THE USE OF NURSE CROPS FOR ROADSIDE REVEGETATION

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AUTHORIZATION TO SUBMIT THESIS

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Abstract

Roadside slope failures, erosion, and stream sedimentation represent major challenges to highway building and repair in Idaho. Slope failures on roadsides increase the need for ditch maintenance, degrade the aesthetic character of the environment, pollute streams, increase opportunities for weed establishment, and decrease motorist safety. Roadside vegetation reduces erosion by intercepting precipitation and increasing infiltration, which leads to decreased surface erosion. Considerable resources must be invested into roadside revegetation, because the soil of these sites is highly altered and commonly infertile. Construction and maintenance schedules often do not correspond to the proper planting times for roadside seeding creating further challenges for roadside revegetation. Perennial grasses, low growing forbs and shrubs have proven superior for their soil-holding abilities, but they are often slow to establish. Nurse crops can be utilized to fill the gap in the slow establishment phase of perennial plants. Nurse crops are rapidly growing annual plants sown with slower growing perennial plants. The overall objective of this study was to provide information on nurse crops to roadside maintenance personnel for their revegetation efforts. The study was conducted on newly created roadsides in Idaho during the summer and fall of 2000. The sites were located near the towns of Potlatch, Juliaetta, and McCammon. The experimental design was a randomized block, with the treatment being nurse crops. Four nurse crop species were used annual ryegrass (*Lolium multiflorum* Lam.), triticale (*XTriticosecale* Wittmack), hairy vetch (*Vicia villosa* Roth), and rose clover (*Trifolium hirtum* All.). Due to drought and a late perennial seed date at McCammon, the McCammon data sets were analyzed

separately from the Potlatch and Juliaetta data sets. The study found triticale increased the amount of bareground by 6% at the Potlatch and Juliaetta sites. The study found that rose clover reduced the density of perennial forbs by 6.9 plants/m^2 at the Potlatch and Juliaetta sites. The cover of annual forbs was reduced by annual ryegrass, triticale, and hairy vetch by 15%, 15%, and 9%, respectively at the Potlatch and Juliaetta sites. Dry matter production was increased by 53.4% from the triticale treatment at the McCammon site. Triticale also decreased bareground at the McCammon site by 16.0%.

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Dedication

I would like to dedicate this thesis to my loving friend Katy Coddington, who helped me every step of the way in finishing my graduate career.

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Introduction

Roadside slope failures, erosion, and stream sedimentation represent major challenges to highway building and repair in Idaho. Slope failures on roadsides increase the need for ditch maintenance, degrade the aesthetic character of the environment, pollute streams, increase opportunities for weed establishment, and decrease motorist safety. Litigation costs from environmental groups and affected motorists have catalyzed the need for a reduction in roadside erosion. Roadside vegetation reduces erosion by intercepting precipitation and increasing infiltration, which leads to decreased surface erosion. Considerable resources must be invested into roadside revegetation, because the soil of these sites is highly altered and commonly infertile.

Highway construction and repair is very difficult in the state of Idaho. There are few alternative routes when traversing the state, which makes utilizing detours difficult to impossible. High mountains, steep slopes, sandy dunes, snow, ice, rain, deep canyons, rivers, and lakes all create difficulties for highway engineers and maintenance crews. These conditions also create challenges to roadside revegetation efforts. Construction and maintenance schedules often do not correspond to the proper planting times for roadside seeding creating further challenges for roadside revegetation.

Perennial grasses, low growing forbs and shrubs have proven superior for their soil-holding abilities and for reducing roadside maintenance requirements. Unfortunately, perennial plants can be very difficult to establish. Perennial plants are slower to establish than annual plants. Without annual plants in a roadside seed mix, an ecological vacuum may occur allowing weedy annual grasses and forbs to colonize and compete for the available plant nutrients of a site. Weeds can quickly utilize what little soil moisture and soil nutrients are on the site before many perennial plants have even germinated.

Objectives

The Idaho Transportation Department, the National Institute for Advanced Transportation Technology, and the University of Idaho worked cooperatively to complete this study. The overall objective of this study was to provide information on nurse crops to roadside maintenance personnel for their revegetation efforts.

Specific objectives are to:

- Compare the different species of annual plants as nurse crop alternatives for roadside revegetation.
- Determine if the addition of nurse crops to the seed mixture will aid, hinder, or not effect the establishment of perennial plants.
- Measure the effectiveness of nurse crops in controlling erosion.

Justification

Slope stabilization, sedimentation, erosion control, and revegetation efforts are co-dependent. Results of this research will help optimize plant species selection for roadside stabilization in Idaho. It will also provide information about the effectiveness of four different nurse crops for the establishment of roadside perennial vegetation. This project also measured the effectiveness of nurse crops in slowing erosion. The results of this project may also be used by other agencies and industries for erosion control and soil stability.

Literature review

Introduction

Reclamation of disturbed soils resulting from road construction is integral for erosion control, sediment abatement, the safety of people that utilize the roadway system, and the health of the land they live on. To achieve these goals, vegetation represents an effective, thorough, and long lasting alternative that is commonly used by roadside managers. Early maturing, high-yielding grasses and forbs are often not popular due to large amounts of palatable biomass that may attract wildlife and livestock to the road, require mowing, and pose a fire hazard. Roadside vegetation commonly seeded is short in stature with low maintenance requirements; however, many of these species are difficult to establish. Some perennial grass examples would include: hard fescue (*Festuca ovina* var. *duriuscula* L.), sheep fescue (*Festuca ovina* L.), red fescue (*Festuca rubra* L.), and streambank wheatgrass (*Agropyron riparium* Scribn. and Smith). The establishment of reclamation plants can often be enhanced by the use of rapidly-growing annual grasses or forbs which are often called nurse crops. The following discussion is restricted to the four nurse crop species utilized in this study.

Nurse crops

By planting a nurse crop at or near the time perennial plant species are sown, the following advantages are realized: (1) reduction of wind and water erosion; (2) protection of plant seedlings from wind and harsh temperatures; (3) reduction of weed competition (including unwanted grasses); and (4) providing foliage prior to the development of a perennial species (Idaho Agric. Extension Service, 1961; Vallentine, 1971).

Erosion reduction is directly related to foliar canopy cover, which is correlated to forage production of grasses and forbs. When raindrops strike exposed topsoil they mobilize soil particles and result in loss of the topsoil. Partial or complete loss of the topsoil can result in lower nutrient availability that lowers the site potential. In a erosion control study on the Edwards Plateau of Texas soil runoff for a bunchgrass site was 200 kg/ha of sediment, while bareground produced 6000 kg/ha of sediment (Blackburn et al., 1986).

Nurse crops, or companion crops as they are sometimes called, provide protection for perennial plants from wind and harsh temperatures by decreasing wind speeds near the perennial plant (Vallentine, 1971). Nurse crops also increase the relative humidity near their perennial neighbors and moderate environmental extremes that result in decreased evapotranspiration pressures on the perennial seedlings. In addition, nurse crops function as a future source of organic matter and nutrients for the perennial plant. Jones and Johnson (1998) reported that early-seral species may alter soil characteristics to promote desired late seral species, by increasing soil nutrients, soil organic matter, and soil infiltration rates.

Forage production studies in Agassiz, British Columbia demonstrated that using nurse crops for the establishment of orchardgrass (*Dactylis glomerata* L.) and/or perennial ryegrass (*Lolium perenne* L.) eliminated the need for applying herbicides for weed control (Bittman et al., 1999). Harvested grass forage contained only 24% weeds when grown with oats (*Avena sativa* L.), as opposed to containing 65% weeds when grown without a cover crop. Yields of perennial ryegrass and orchardgrass in British Columbia were 8100 kg/ha when grown with a companion crop, 7100 kg/ha with herbicide treatments, and 7300 kg/ha without a companion crop or herbicide treatment (Bittman et al., 1999).

An important characteristic of nurse crop species is their short life span which may lower perennial grass production in the establishment year, but not in later years. In Corvalis, Oregon during a seed production trial, ‘Penlawn’ red fescue (*Festuca rubra* L.) was planted with ‘Hill 81’ winter wheat (*Triticum aestivum* L.). Red fescue seed yields averaged 490 kg/ha when sown with 'Hill 81' winter wheat. Seed yields without a companion crop were 589 kg/ha in the first year. In the second year, red fescue yields were not affected by the use of a nurse crop (Chastain and Grabe, 1988).

A disadvantage of nurse crops is that they compete with perennial plant seedlings for nutrients, light, and moisture and can cause more competition than weeds (Miller and Stritzke, 1995). Shading by the nurse crop may reduce grass and legume stands (Smith, 1981). It is most pronounced when a grain nurse crop lodges, smothering the perennial seedlings beneath (Smith, 1981). Taller varieties of annual grasses tend to cause more losses to seedlings from lodging than shorter types of annual grasses (Smith, 1981). The plant species most commonly utilized as nurse crops are spring barley (*Hordeum vulgare* L.) and oats because they are readily available and provide high forage yields. There has been little research done evaluating the use of winter annual plants as nurse crops.

Winter Annual Grasses

The climate in most of Idaho favors winter annual vegetation. This is why winter annual crops, such as wheat and triticale, grow so well in this state. Winter wheat production acres equaled 372,000 ha generating $229,680,000 for Idaho farmers in 1997 (Idaho Agricultural Statistics, 1998). Winter annual grasses such as annual ryegrass

(*Lolium multiflorum* Lam.) are commonly used as cover crops in many cropping systems throughout the United States. Winter annual weeds such as downy brome (*Bromus tectorum* L.), medusa head ryegrass (*Taeniatherum aesperum* Simonkai), and yellow star thistle (*Centaurea solstitialis*) are also very aggressive in this climate.

