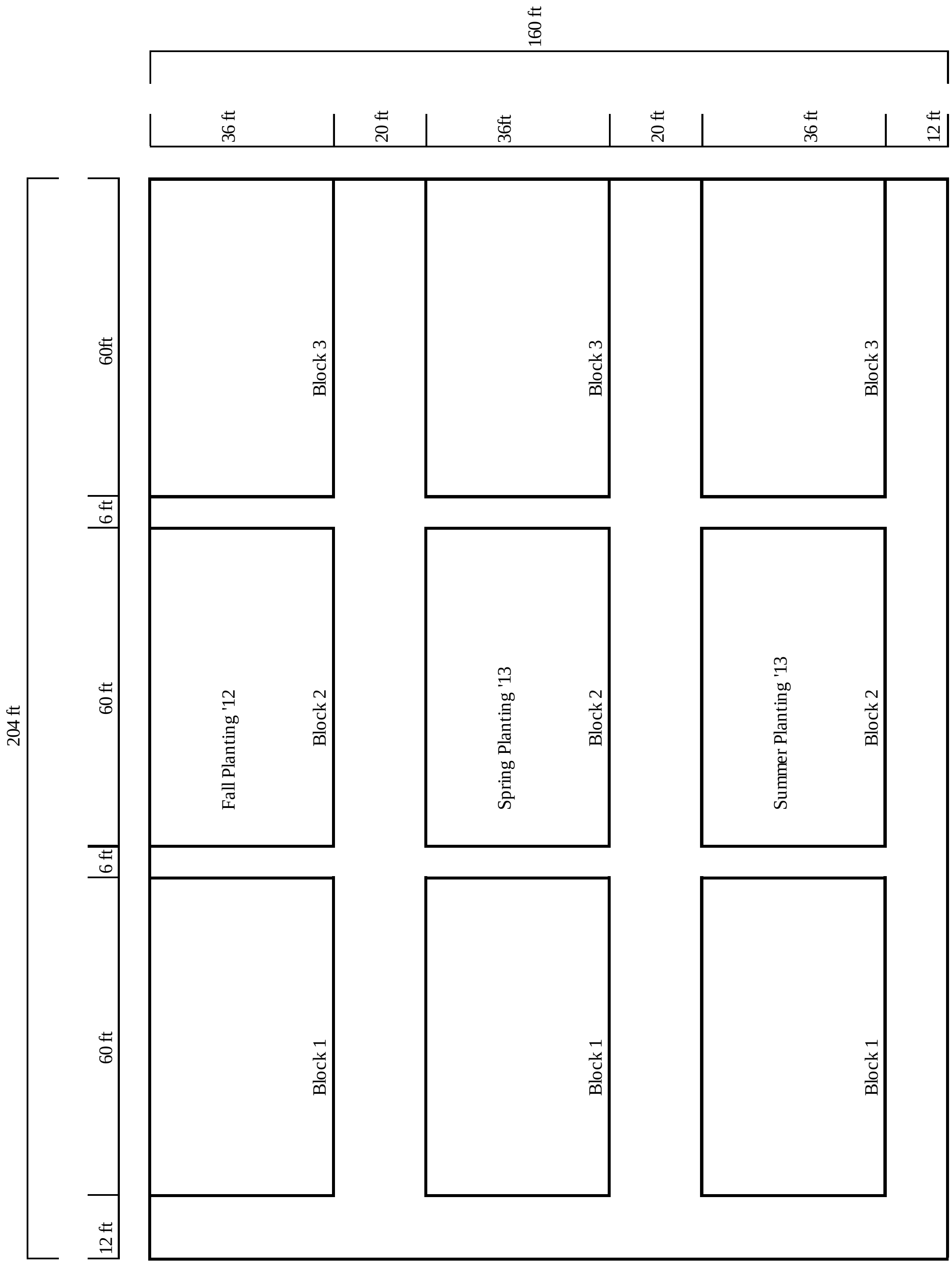


Dixon Springs Summer

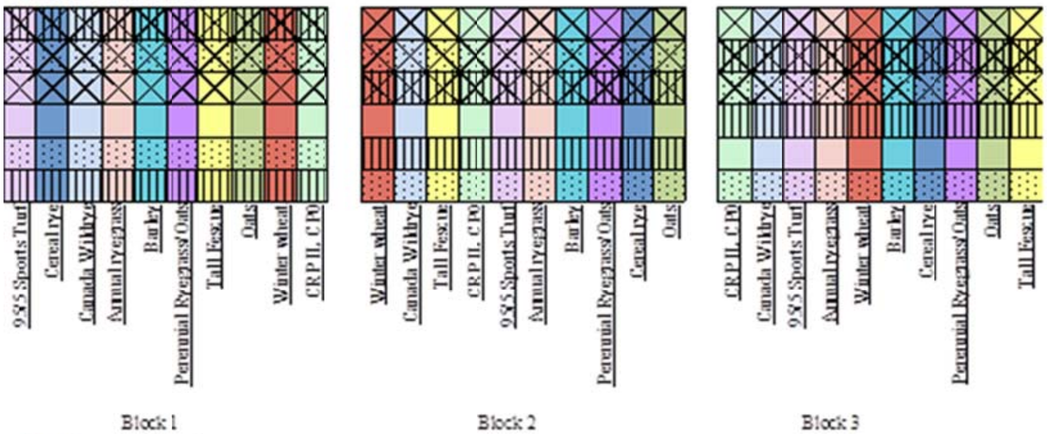




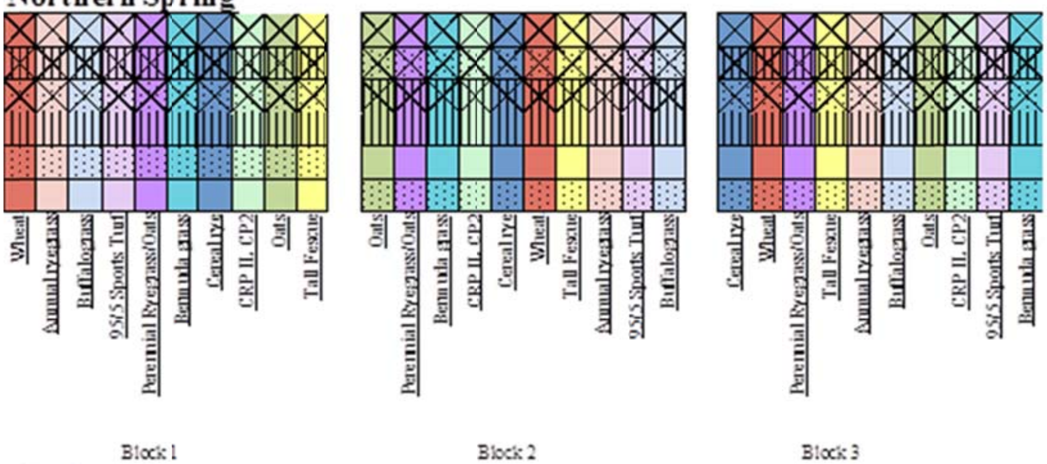