<u>Annual Ryegrass</u>

Annual ryegrass, sometimes called Italian ryegrass, is a bunchgrass that grows to 130cm in height (Frakes, 1985), and has a heavy fibrous root system which reduces soil erosion losses until the establishment of the perennial plants (McLeod, 1982). Annual ryegrass can be fall-seeded in areas where the winters are relatively mild. Late fall plantings are generally more susceptible to stand reduction from winter freezing than early fall plantings (Frakes, 1985). Under favorable conditions ryegrass will germinate and emerge quickly, thus suppressing weeds (Frakes, 1985). Annual ryegrass is not a true annual, but under most conditions few of the plants persist for more than one year (McLeod, 1982).

Annual ryegrass is very aggressive when broadcasted on bare ground free from competition. Optimum germination temperatures for annual ryegrass range from $5^{o}C$ to $40^{o}C$. Litter germinated seeds (volunteer plants) of annual ryegrass are very susceptible to drying and have very little root penetration when compared to other species of annual grass (Young et al., 1975). These attributes make annual ryegrass a suitable nurse crop candidate for vegetation establishment.

Annual ryegrass has been grown at many different seed rates for many different purposes. Frakes (1985) stated that the seeding rate for forage production should be 16-22 kg/ha in a pure stand, 5-6 kg/ha when grown with a legume, and 33 kg/ha when utilized for erosion control. However, Sulc et al. (1993) determined the optimum seeding rate for annual ryegrass should be 215 seeds/m^2 which is 6 kg/ha when sown as a nurse crop with alfalfa (*Medicago sativa* L.). Kunelius and Narasimhalu (1983) discovered that when alfalfa was sown at a rate of 12 kg/ha and annual ryegrass sown at a rate of 5 kg/ha, alfalfa maintained a botanical composition of 58%.

In Marshfield and Arlington, Wisconsin, annual ryegrass sown with alfalfa yielded an average of 5010 kg/ha of total dry matter with 3890 kg/ha of total production from alfalfa in the first year of the biomass production study (Sulc et al., 1993). During a year with high precipitation and high potential for erosion, the annual ryegrass-alfalfa mixtures provided more ground cover and erosion control than alfalfa sown alone (Sulc et al., 1993).

In Charlottetown, on Prince Edward Island, Canada, annual ryegrass was seeded with alfalfa and yielded 6101 kg/ha of dry matter during a biomass production trial (Kunelius and Narasimhalu, 1983). At the same location, annual ryegrass grown alone yielded 9755 kg/ha of dry matter (Kunelius and Narasimhalu, 1983). In a cover crop study in Georgetown, Delaware, annual ryegrass and crimson clover (*Trifolium incarnatum* L.) produced 4,126 kg/ha and 8,288 kg/ha of root and top growth, respectively, as well as total nitrogen of about 210 kg/ha (Mitchell and Teel, 1977).

In a greenhouse moisture competition study between annual ryegrass and native shrub seedlings, moisture stress became severe and the mortality of brush seedlings dramatically increased (Gartner et al., 1958). Annual ryegrass has also exhibited allelopathic properties toward native shrubs (Graves et al., 1983).

<u>Triticale</u>

Triticale (*X Triticosecale* Wittmack) is a winter annual grass that was developed from a cross of winter wheat and cereal rye (*Secale cereale* L.). It is similar in appearance to cereal rye, but it is blue in color and its seed heads are thicker. In the Pacific Northwest, it has been utilized as a cover crop to minimize residual fertilizer leaching in corn and potato fields. Since triticale grows in a vegetative state during the winter in the Pacific Northwest, it has been used as a source of forage by livestock operators. Seedling establishment is greatest when drilled, but it can be established by broadcasting. In northern Nevada, the Bureau of Land Management seeded 163,400 kg of triticale as a nurse crop in some fire reclamation projects during the winter of 2000-2001 (Mike Zillinski, June 2000, personal communication). There were no data collected from this work; however, it was observed that triticale became established and served as ground cover for the perennial plants at elevations above 2600 m.

In a survey of 351 Minnesota farmers, 298 (85%) said they used nurse crops for vegetation establishment and 4% of them used triticale (Simmons et al., 1992). Triticale used as a nurse crop with legumes allowed for more legume growth than oats in the early period of a forage trial in Laxia and Dromolaxia, Cyprus (Droushiotis, 1989).

Early varieties of triticale were plagued by low yields, late maturity, susceptibility to shattering, and ergot (Wichman et al., 1995). Improved varieties of this plant were developed in the 1970's and 1980's (Wichman et al., 1995). Cold tolerance of triticale has ranged from -9^{o}C (Van Esbroek et al., 1993b) to -29^{o}C (Progressive Dairyman, 1996). Resource Seeds of Kentucky (1998) recommends a seeding rate of 112 to 135 kg/ha for a monoculture seeding. Wooding et al. (1980) seeded triticale at a rate of 112 kg/ha in Fairbanks and Delta Junction, Alaska, for a monoculture seeding.

Winter Annual Legumes

Winter annual legumes have received little attention for their potential in aiding vegetation establishment as nurse crops. Legumes fix nitrogen, which is one of the essential elements needed for plant growth. Without nitrogen, plants are unable to fully tap the potential of their biological surroundings nor achieve their genetic potential. Soils deficient in nitrogen will yield plants that are dwarfed and yellowish in color (Lyle, 1987). The addition of nitrogen to a plant growing in a nitrogen deficient soil will accelerate growth and alter the color of the plant to a healthier shade of green (Lyle, 1987). Farmers typically fertilize their crops with nitrogen to enhance root and vegetative growth, thus increasing grain and/or forage yields. Increased root and vegetative growth enhance slope stabilization, thus reducing erosion.

Legumes may fix from 56 to 112 kg/ha of nitrogen back into the soil in a year. The foliage of properly inoculated legumes will be a deeper, darker green than plants without the proper inoculation (Erdman, 1959). By inoculating legume seed with nitrogen fixing rhizobium prior to planting, nitrogen fixation may be enhanced. Rhizobium are generally plant species specific (Holland et al., 1969).

The use of legumes in a Delaware cover crop study, in a no till corn (*Zea mays* L.) production system, worked as a mulch for soil protection and as a supplemental nitrogen source. Approximately 1/3rd of the nitrogen from mulch covers was released to corn in one season, with 90% of this nitrogen from the top growth. Soil surface temperatures below the mulch covers were 10^{o}C lower than temperatures on the bare soil surface

(Mitchell and Teel, 1977) which hypothetically lowered evapotranspiration pressures placed on plant seedlings from severe warming events. Runoff studies from the 1940's and 1950's reported that a 50% to 90% reduction in annual runoff could be achieved due to an increased soil infiltration rate when a winter annual legume was incorporated into a multiple cropping system (Hargrove and Frye, 1987).

The ability to fix nitrogen gives annual legumes an advantage over annual grasses because of the high cost of nitrogen fertilizer. The energy crisis of the 1970's caused revegetation specialists to focus their attention on cheaper means of revegetation (Graves et al., 1983). University of Georgia agronomist Bill Hargrove reported that a legume that adds 90 to 112 kg/ha of nitrogen is worth $49 to $62 per hectare. This cost is about equivalent to the cost of establishing an annual legume (Leidner, 1992).

<u>Hairy Vetch</u>

Hairy vetch, or winter vetch (*Vicia villosa* Roth) is an annual legume which can sometimes grow as a biennial. The pubescent varieties are generally more winter hardy and grow throughout the U.S. during cool, moist conditions (McLeod, 1982). When hairy vetch is grown on coarse textured soils, in areas with low winter temperatures, or on slightly alkaline soils it will yield more than other species of vetch (Miller et al, 1989). For this reason it is sometimes called sand vetch (Goar, 1934). In addition to winter-hardiness, hairy vetch is the most drought resistant of the vetches. During winter months it produces more below ground growth than above ground cover. In the spring, its stems will reach a length of 3.5 m, but due to its prostrate nature it rarely attains a height of 1 m (Goar, 1934).

At higher elevations with cold temperatures, hairy vetch can be seeded and germinate before the ground freezes. In cold regions, it will remain dormant during the winter and renew growth when the soil thaws out. In warmer regions, it still goes dormant for a brief period in the winter (Miller et al, 1989).

In a cover crop experiment in the Limestone Valley and Coastal Plain areas of Georgia, hairy vetch improved the soil infiltration rates by 58.4 mm/h compared to 37.8 mm/h for fallow ground (McVay et al., 1989).

Hairy vetch is well known for its nitrogen fixation capabilities. McLeod (1982) found it may fix up to 112 kg/ha of nitrogen. Work by Smith et al. (1992) in Overton, Texas, stated that hairy vetch added 103, 134, and 137 kg/ha of nitrogen to the soil for pearl millet (*Pennisetum americanum* L.) uptake in 1984, 1985, and 1986, respectively. During a forage production trial, in Ft. Bend, Texas, 161 kg/ha and 177 kg/ha of nitrogen was produced by hairy vetch, in 1989 and 1990, respectively (Evers and Gabrysch, 1992). In Lexington, Kentucky, hairy vetch provided nitrogen to no till corn at an estimated rate of 90 to 100 kg/ha (Ebelhar et al., 1984). The estimated fertilizer nitrogen equivalency of hairy vetch used as part of a cover crop experiment in Princeton, Kentucky, was 75 kg/N/ha (Blevins et al., 1990). Hairy vetch used in a cover crop experiment replaced as much as 123 kg/ha of nitrogen over fallow in Georgia (McVay et al., 1989). In Knoxville, Tennessee, agronomists Bob Duck and Don Tyler found that hairy vetch added 110 kg/N/ha to the soil (Leidner, 1992).

Hairy vetch may also aid in weed suppression. During a cover crop study in Columbus, Ohio, hairy vetch reduced weed biomass by 96% in 1990 and 58% in 1991, but lowered yields by 76% in April planted corn (Hoffman et al., 1993). When corn planting was delayed until May, there was no competition between hairy vetch and corn resulting in higher yields (Hoffman et al., 1993). In a cover crop study in Beltsville, Maryland, live hairy vetch was shown to suppress weeds more than dead hairy vetch. A field containing live hairy vetch contained 1980 kg/ha of weedy dry matter compared to 4180 kg/ha of weedy dry matter weed in a fallow field (Teasdale and Daughtry, 1993).

Rose Clover

Rose clover (*Trifolium hirtum* All.) is a winter annual legume and a poor competitor with other species, but it has survived under adverse conditions (McLeod, 1982). Rose clover can grow in areas receiving as little as 25 cm of annual precipitation and at elevations up to 1,000 m; late spring frost usually does not kill this plant (McLeod, 1982). Rose clover grows best on sandy to loam soils with a pH range from neutral to acidic (Graves and Munoz, 1988).

Rose clover is a low maintenance, soil holding plant on disturbed areas. In its original setting, the Mediterranean region of North Africa, Asia Minor, and southern Europe, rose clover persists in sterile fields, on slopes, sandy steppes, and along roadsides (Graves et al., 1980). Rose clover was introduced into California in 1944 by R.M. Love (Graves et al., 1980). It will grow on sites that support filaree (*Erodium cicutarium* and *E.botrys*) (Love, 1985). Rose clover has an upright growing habit and attains a height of 20 to 30 cm (Graves et al., 1986). Rose clover roots to a depth of 2 m, which makes it less susceptible to drought than subterranean clover (*Trifolium subterranean* L.). Rose clover will grow and thrive on sites where bur clover (*Medicago polymorpha* L.) or subterranean clover will not grow in abundance. Successful seedings of rose clover have occurred in both Shasta and Butte Counties of California following controlled burns (Lover and Sumner, 1952).

Rose clover will reseed if allowed a 3 to 4 week regrowth period after mowing to set seed (Graves et al., 1986). Rose clover has 300,000 to 363,000 seeds/kg. In a forage production study in El Reno, Oklahoma, Volesky et al. (1996) found that rose clover seed averaged 87% hard seed, which indicated a 5 kg/ha natural seeding rate the first year after production.

The recommended seeding rate of rose clover is 10 to 15 kg/ha, if broadcasted (Love, 1985). As a cover crop, it should be seeded at a rate of 10 to 22 kg/ha (Graves et al., 1986).

'Overton R18' is a rose clover cultivar developed by the Texas Agricultural Experiment Station and released in 1991 in cooperation with the USDA Soil Conservation Service. This cultivar was a seed increase from a single plant introduced from Spain. From 1985 to 1989, it was grown at different sites throughout Texas. It was grown with 'Kondinin' and 'Hykon' rose clover varieties, and produced more forage for a greater amount of time than the other two cultivars (Smith et al., 1992). It will tolerate a pH ranging from 6.0 to 8.0. 'Overton R18' rose clover performs poorly on undrained sites, but it is drought tolerant (Smith et al., 1992). The cold tolerance of 'Overton R18' rose clover ranges from $-3^{o}C$ (Grichar et al., 1994) to $-27^{o}C$ (Volesky et al., 1996), as it was developed for use in upper Texas and lower Oklahoma (Thomas, 1999). 'Overton R18' rose clover is a very hard seeded legume (80%), and is often selected for its hard-seededness (Thomas, 1999).

Rose clover, like all other legumes, requires proper rhizobium inoculation to fix atmospheric nitrogen into the soil. Sporadic establishment results of rose clover have occurred when the innoculated seed was hydramulched. Water slurries tend to wash off rhizobia bacteria, thus taking away the advantage of innoculation. Phosphate fertilizers acidify water slurry to the extent that most of the root-nodule bacteria are killed (Graves et al., 1983). Rose clover has demonstrated slow seedling growth which Texas authors hypothesized to be the result of poor nodulation from ineffective rhizobia inoculation (Evers, 1999). Inoculation of rose clover can be achieved with the same strains used for subterranean clover and crimson clover (Love, 1985).

Rose clover fixed 56 to 112 kg/ha of nitrogen into the soil in California (Graves and Munoz, 1988). During a forage production trial in Ft. Bend, Texas, ‘Overton R18’ rose clover fixed 396 kg/ha and 112 kg/ha of nitrogen into the soil in 1990 and 1989 respectively (Evers and Gabrysch, 1992). In Lincoln, California, Johnson et al. (1956) observed that rose clover fixed 67 kg/ha of nitrogen in the soil. In Escondido, California, following a erosion control study, improved ground cover of fill-in grasses and shrubs from outside of rose clover seeded plots was hypothesized as being caused by a build up of nitrogen fixed by the rose clover (Graves et al., 1982).

In 1981, on a four-year-old-stand, ‘Hykon’ rose clover produced 177 kg/ha of dry matter yield, but supported 2547 kg/ha of dry matter yield from naturalized forbs and shrubs due to the nitrogen it fixed in the soil in a Escondino, California, erosion control study (Graves et al., 1982).

Methods and Procedures

Site Description

The study was conducted from May 2000 through December 2001 on three sites located in northern and southern Idaho.

The sites were chosen based on the criteria that they be newly created roadsides in Idaho, they must have enough soil to support plant cover, and they must be gentle enough to access for monitoring yet steep enough to be considered a high priority in roadside erosion control. Study sites were chosen to reflect a range of differing temperature regimes and soil types. The three sites selected were near Juliaetta, Potlatch, and McCammon, Idaho.

Juliaetta, Idaho

The Juliaetta study site was selected in early June of 2000 and is located in Nez Perce County. The site is located on state highway 3, six km south of Juliaetta. The natural vegetation community is characterized by perennial bunchgrasses. The former land use of this site was a vegetable garden, hayfield, and pasture. The elevation is 305 m. The average annual precipitation is between 38 and 50 cm (Malna 1999). There is not a weather station located at Juliaetta, Idaho but it serves as a mid-point of Lewiston, Idaho and Dworshak, Idaho. Dworshak received 50 cm and Lewiston received 24 cm of precipitation for the 2000-2001 growing season (Figure 1 and Figure 2) (Western Regional Climate Center, 2001). The slope ranges from 2:1 to 1:1 and the aspect is southeast.

Potlatch, Idaho

The Potlatch study site was selected in early June, 2000 and is located in Latah County. The site is located on U.S. highway 95, five miles north of the Potlatch junction. The natural vegetation community is characterized by an ecotone of perennial bunchgrasses and Ponderosa pine (*Pinus ponderosa*). The former land use of this site was as a pasture. The elevation is 792 ms. The average annual precipitation is 63 centims and the 2000-2001 growing season precipitation was 43 cm (Figure 3) (Western Regional Climate Center, 2001). The slope is 3:1 and the aspect is east facing.

McCammon, Idaho

The McCammon study site was selected on 19 July 2000 is located in Bannock County. The study site is located at the junction of interstate 15 and U.S. highway 30, on the outskirts of McCammon. The natural vegetation community is characterized by sagebrush steppe. The former land use of this site was for pasture. The elevation is 1458 m. The average annual precipitation is 41 cm. The annual precipitation for October, 2000 through September, 2001 was 21.72 cm (Figure 4) (Western Regional Climate Center, 2001). The slope is 3:1 and the aspect is southwest.

Study Design

The square shaped plots had dimensions of 3x3 m and separated by a buffer of 0.5 m. Plot corners were marked with wooden survey stakes. Two transects were established in each plot and ran parallel to the slope. Each transect was located 0.5 ms in from plot corners. Five quadrats were established on each transect at intervals of 30, 91, 152, 210, and 260 cm and ran downhill. The quadrat dimensions were 20x50 cm

(Daubenmire, 1958) and were placed parallel to the slope along the transect. This transect design was used for all sites.

Soil Collection

All soil samples were analyzed at the University of Idaho Analytical Sciences Laboratory in Moscow,Idaho. Soil was sampled to determine possible deficiencies or toxicities that may severely limit plant growth. The analysis run on the Juliaetta and Potlatch sites were percent OM, TKN available NH_4^+ and NO_3^-, saturated paste pH, and NaOac available P and K. The analysis run on the McCammon sites were percent OM, TKN available NH_4^+ and NO_3^-, saturated paste pH, $NaHCO_3$ available P and K, CaCO3 equivalent, and SO_4^-S.

Juliaetta, Idaho

Eight soil samples were collected from a depth of 30 cm. Soil samples were collected from 1 plot in each replication. Plots sampled were selected using a random number table.

The soil had a pH range of 7.7 to 8.1. Soil organic matter content ranged from 1.07 to 0.48 % in the surface 30cm. The available phosphorous ranged from 13.2 to 21.4 µg. The available potassium ranged from 198 to 154 µg. The available nitrogen ranged from 10.5 µg to 6.3 µg.

ID	Location	pH	P	K	OM	TKN	SO_4-S	$CaCO_3$
AK	Juliaetta	7.7	13.2	197.5	1.1	10.7	NA	NA
BK	Juliaetta	8.1	21.4	154.3	0.5	6.4	NA	NA
AP	Potlatch	6.4	4.1	140.0	1.7	17.3	NA	NA
BSub	McCammon	7.8	21.5	360.0	1.9	34.5	6.0	8.9
BTop	McCammon	7.8	22.3	302.5	2.1	40.9	5.7	7.6

Table 1. Soil analysis results for Juliaetta, Potlatch, and McCammon. NA=Not Analyzed.

Potlatch, Idaho

Four soil samples were collected to a depth of 30 cm. Soil samples were collected from 1 plot in each replication. Plots to be sampled were selected using a random number table.

The soil had a saturated pH of 6.4. The organic matter content was 1.67 %. The available phosphorous content was 4.1 µg. The available potassium was 140 µg. The available nitrogen was 17.3 µg.