NORTHERN PLOT DESIGN



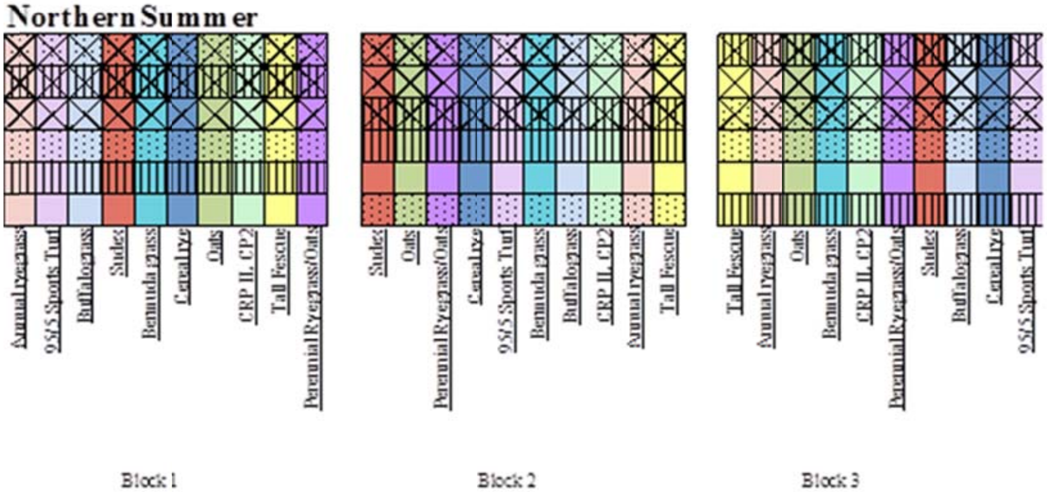
Northern Fall

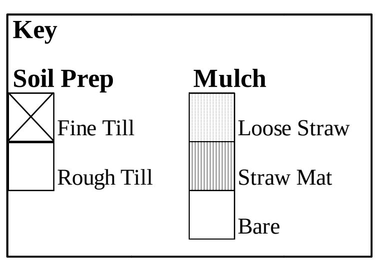