McCammon, Idaho

Twelve topsoil samples were collected from a depth of 7.6 cm. Twelve subsoil samples were collected to a depth of 37 cm. Soil samples were collected from 1 plot in each replication. Only one block, thus four plots out of twelve, had soil samples which were analyzed due to the homogeneity of the soil. Plots to be sampled, in the chosen block, were selected using a random number table.

Both the topsoil and the subsoil had pH values of 7.8. The organic matter content was 2.1% for the topsoil and 1.9% for the subsoil. The available phosphorous was 22.3 µg for the topsoil and 21.5 µg for the subsoil. Available potassium levels were 302 µg in the topsoil and 360 µg in the subsoil. The available nitrogen was 40.8 µg for the topsoil and 34.5 µg for the subsoil. The available sulfur was 5.6 µg for the topsoil and 5.9 µg for the subsoil. The available calcium carbonate was 30.5 % for the topsoil and 8.9 % for the subsoil.

Seeding and Fertilization

Juliaetta, Idaho

All the plots at the Juliaetta study site were mowed with a gas powered weed eater on 23 August, 2000. Mowing was done to prevent the taller volunteer vegetation from interfering with the broadcast seeding efforts. The seeding took place at the Juliaetta site in mid October, 2000. Each plot was scarified with a rake, then hand-broadcasted with a nurse crop treatment. Afterward, each plot was raked. The next day a hand broad-cast seeder was utilized to distribute perennial grass seed over the plot. The Juliaetta site was fertilized and mulched with a hydro seeder in late November, 2000.

The bulk blended fertilizer was composed of 0-44-0, 0-60-0, and 45-0-0 to make 14-17-17-11 and was applied at a rate of 258 kg/ha. The mulch was applied at the rate of 2300 kg/ha and consisted of 2243 kg/ha of recycled paper mulch and 67 kg/ha of a poly accrylamide granular soil tackifier.

Perennial plant species and seed rates used were “Durar” hard fescue (*Festuca ovina duriuscula* (L.) Koch) at 8 kg/ha; “Covar” sheep fescue (*Festuca ovina* L.) at 8 kg/ha; Canada bluegrass (*Poa compressa* L.) at 1 kg/ha; and White Dutch clover (*Trifolium repens* L.) at 1 kg/ha.

The nurse crops used, which were used consistently over the three study sites, were hairy vetch at 13.5 kg/ha, annual ryegrass at 6.7 kg/ha, triticale at 8.2 kg/ha, and rose clover at 12.9 kg/ha. Both hairy vetch and rose clover were inoculated with peat-based inoculants (*Rhizobium leguminosareum* biovar *viceae* and *Rhizobium leguminosareum* biovar *triofoli*), respectively.

Potlatch, Idaho

Seeding took place at the Potlatch site in late October, 2000. Each plot was scarified with a rake, hand-broadcasted with a nurse crop treatment, and raked again. The same day, a hydro-seeder was utilized to distribute perennial grass seed, fertilizer, and mulch over the site.

The bulk blended fertilizer was composed of 0-44-0, 0-60-0, and 45-0-0 to make 14-17-17-5 and was applied at a rate of 375 kg/ha. Fertilizer borate 0-0-0-0-14B was also added at a rate of 8 kg/ha. The mulch was applied at the rate of 2300 kg/ha and consisted of 2242.7 kg/ha of recycled paper mulch and 67.3 kg/ha of a poly accrylamide granular soil tackifier.

Perennial plant species and seed rates used were “Durar” hard fescue at 8 kg/ha; “Fortress” red fescue (*Festuca rubra* L.) at 8 kg/ha; Canada bluegrass at 1 kg/ha; and White Dutch clover at 1 kg/ha.

McCammon, Idaho

Nurse crop seeding took place at the McCammon site in mid-September, 2000. Each plot was scarified with a rake, hand-broadcasted with a nurse crop treatment, and raked again. A hydro-seeder was utilized to distribute perennial grass seed, fertilizer, and mulch over the site in late March, 2001. A jute mat was installed on the site during the middle of April, 2001.

The McCammon site was fertilized and mulched with a hydro seeder. The fertilizer mix consisted of Kiwi Power (0-0-0-2) applied at a rate of 19 kg/ha and Fertile Fiber (6-4-1) applied at a rate of 1121 kg/ha. The mulch was applied at the rate of 2300 kg/ha and consisted of 2242.7 kg/ha of recycled paper mulch and 67.3 kg/ha of a poly accrylamide granular soil tackifier.

Perennial plant species and seed rates used were “Sodar” streambank wheatgrass (*Agropyron riparium* Scribn. and Smith) at 10.1 kg/ha; “Covar” sheep fescue at 7.8 kg/ha; “Ephraim” crested wheatgrass (*Agropyron desertorum* (Fisch) Schult.) at 3.4 kg/ha; and alfalfa (*Medicago sativa* L.) at 1.1 kg/ha.

Measurements

Plant density was counted in each quadrat. A plant was considered inside the quadrat if 50% or more of its basal area was inside the quadrat. Plants were classed as nurse crops, perennial grasses, perennial forbs, annual grasses, annual forbs, or shrubs.

Plant biomass was determined by clipping all plants that had 50% or greater of their stems inside the quadrat. Plants were clipped at ground level and stored in paper bags. After several days of air-drying, bags from 92 plots were inserted in an oven and dried at 50^{o}C for 96 hours. Two hundred forty quadrats, or 24 plots, of bags were oven dried at 100^{o}C for 48 hours. Unfortunately, a portion of the remaining bags were lost in a oven fire.

Plant canopy coverage was estimated by classifying plants that had 50% or more of their basal area inside the quadrat. Plants with less than 50% were not counted. Plants were classified as nurse crops, perennial grasses, perennial forbs, annual grasses, annual forbs, or shrubs. Percent bareground was also estimated. With this methodology, it was possible for total canopy coverage to reach over 100%. For example, if a tall annual forb plant had 100% coverage in a quadrat but it had several short perennial grasses that equaled 50% coverage, then the total coverage for that particular quadrat would be 150%.

Each plant group received a score of 0 to 6 in each quadrat. Canopy coverage scores were recorded as 0%=0, 1-5%=1, 5-10%=2, 11-25%=3, 26-50%=4, 51-75%=5, and 76-100%=6. All cover data were converted from their respective rankings to a midpoint value for statistical analysis. Thus 0=0% canopy coverage, 1=2.5%, 2=7.5%, 3=17.5%, 4=37.5%, 5=62.5%, and 6=87.5%

An erosion rating (Clark, 1980) was performed at the Juliaetta and Potlatch sites. This erosion rating was developed by the Bureau of Land Management to classify the degree of accelerated erosion that was occurring on BLM administered land. Site data were collected on seven soil surface factors, which can be visually documented by field technicians. These were soil movement, surface litter, surface rock fragments, pedastalling, flow patterns, rills, and gullies. These seven factors were not expected to occur in the same degree at the time of sampling for a given site. In some instances, a soil surface factor, such as rock fragments, might not be potentially present. The seven factors were rated as follows: soil movement, 1-14; surface litter, 1-14; surface rock fragments, 1-14; pedastalling, 1-14; flow patterns, 1-14; rills, 1-14; and gullies, 1-15. A rating of 1 would be considered low and a rating of 14 would be considered high for a soil surface factor. A site with a rating of 100 would be considered high accelerated erosion and a site with a rating of 1 would be considered low accelerated erosion. If a site lacked a soil surface factor (SSF) like rock fragments and the total sum of the other six SSF was 43, then a technician must divide 43 by 86, which would equal a site erosion rating of 50% accelerated erosion rating.

When Measurements Were Taken

Juliaetta, Idaho

In early August 2000, forty plots were established at this site. Transects were established in each of the 3x3 m plots at the Juliaetta site in mid May, 2001. Density and canopy coverage data were collected at the Juliaetta site from late May to early June. In early June, the plots were harvested for biomass data. An erosion rating assessment was completed on the Juliaetta site in late June, 2001.

Potlatch, Idaho

In early August, 2000, twenty plots were established at this site. Transects were established in each of the 3x3 m plots at the Potlatch site in mid July, 2001. During late July, density and canopy coverage data were collected at the Potlatch site. The plots were harvested for biomass data in late July, 2001. An erosion rating assessment was completed on the Potlatch site in early September, 2001.

McCammon, Idaho

In early August, 2000, sixty plots were established at this site. Transects were established in each of the 3x3 m plots at the McCammon site in mid June, 2001. During the middle of June, 2001, density and canopy coverage data were collected at the McCammon site. Density and canopy coverage data were collected at the McCammon site in early July, 2001. The plots were harvested for biomass data in mid July, 2001. Data collection was completed at the McCammon study site by early August, 2001. An erosion rating assessment was not attempted on the McCammon site due to the presence of the jute mat.

Statistical Analysis

The experimental design for this study was a randomized block design. There were six blocks, two blocks at Juliaetta, one at Potlatch, and three at McCammon. There were twenty plots in a block, four replications in a block, and five nurse crop treatments in a replication. The treatments were control (no nurse crop), triticale, annual ryegrass, hairy vetch, and rose clover. There were 10 quadrats to a plot, which equaled 1200 quadrats in this study. There were 120 plots in this study.

Statistical analysis was completed using SAS (SAS, 2000). Analysis of variance (ANOVA) tests were used to analyze data sets. Tukey tests were used to determine which treatments were significant (SAS, 2000). Significance levels were evaluated at alpha=0.05.

Due to unequal varying patterns (Figures 1,2,3, and 4) the McCammon data sets were analyzed separately from the Potlatch and Juliaetta data sets. The McCammon data sets were also analyzed separately due to the late perennial seeding.

Since all data sets failed to meet the homogeneity of variance, they were all transformed with the log function. Four data sets failed to meet the normality assumptions and/or homogeneity of variance with the log function. These four sets were cover of perennial grasses, cover of perennial forbs, density of perennial grasses, and density of perennial forbs. These four sets had a large amount of zero values at the McCammon site, therefore the McCammon site data was dropped for these four parameters. These four sets were transformed with the square root function to meet the normality assumptions and/or homogeneity of variance.

Results and Discussion

The following results and discussion evaluate the impact of seeding certain nurse crops with standard reclamation vegetation in Idaho.

Juliaetta and Potlatch

Results from this study discovered that nurse crops altered the amount of bareground (P= 0.0103). Triticale reduced bareground the most of the species tested. Triticale (P= 0.1587) had 23% bareground while the control had 17% bareground. Thus, there was 26% more relative bareground when triticale was planted versus the control (Figure 5).

Nurse crops had no effect on dry matter production (P= 0.1720) over the treatments. These findings disagree with the work of (Bittman et al., 1999) that found nurse crops increase dry matter production in the seeding year. Nurse crops failed to significantly alter the density of annual forbs over the treatments (P= 0.1846); however, it was observed that triticale and annual ryegrass reduced annual forbs by 30% relative to the control (Figure 6). There were no significant differences in the density of perennial grasses (P= 0.6839) by using nurse crops; however, it was observed that triticale reduced perennial grasses by 15% relative to the control (Figure 7).

Density of annual grasses were unaffected by the nurse crop treatments (P= 0.5526). There were no differences in the cover of annual grasses (P= 0.3500) over the treatments. Unfortunately these two findings are skewed since there were annual ryegrass volunteer plants over the entire Potlatch site. These plants were recorded separately in the annual ryegrass seeded plots, but were placed into the annual grass groups for all other treatments.

Nurse crops altered the density of perennial forbs (P= 0.0162). The species to impact perennial forb density the greatest was rose clover (P= 0.0442) with an average density of 16.38 plants/m^2 compared to the control with an average density of 23.25 plants/m^2 (Figure 8). Therefore, the use of rose clover resulted in 29.5% less perennial forbs for the Juliaetta and Potlatch sites. A regression line (R^2= 0.553) demonstrated a decrease in perennial forbs as the density of rose clover plants increased (Figure 9).

Cover of annual forbs was lowered by using nurse crops (P=0.0029). The species to impact the cover of annual forbs the greatest was annual ryegrass (P= 0.0062) with an average annual forb cover of 22% versus the control with 37% (Figure 10). Other species that exhibited a significant negative affect on the cover of annual forbs were triticale, (P= 0.0083) and hairy vetch (P= 0.0658), with annual forb covers of 26% and 23%, respectively (Figure 10). Thus using annual ryegrass, triticale, and hairy vetch resulted in 40%, 39%, and 30% less relative cover of annual forbs than the control, respectively.

There were no differences in the cover of perennial grasses (P= 0.3116) over the treatments despite the findings of Miller and Striske (1995); and Smith (1981) whom noted that perennial grass establishment is reduced in the seeding year.

Differences in the cover of perennial forbs by using nurse crops were observed (P= 0.0761). The species to impact the cover of perennial forbs the greatest was rose clover (P= 0.2285) with an average perennial forb cover of 8.9% versus the control with 5.9% (Figure 11). Thus using rose clover resulted in 33% more relative perennial forb canopy cover than the control.

McCammon

Dry matter production was affected by the use of nurse crops (P= <0.0001). Triticale yielded significantly more dry matter (222.9 g/m^2 or 2229 kg/ha) than the control. Thus using triticale resulted in 53.4% more dry matter than the control (Figure 12). These findings agree with the work of (Bittman et al., 1999) that found nurse crops increase dry matter production in the seeding year.

Nurse crops altered percent bareground (P= 0.0009). Triticale treatments resulted in less bareground (P= 0.0004) with 34.3% than the control with 50.3% (Figure 13). Thus using triticale resulted in 32% less relative bareground than the control.

This study failed to demonstrate any differences in the density of annual forbs (P= 0.8878) across the treatments. There were no differences in the density of annual grasses (P= 0.6258) across the treatments.

There were also no significant differences in the density of perennial grasses (P= 0.2302) or the cover of perennial grasses (P= 0.1302) over the treatments. There were no perennial forbs detected at the site, thus no tests on density or cover of perennial forbs were performed.

Poor perennial grass and forb establishment was noted on the McCammon site. There were no perennial forbs from seeding or natural regeneration found at the site and only 2.78 plants/m^2 of perennial grass. This was attributed to two factors: a late perennial seeding date and droughty conditions. Seeding took place on 23 March 2000. The drought conditions at the McCammon site were severe with total precipitation from October, 2000 through September, 2001 equaling 21.72 cm while the average annual precipitation for this site is 40.92 cm (Figure 4). This was 47% less than normal.

Nurse crop treatments did not influence the cover of annual forbs (P= 0.1554) and did not affect the cover of annual grasses (P= 0.3367) across the treatments.

Conclusion

Nurse crops may be successfully utilized for roadside revegetation. Nurse crops have been known to reduce perennial plant establishment (Miller and Striske, 1995; Smith, 1981), yet this occurred only with perennial forbs on the Juliaetta and Potlatch sites. In addition, the use of nurse crops resulted in a reduction of weed canopy coverage and reduced bareground in the northern Idaho sites. At the McCammon site nurse crops reduced bareground and increased biomass production which should aid in controlling erosion.

The results of this study indicate that the nurse crop treatments had no effect on the density of annual forbs, density of annual grasses, density of perennial grasses, dry matter production, cover of annual grasses, and cover of perennial grasses at the Juliaetta and Potlatch sites. It is important to note that nurse crops have been found to reduce perennial grass establishment (Smith, 1981; Miller and Striske, 1995), yet we did not discover this. We found the density of annual forbs, density of annual grasses, density of perennial grasses, cover of annual forbs, cover of annual grasses, and cover of perennial grasses was unaffected by the nurse crop treatments at the McCammon site which presumably was the result of drought and time of seeding.

On the Juliaetta and Potlatch sites perennial forb density was decreased only by the rose clover treatment but overall perennial forb cover was increased which may be more important for erosion control than production. This is possible because rose clover may compete with perennial forbs early in the season, but later when rose clover reaches maturity it no longer competes with the perennial forbs. Therefore, late in the growing season perennial forbs would not experience competition from the rose clover. The perennial forbs would be present at a lower density than the adjacent control plots. Perennial forbs present at a lower density would allow the existing perennial forbs to be greater in size due to a release from intraspecific competition.

Nurse crops are known to reduce weeds (Idaho Extension, 1961; Vallentine, 1971; Bittman, 1999) which was supported by data from this study. The hairy vetch, triticale, and annual ryegrass nurse crop treatments all produced a significant reduction in annual forb cover. Because one of the objectives of roadside revegetation is weed control, the reduction of annual forb cover resulting from these three nurse crop species may offer an opportunity to control annual weeds on roadsides in northern Idaho.

Triticale increased bareground on the Juliaetta and Potlatch which can be attributed to triticale's ability to reduce the cover of annual weeds. The upright, condensed structure of triticale compared to the diffuse, spreading nature of many annual forbs causes triticale to receive a lower canopy cover rating and thus a higher bareground rating from the reduction of annual forb cover.

Triticale resulted in decreased bareground at the McCammon site, which may be due to triticale's physiological traits and because optimum germination, seeding, and establishment conditions took place in October, 2000 right after the nurse crops were seeded. Graves et al. (1982) also found that nurse crops decreased bareground in some erosion control studies in Escondido, California.

Triticale also increased biomass production at McCammon. By reducing bareground and increasing biomass production, erosion control is enhanced. Sediment and erosion control are two important reasons for seeding a nurse crop (Idaho Extension, 1961; Blackburn et al, 1986).

Further Study

It is integral to see how the four nurse crop species influence the long-term establishment of perennial roadside vegetation. Consequently continued monitoring of the study sites is essential to the success of further roadside revegetation success. Due to the drier than average conditions for the 2000-2001 growing season, it would be interesting to explore the affects of nurse crops on roadside vegetation in wetter years. In addition, it is important to test nurse crops on roadsides in areas wetter, colder, drier, or warmer than the areas evaluated in this study. Studies in quantifying the optimum seed rate for the different nurse crops could be beneficial as well.