Northern Spring



Northern Summer

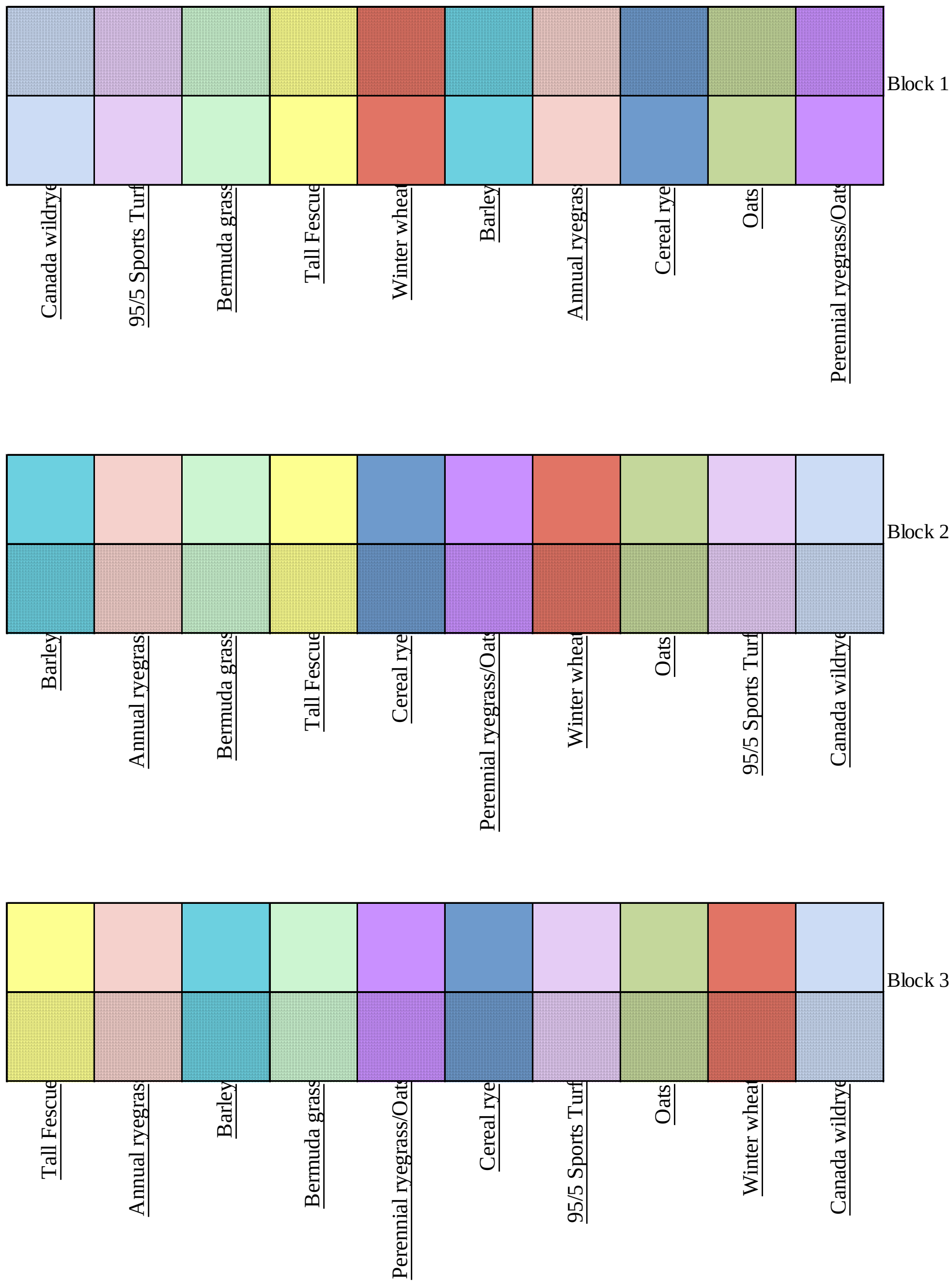




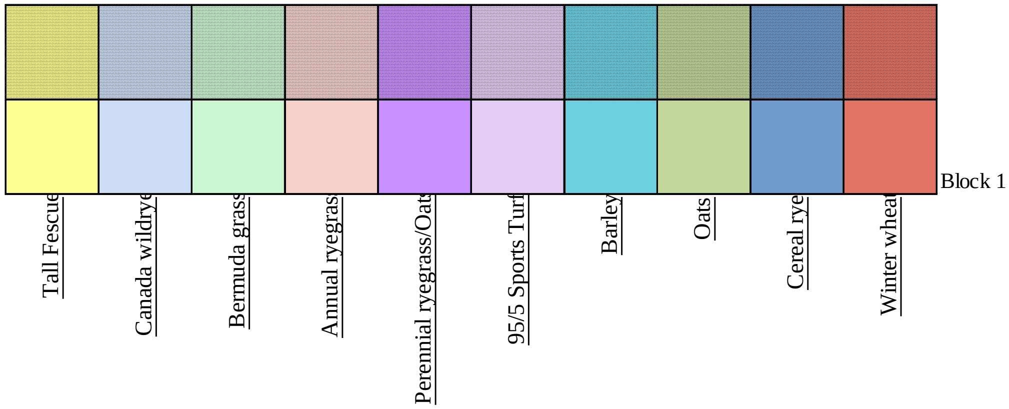