Further studies using other plants (annuals and short lived perennials) as nurse crops could be informative as well. Despite the high utility of the four nurse crops used there are several other plants that may perform as well or better due to their pioneering life cycles. The following lists of plants are species that could be useful as nurse crops:

Latin name	Common name	Growth type
Avena sativa L.	oats	annual grass
Hordeum vulgare L.	winter barley	annual grass
Hordeum vulgare L.	spring barley	annual grass
Triticum aestivum L	winter wheat	annual grass
Triticum aestivum L.	spring wheat	annual grass
Secale cereale L.	cereal rye	annual grass
Agropyron trachycaulum (Link) Malte	slender wheatgrass	perennial grass
Bromus marginatus Nees ex Stued	mountain brome	perennial grass
Danthonia intermeia Vassey	timber oatgrass	perennial grass
Elymus glaucus Buckl.	blue wild rye	perennial grass
Lolium perenne L.	perennial ryegrass	perennial grass
Sporobolus cryptandrus (Torr.) Gray	sand drop seed	perennial grass

Brassica napus L.	canola	annual forb
Lathyrus hirsutus L.	Austrian winter pea	annual legume
Melilotus officinalis Lam.	yellow sweet clover	annual legume
Trifolium subterranean L.	subterranean clover	annual legume
Lupinus sp. L.	lupine	annual/perennial legume

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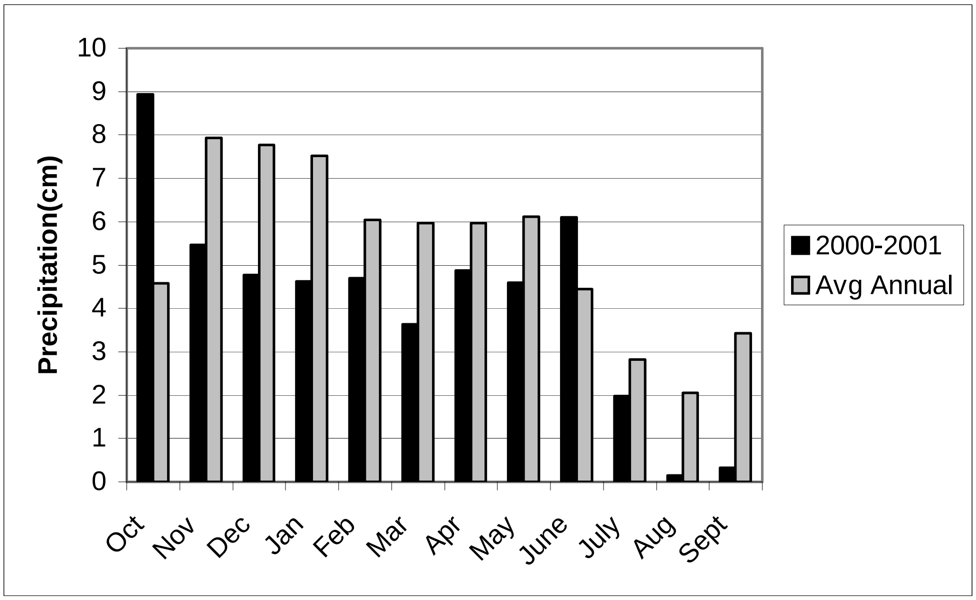

Figure 1. Average monthly precipitation for Dworshak, Idaho

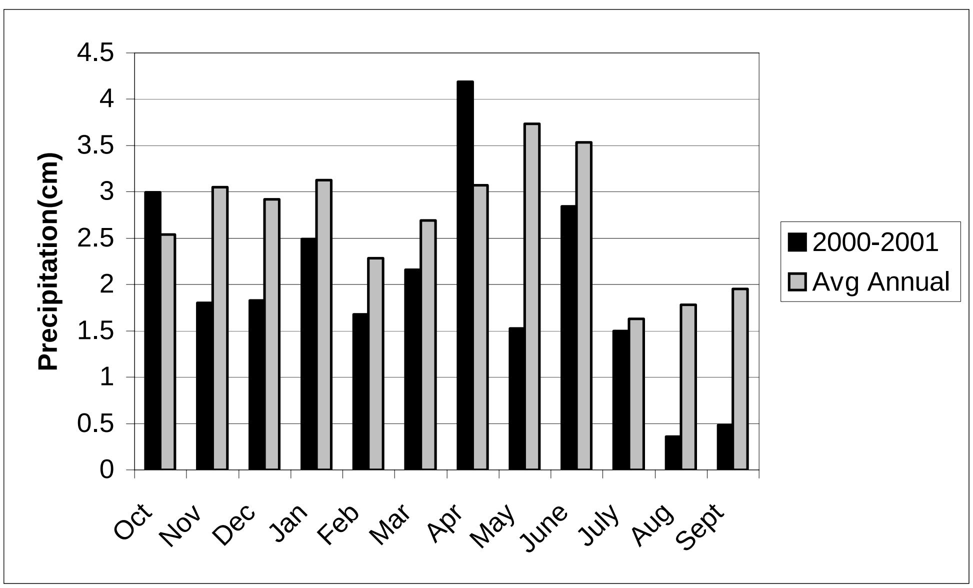

Figure 2. Average monthly precipitation for Lewiston, Idaho

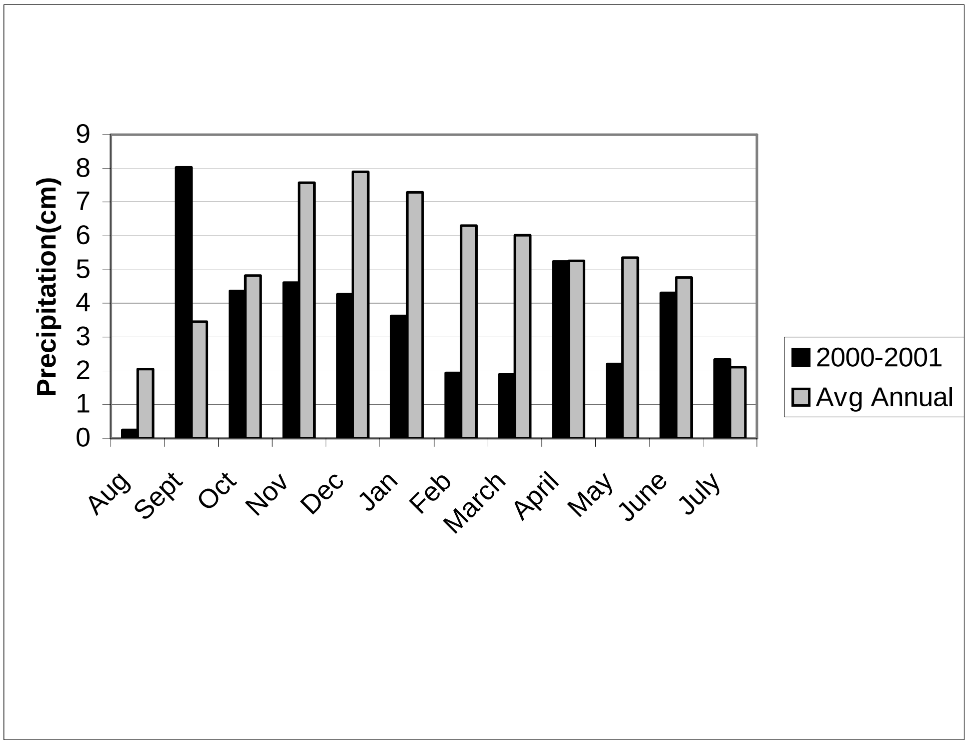

Figure 3. Average monthly precipitation for Potlatch, Idaho

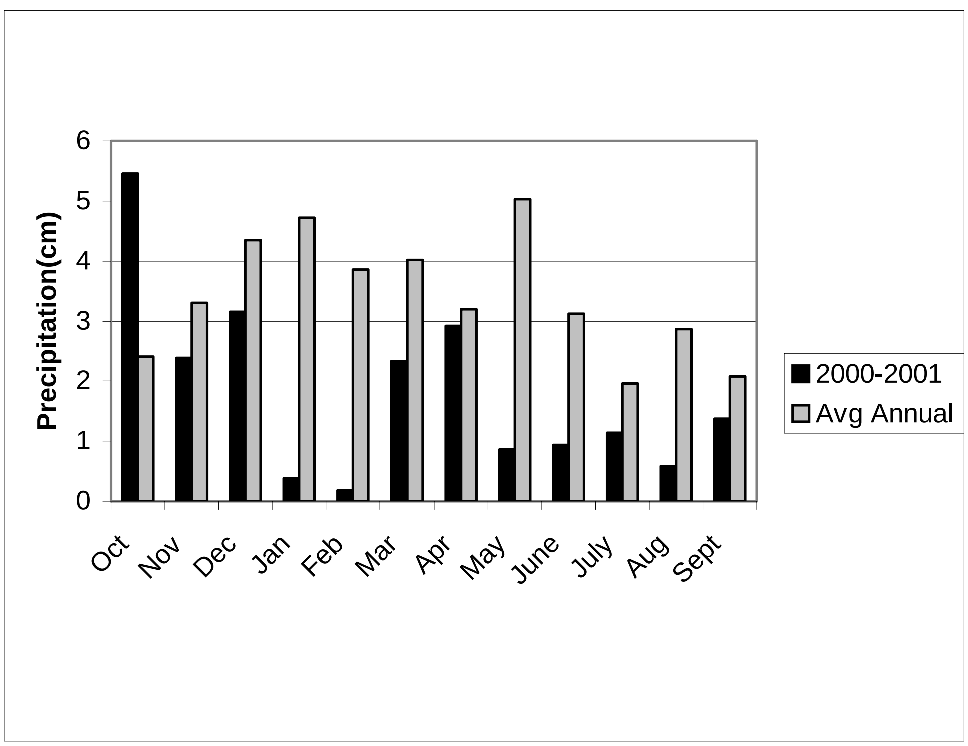

Figure 4. Average monthly precipitation for McCammon, Idaho.

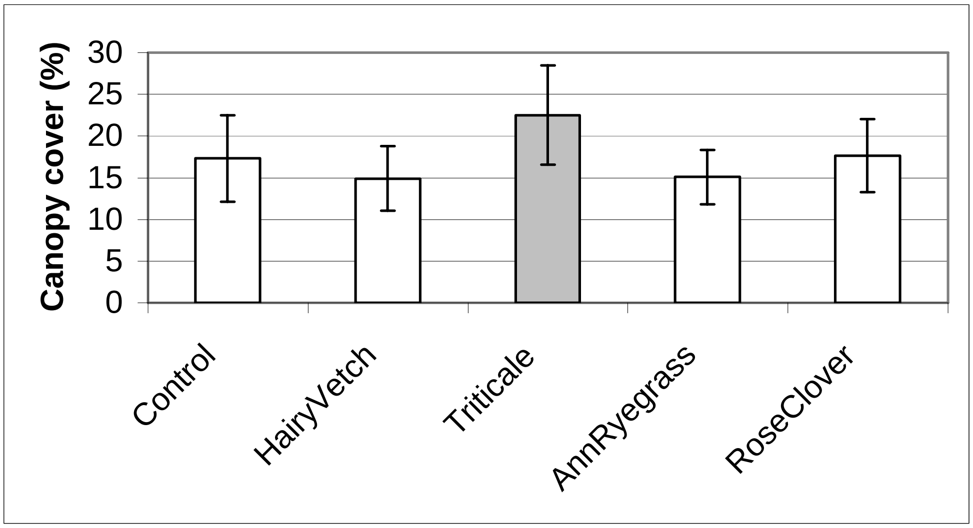

Figure 5. Percent of bareground at Juliaetta and Potlatch. Shaded bar indicates a significant difference from the control (P=0.1587). Standard error indicated by (I).