APPENDIX B MODIFIED WINTER PLANTING DESIGN

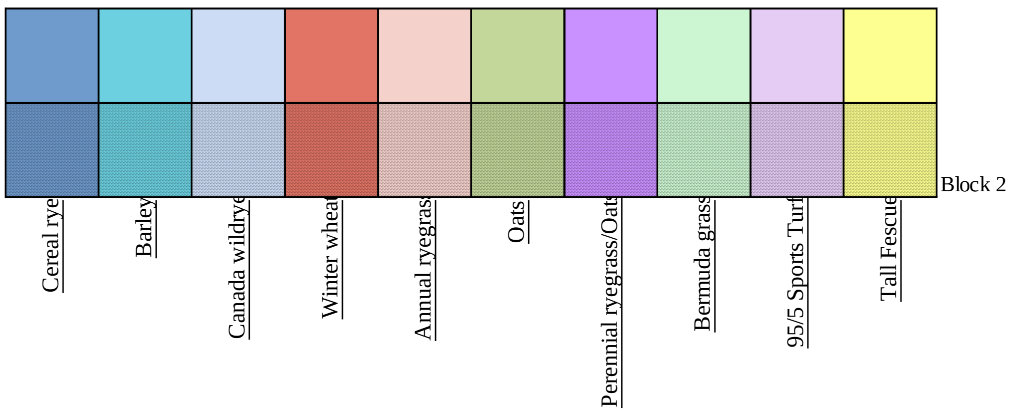
Cells with hatching represent straw-mulch treatment.

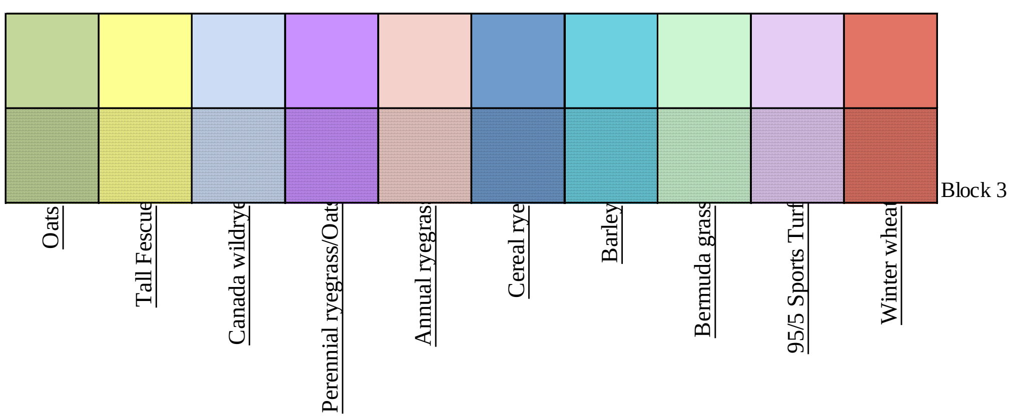
SIUE Winter



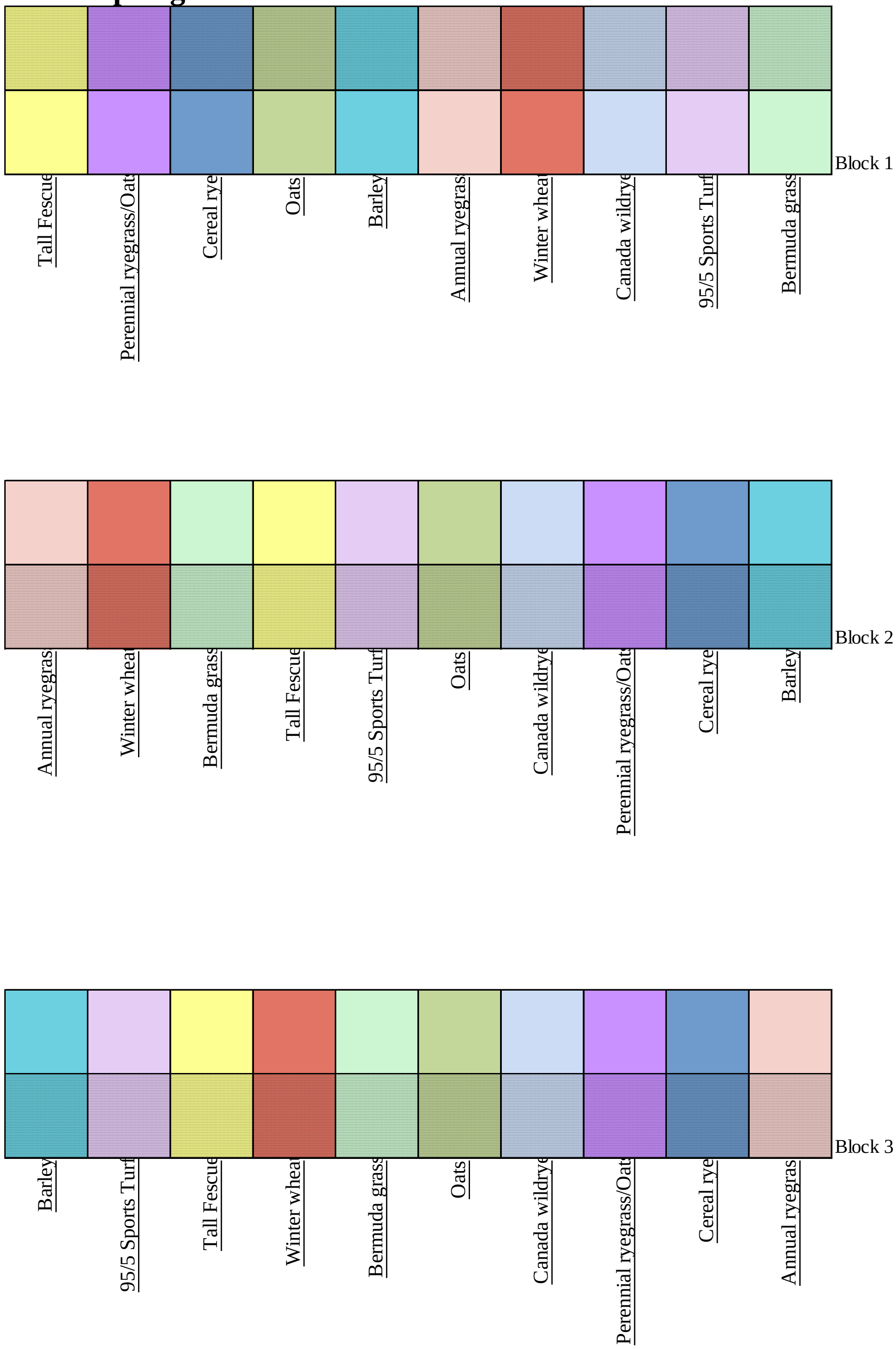
Orr Winter


Block 1
Tall Fescue
Canada wildrye
Bermuda grass
Annual ryegras
Perennial ryegrass/Oats
95/5 Sports Turf
Barley
Oats
Cereal rye
Winter wheat