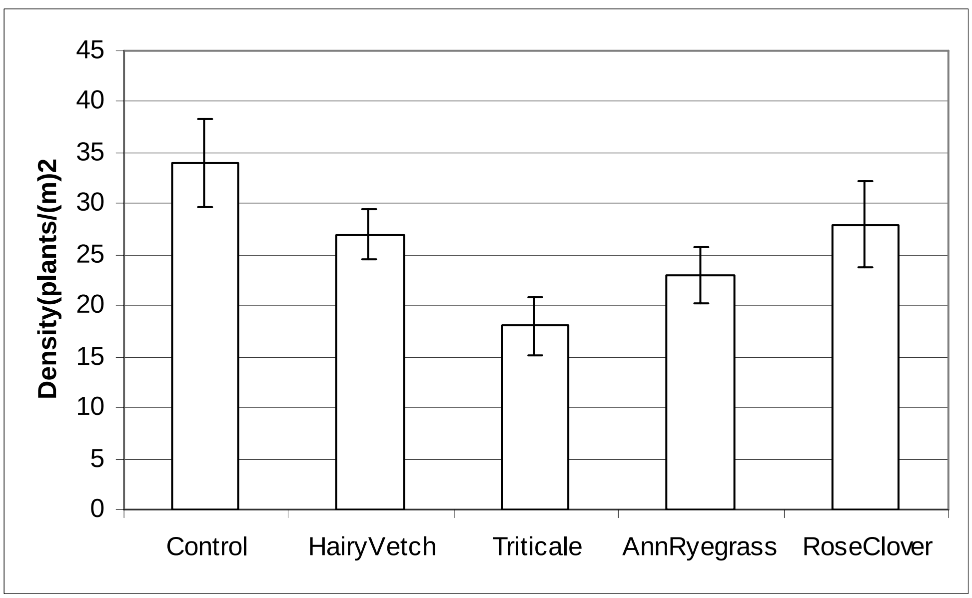

Figure 6. Density of annual forbs for Juliaetta and Potlatch. Standard error indicated by (I).

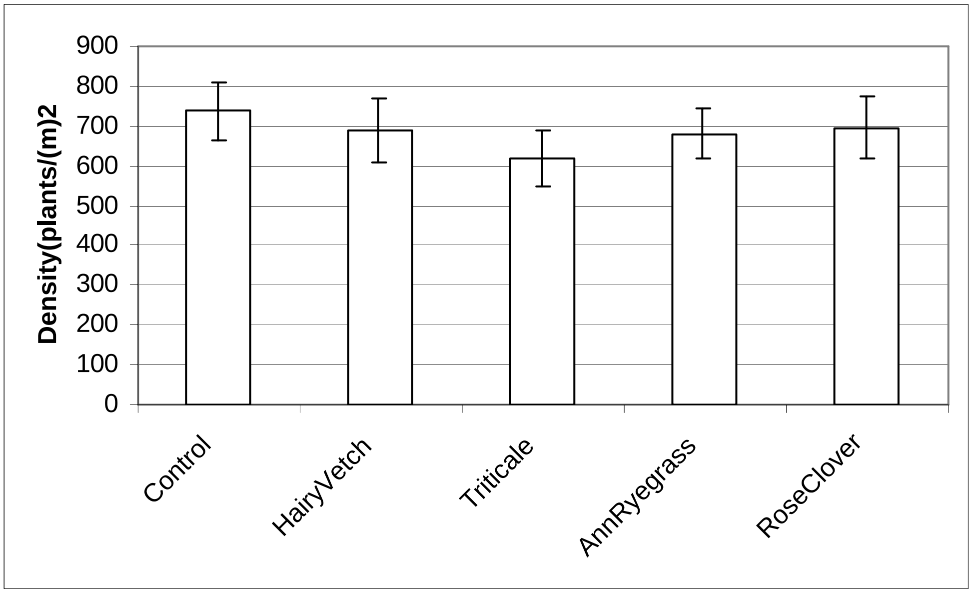

Figure 7. Density of perennial grasses for Juliaetta and Potlatch. Standard error indicated by (I).

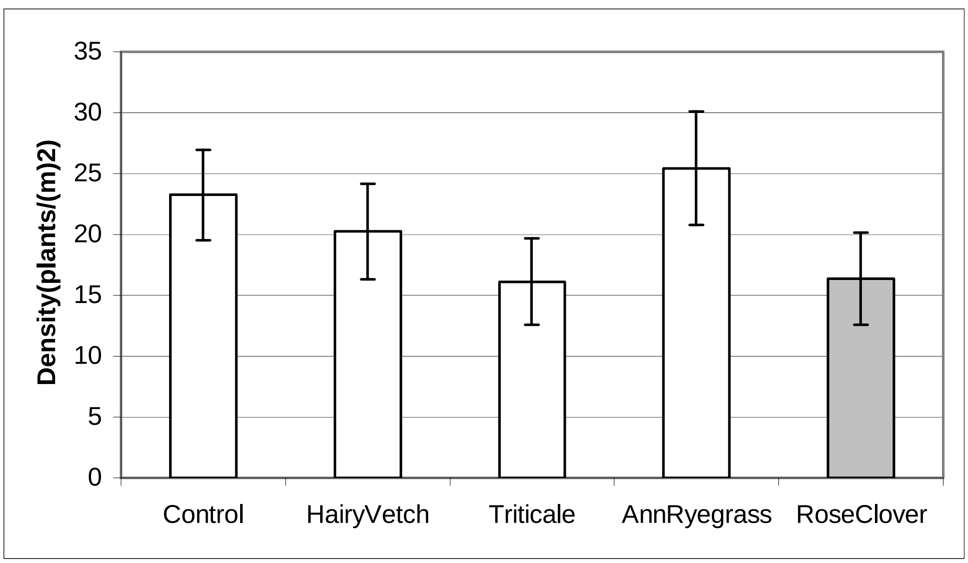

Figure 8. Average perennial forb density for Juliaetta and Potlatch. Shaded bar indicates a significant difference from the control (P=0.0442). Standard error indicated by (I).

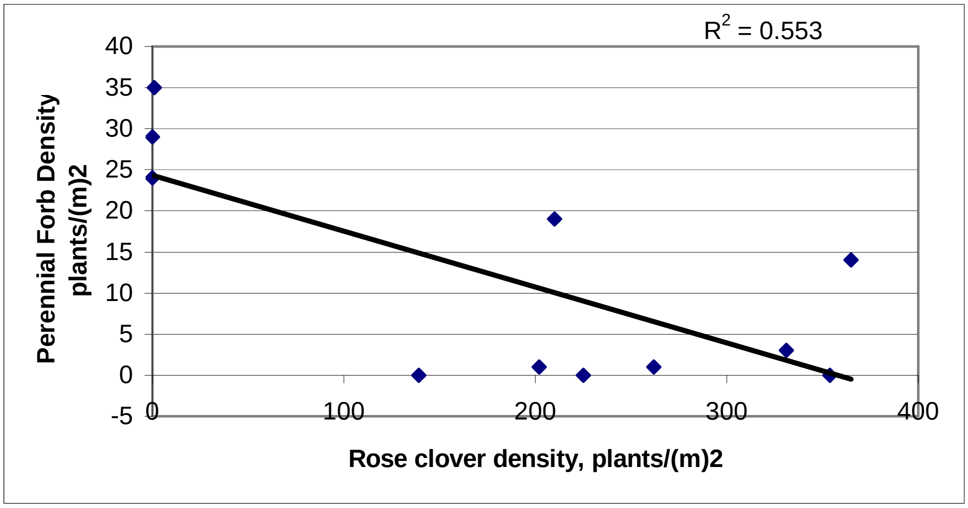

Figure 9. Rose clover effect (density) on density of perennial forbs at Potlatch and Juliaetta.

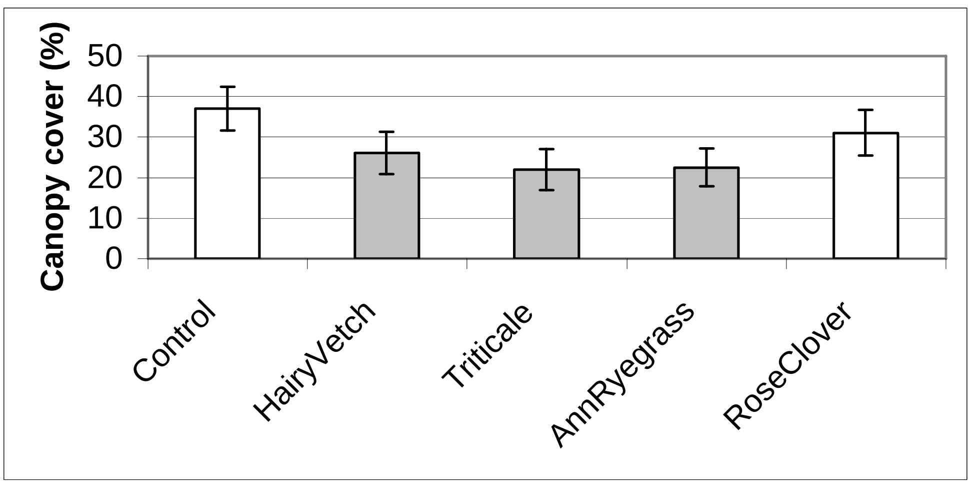

Figure 10. Average percent canopy cover of annual forbs for Juliaetta and Potlatch. Shaded bar indicates a significant difference from the control (P=0.0062). Standard error indicated by (I).