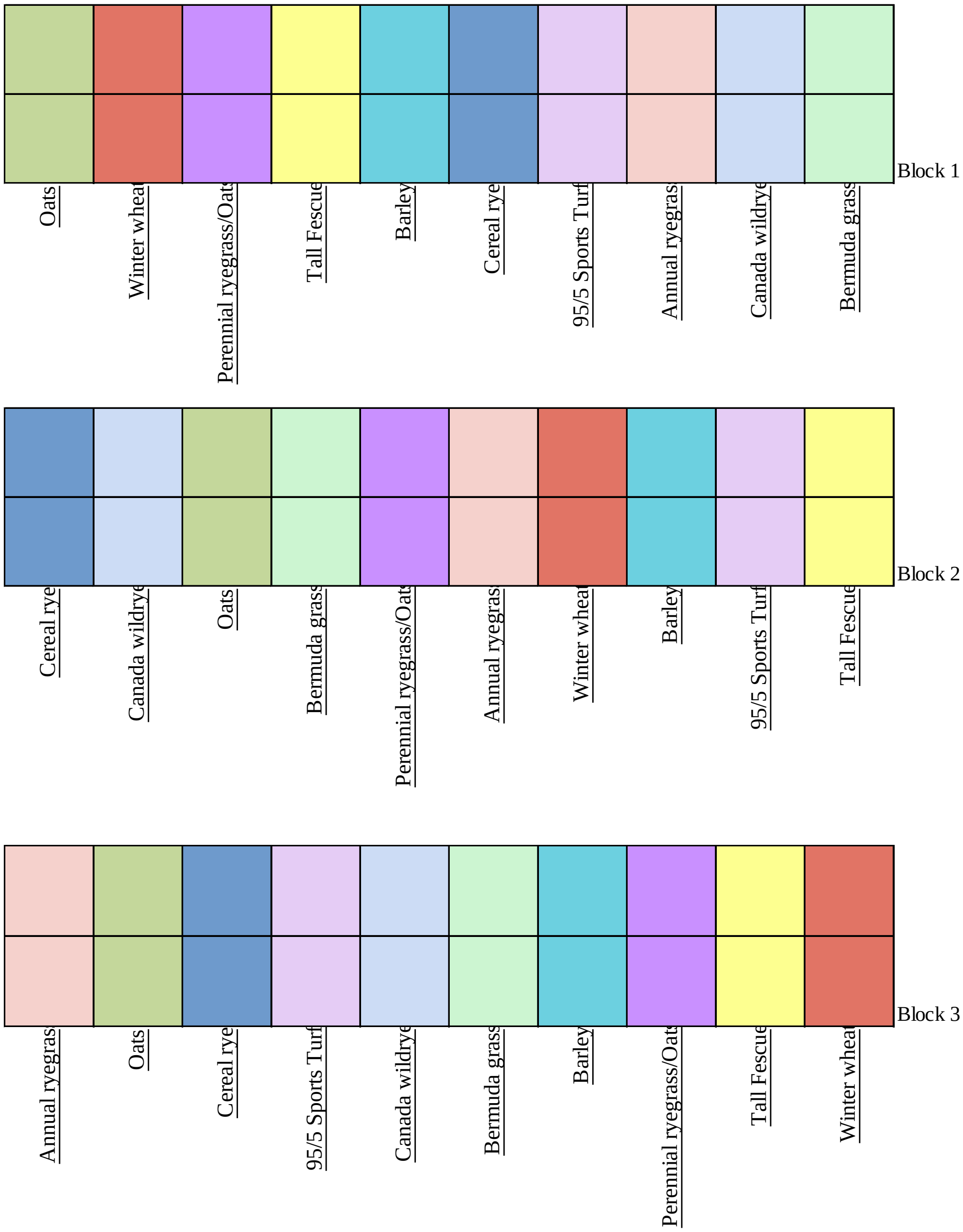

Block 2
Cereal rye
Barley
Canada wildrye
Winter wheat
Annual ryegras
Oats
Perennial ryegrass/Oats
Bermuda grass
95/5 Sports Turf
Tall Fescue


Block 3
Oats
Tall Fescue
Canada wildrye
Perennial ryegrass/Oats
Annual ryegras
Cereal rye
Barley
Bermuda grass
95/5 Sports Turf
Winter wheat

Dixon Springs Winter



Northern Winter



APPENDIX C ANOVA TABLES

Table C1. SIUE Fall ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	2259.29	1129.65	32.82	< 0.0001
Soil Prep	1	43.38	43.38	1.26	0.2644
Mulch	2	515.56	257.78	7.49	0.0010
Soil Prep x Mulch	2	42.64	21.32	0.62	0.5404
Seed Variety	7	3313.51	473.36	13.75	< 0.0001
Seed Variety x Soil Prep	7	69.85	9.98	0.29	0.9564
Seed Variety x Mulch	14	644.47	46.03	1.34	0.2008
Seed Variety x Soil Prep x Mulch	14	113.92	8.14	0.24	0.9979
Error	94	3235.58	34.42		
Total	143	10238.20			

Table C2. SIUE Winter ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	3762.61	1881.31	5.88	0.0059
Mulch	1	32.94	32.94	0.1	0.7500
Seed Variety	9	2318.08	257.56	0.81	0.6139
Seed Variety x Mulch	9	1123.29	124.81	0.39	0.9323
Total	21	7236.92			

Table C3. SIUE Spring ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	1687.58	843.79	18.71	< 0.0001
Soil Prep	1	913.05	913.05	20.24	< 0.0001
Mulch	2	1234.86	617.43	13.69	< 0.0001
Soil Prep x Mulch	2	19.65	9.82	0.22	0.8046
Seed Variety	9	9475.86	1052.87	23.34	< 0.0001
Seed Variety x Soil Prep	9	1025.24	113.92	2.53	0.0110
Seed Variety x Mulch	18	859.95	47.77	1.06	0.4016
Seed Variety x Soil Prep x Mulch	18	311.65	17.31	0.38	0.9887
Error	118	5321.91	45.10		
Total	179	20849.74			

Table C4. SIUE Summer ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	868.53	434.26	8.81	0.0003
Soil Prep	1	131.84	131.84	2.67	0.1046
Mulch	2	1004.44	502.22	10.19	< 0.0001
Soil Prep x Mulch	2	24.79	12.40	0.25	0.7781
Seed Variety	9	7214.97	801.66	16.26	< 0.0001
Seed Variety x Soil Prep	9	349.28	38.81	0.79	0.6285
Seed Variety x Mulch	18	1090.96	60.61	1.23	0.2492
Seed Variety x Soil Prep x Mulch	18	174.53	9.70	0.20	0.9999
Error	118	5816.64	49.29		
Total	179	16675.98			

Table C5. Orr Fall ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	11.20	5.60	10.75	0.0002
Soil Prep	1	7.34	7.34	14.09	0.0007
Mulch	2	4.69	2.34	4.50	0.0185
Soil Prep x Mulch	2	6.90	3.45	6.62	0.0037
Seed Variety	2	0.46	0.23	0.44	0.6457
Seed Variety x Soil Prep	2	1.65	0.83	1.59	0.2193
Seed Variety x Mulch	4	0.83	0.21	0.40	0.8066
Seed Variety x Soil Prep x Mulch	4	1.23	0.31	0.59	0.6711
Error	34	17.70	0.52		
Total	53	52.00			

Table C6. Orr Winter ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	3535.22	1767.61	3.54	0.0390
Mulch	1	255.48	255.48	0.51	0.4790
Seed Variety	9	9191.65	1021.29	2.04	0.0608
Seed Variety x Mulch	9	7236.02	804.00	1.61	0.1478
Total	21	20218.37			

Table C7. Orr Spring ANOVA Table

Source	**DF**	**Type III SS**	**Mean Square**	**F**	**P**
Block	2	22228.18	11114.09	102.20	< 0.0001
Soil Prep	1	3432.04	3432.04	31.56	< 0.0001
Mulch	2	635.09	317.55	2.92	0.0578
Soil Prep x Mulch	2	413.71	206.85	1.90	0.1538
Seed Variety	9	51800.91	5755.66	52.93	< 0.0001
Seed Variety x Soil Prep	9	1916.76	212.97	1.96	0.0502
Seed Variety x Mulch	18	1585.94	88.11	0.81	0.6851
Seed Variety x Soil Prep x Mulch	18	617.07	34.28	0.32	0.9965
Error	118	12832.05	108.75		
Total	179	95461.76			