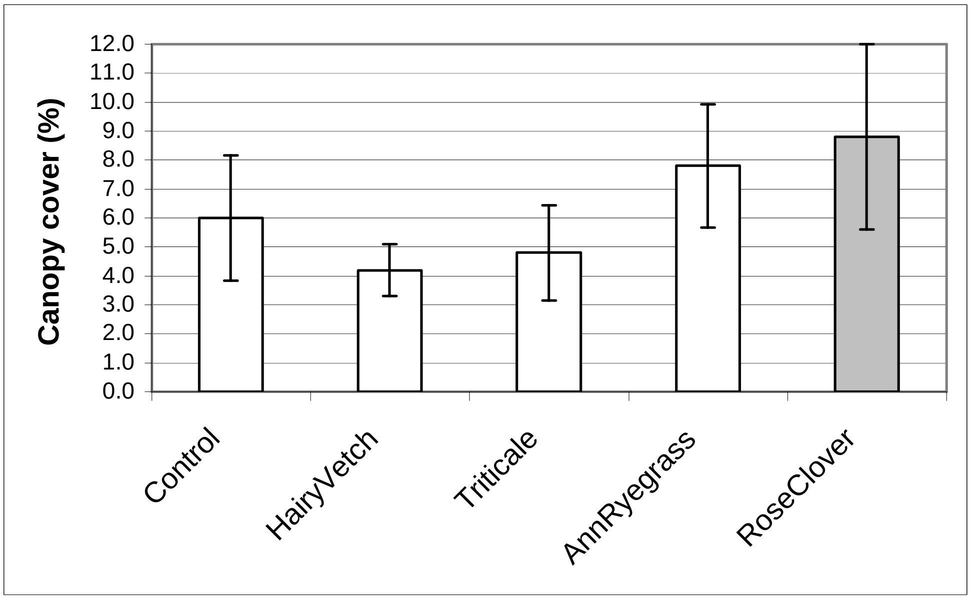

Figure 11. Average percent canopy cover of perennial forbs for Juliaetta and Potlatch. Shaded bar indicates a significant difference from the control (P=0.2285). Standard error indicated by (I).

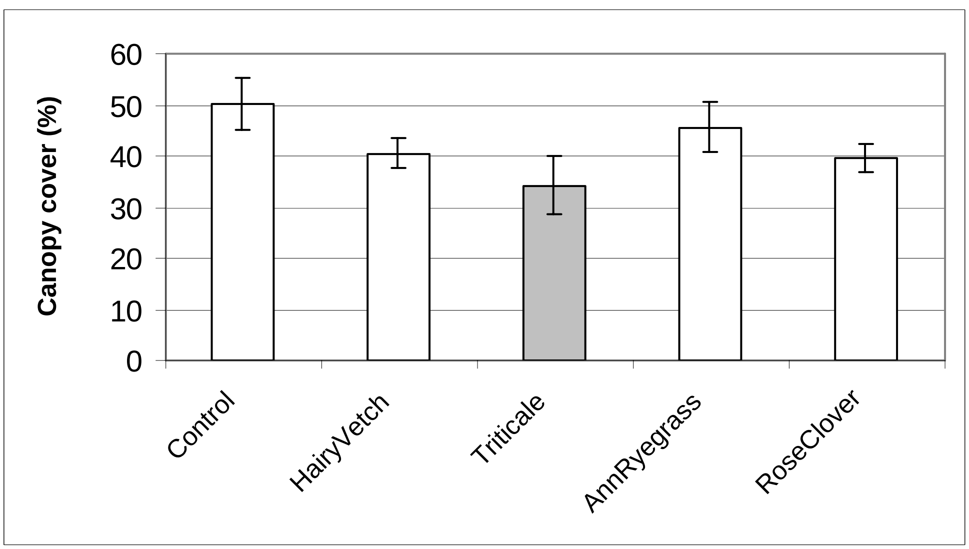

Figure 12. Average biomass production in $g/(m)^2$ for McCammon. Shaded bar indicates a significant difference from the control (P=<0.0001). Standard error indicated by (I).

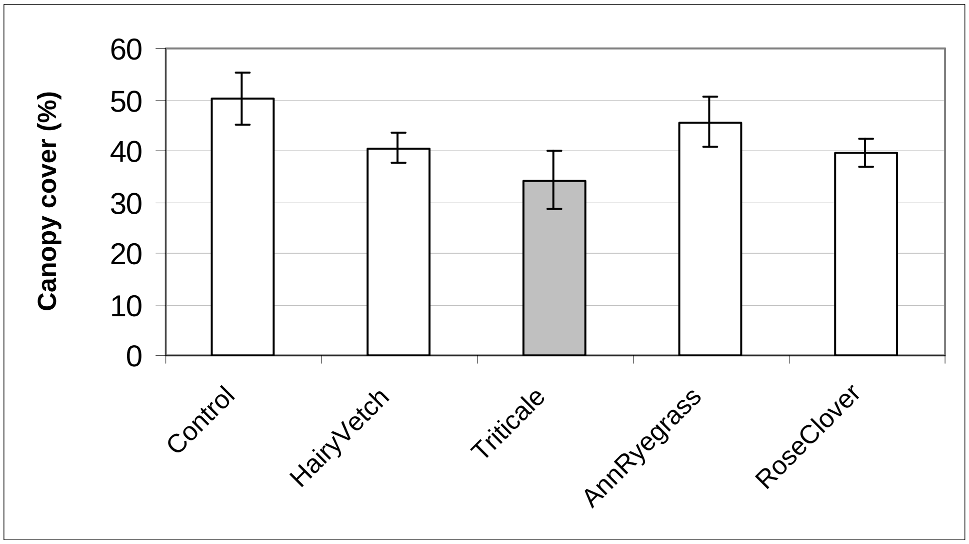

Figure 13. Average percent bareground for McCammon. Shaded bar indicates a significant difference from the control (P=0.0009). Standard error indicated by (I).

ID	Location	pH	P	K	OM	TKN	SO_4S	$CaCO_3$
AK	Juliaetta	7.70	13.23	197.50	1.07	10.65	NA	NA
BK	Juliaetta	8.10	21.38	154.25	0.48	6.38	NA	NA
AP	Potlatch	6.35	4.08	140.0	1.67	17.33	NA	NA
BSub	McCammon	7.75	21.50	360.0	1.87	34.50	5.98	8.93
BTop	McCammon	7.75	22.25	302.50	213	40.85	5.65	7.63

Table 1. Soil analysis results for Juliaetta, Potlatch, and McCammon. NA, Not Analyzed.

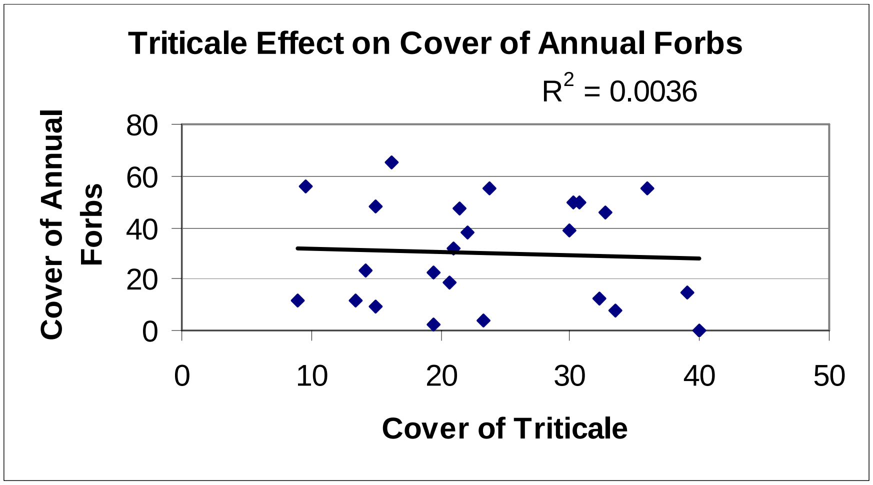

Figure 14. Triticale effect (cover) on cover of annual forbs

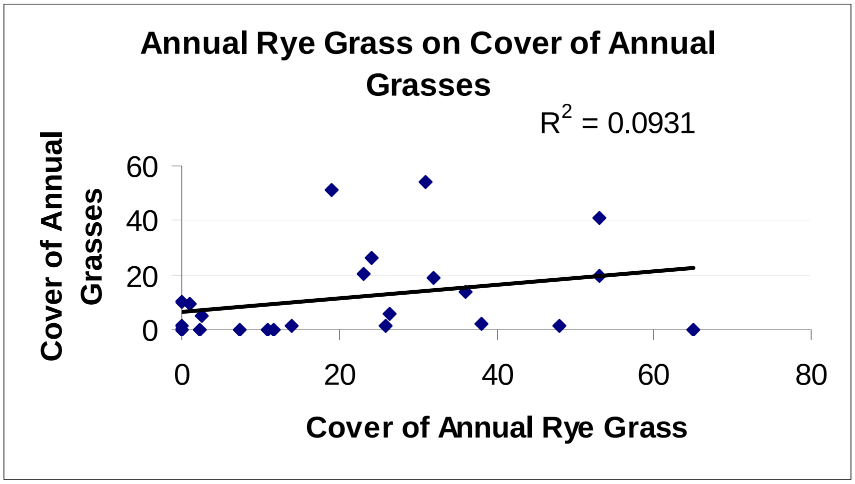

Figure 15. Annual rye grass effect (cover) on cover of annual grasses