Table C8. Orr Summer ANOVA Table

Source	**DF**	**Type III SS**	**Mean Square**	**F**	**P**
Block	2	1181.59	590.79	7.04	0.0013
Soil Prep	1	1971.01	1971.01	23.47	< 0.0001
Mulch	2	589.23	294.62	3.51	0.0331
Soil Prep x Mulch	2	1067.72	533.86	6.36	0.0024
Seed Variety	9	40904.63	4544.96	54.12	< 0.0001
Seed Variety x Soil Prep	9	858.53	95.39	1.14	0.3431
Seed Variety x Mulch	18	3048.54	169.36	2.02	0.0136
Seed Variety x Soil Prep x Mulch	18	1138.48	63.25	0.75	0.7494
Error	118	9909.07	83.98		
Total	179	60668.80			

Table C9. Dixon Springs Fall ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	197.25	98.62	12.32	< 0.0001
Soil Prep	1	23.61	23.61	2.95	0.0886
Mulch	2	127.75	63.87	7.98	0.0006
Soil Prep x Mulch	2	69.59	34.79	4.34	0.0151
Seed Variety	9	9098.46	1010.94	126.24	< 0.0001
Seed Variety x Soil Prep	9	124.40	13.82	1.73	0.0904
Seed Variety x Mulch	18	813.49	45.19	5.64	< 0.0001
Seed Variety x Soil Prep x Mulch	18	159.28	8.85	1.11	0.3561
Error	118	944.92	8.01		
Total	179	11558.74			

Table C10. Dixon Springs Winter ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	18.13	9.07	1.07	0.3538
Mulch	1	0.30	0.30	0.04	0.8512
Seed Variety	9	730.49	81.17	9.56	< 0.0001
Seed Variety x Mulch	9	25.60	2.84	0.34	0.9576
Total	21	774.52			

Table C11. Dixon Springs Spring ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	1554.95	777.47	6.69	0.0018
Soil Prep	1	20828.13	20828.13	179.15	< 0.0001
Mulch	2	4348.11	2174.06	18.70	< 0.0001
Soil Prep x Mulch	2	2346.54	1173.27	10.09	< 0.0001
Seed Variety	9	41507.33	4611.93	39.67	< 0.0001
Seed Variety x Soil Prep	9	2611.46	290.16	2.50	0.0120
Seed Variety x Mulch	18	4630.90	257.27	2.21	0.0060
Seed Variety x Soil Prep x Mulch	18	2382.80	132.38	1.14	0.3247
Error	118	13718.48	116.26		
Total	179	93928.71			

Table C12. Dixon Springs Summer ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	107.66	53.83	0.34	0.7112
Mulch	2	2557.88	1278.94	8.14	0.0008
Seed Variety	9	17280.72	1920.08	12.23	< 0.0001
Seed Variety x Mulch	18	3697.95	205.44	1.31	0.2172
Error	58	9109.49	157.06		
Total	89	32753.70			

Table C13. Northern Winter ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	6.60	3.30	1.29	0.3000
Seed Variety	9	74.37	8.26	3.23	0.0165
Total	11	80.97			

Table C14. Northern Spring ANOVA Table

Source	DF	Type III SS	Mean Square	F	P
Block	2	376.56	188.28	2.45	0.0906
Soil Prep	1	494.21	494.21	6.43	0.0125
Mulch	2	288.95	144.47	1.88	0.1571
Soil Prep x Mulch	2	232.34	116.17	1.51	0.2247
Seed Variety	9	115512.16	12834.68	167.05	< 0.0001
Seed Variety x Soil Prep	9	2089.61	232.18	3.02	0.0028
Seed Variety x Mulch	18	5929.16	329.40	4.29	< 0.0001
Seed Variety x Soil Prep x Mulch	18	1328.27	73.79	0.96	0.5094
Error	118	9066.10	76.83		
Total	179	135317.35			

Table C15. Northern Summer ANOVA Table

Source	**DF**	**Type III SS**	**Mean Square**	**F**	**P**
Block	2	119.60	59.80	0.66	0.5211
Soil Prep	1	1664.90	1664.90	18.25	< 0.0001
Mulch	2	9552.98	4776.49	52.35	< 0.0001
Soil Prep x Mulch	2	160.73	80.36	0.88	0.4172
Seed Variety	9	14797.37	1644.15	18.02	< 0.0001
Seed Variety x Soil Prep	9	2405.29	267.25	2.93	0.0036
Seed Variety x Mulch	18	5327.77	295.99	3.24	< 0.0001
Seed Variety x Soil Prep x Mulch	18	2062.43	114.58	1.26	0.2300
Error	118	10766.45	91.24		
Total	179	46857.52			