AN ABSTRACT OF THE THESIS OF

Joseph P. Washington for the degree of Master of Science in Rangeland Resources presented on April 2, 1996. Title: Re-establishment of Native Perennial Bunchgrasses in Juniper/Medusahead Rangelands.

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Planting experiments assessed the potential for re-establishing native perennial bunchgrasses on two study sites within the Warm Springs Indian Reservation in north-central Oregon. The East Site involved an east aspect with relatively low density western juniper (*Juniperus occidentalis* Hook) overstory and dense medusahead (*Taeniatherum caput-medusae* spp. *asperum* [Sink.] Melderis) understory. The West Site involved a west aspect of high density juniper overstory and a sparse understory of mixed annual grasses and Sandberg bluegrass (*Poa sandbergii* Vasey).

Plantings were conducted in the relatively wet and dry years of 1993 and 1994 respectively, and included squirreltail (*Sitanion hystrix* (Nutt.) Smith), bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) Scrib. & Smith), and Thurber needlegrass (*Stipa thurberiana* Piper). All plantings were conducted in patches of nine propagules, and involved comparison of greenhouse tublings versus direct seed. Plant success was measured after two growth seasons by comparison of survival and reproductive effort. Site treatments involved cutting of juniper overstory, and the cut slash material was assessed as a potential means to improve plant establishment. An additional treatment on the East Site involved burning of the medusahead understory. Control treatments involved uncut juniper on

the West Site, and unburned medusahead on the East Site. A second phase of study involved measurement of percent cover by the existing understory community, prior and after juniper cutting. Density and reproductive effort of existing bunchgrasses was also measured.

Survival and reproductive effort were significantly greater for tublings versus direct seed propagules. Tubling survival exceeded 50% and was usually greater than 85%. Direct seed survival was about 50% when planting was conducted in a wet year, but decreased to 2-20% for planting in a dry year. Mean filled seed production by the most successful squirreltail treatments was 3500 seed/patch for tublings, and 740 seed/patch for direct seed. Maximum mean filled seed production for bluebunch wheatgrass was 1230 and 150 seed/patch, for tublings and direct seed respectively. Success of bluebunch wheatgrass was significantly greater with slash versus no-slash on the East Site, but greater success for squirreltail with slash versus no-slash was not consistently significant. The lowest plant success occurred with uncut juniper on the West Site. There was little or no survival, and no reproductive effort by direct seed with uncut juniper. Tubling survival was significantly less with uncut versus cut juniper, and reproductive effort by tublings with uncut juniper was minimal. Mean values of survival and reproductive effort were lower on the East Site relative to the West Site. Greater squirreltail success with burned versus unburned medusahead on the East Site, was more consistently significant for measurements of reproductive effort.

Understory cover increased after juniper cutting on both study sites. On the West Site, the greatest proportional increase in cover occurred among annual grasses, but based on measurements of reproductive effort, the potential for continued increases of existing bunchgrass cover was considered very high. Increases in litter cover and decreases in bare ground were greater with slash versus no-slash, and cut versus uncut juniper. Medusahead was the primary species that increased in cover on the East Site, but biennial forbs also increased.

It was concluded that improved understory growth and composition could be accomplished in areas similar to the West Site after cutting relatively dense juniper. Reseeding was suggested to inhibit observed increases among exotic annual grasses. Plantings conducted without juniper cutting were considered unlikely to succeed, and further studies of medusahead control were suggested before attempting large scale revegetation projects in areas similar to the East Site.

Re-establishment of Native Perennial Bunchgrasses in Juniper/Medusahead Rangelands

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Joseph P. Washington, Author

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CHAPTER I. INTRODUCTION

The general purpose of this study involved assessing the potential for improving the composition and forage quality of rangelands dominated by western juniper (*Juniperus occidentalis* Hook.)[1] and medusahead *(Elymus caput-medusae L.)*[2]. The study was conducted on confederated tribal lands of the Warm Springs Reservation in north-central Oregon.

Medusahead is a non-native annual grass that has invaded rangelands in portions of eastern Oregon and Washington, California, Nevada, Utah, and Idaho (Young, 1992). Although medusahead may provide moderately good forage in the spring, nutritional value quickly decreases when the plant sets seed and dies during early summer (Lusk et al., 1961; Torell et al., 1961). Dead or mature plants are undesirable to herbivores due to high silica content and physical injury from sharp awns on the seed head.

Medusahead is a very efficient seed producer and commonly forms persistent monotypic stands after displacing native plant species. Excessive grazing pressure assists displacement of native species because they are selected over medusahead when it matures and becomes less desirable (Young, 1992; Robertson and Pearse, 1945). Changes in ecosystem processes and community structure that occurs with increasing medusahead dominance, results in less favorable conditions for re-establishment of native perennial species. Hence, return to a more desirable plant

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[1] species nomenclature follows Hitchcock and Cronquist (1973).

[2] synonymous with *Taeniatherum caput-medusae* spp. *asperum* [Sink.] Melderis (Young, 1992).

community during management time frames has required direct intervention (Young, 1992; Laycock, 1991).

Western juniper is indigenous to eastern Oregon and surrounding states, but increases in aerial extent and stand density during the past 100-150 years is well documented (Eddleman 1984; Young and Evans 1981; Burkhardt and Tisdale, 1969). The recent expansion of juniper has been attributed to disturbances of livestock grazing and wildfire suppression, and decreases in understory growth have been correlated with maturation of juniper woodland communities (Miller, 1995; Eddleman, 1984; Young and Evans, 1981; Burkhardt and Tisdale, 1976; 1969). Greater competitive ability of juniper is attributed to extensive lateral root systems and physiologic growth periods that allow for more efficient capture of limited moisture and nutrient resources (Eddleman and Miller, 1992; Johnson, 1987; Evans and Young, 1987; 1985; Jeppeson, 1978). Juniper canopies have been shown to intercept significant portions of rainfall, which is then lost to evaporation and unavailable to the understory community (Larson, 1994; Eddleman and Miller, 1992, Evans and Young, 1987).

The loss of quality forage production resulting from medusahead and juniper dominance, limit the use of rangelands for livestock grazing. Additionally, the overall condition or health of the rangeland ecosystem is likely to be impaired. Relatively new concepts of range health, suggest that many factors be considered in the assessment of range condition (NRC, 1994). Primary considerations tend to focus on processes that the ecosystem normally supports, and the degree to which these processes continue to operate across temporal and spacial scales. When physiologic processes of the system are diminished, functional inputs or resources are under-utilized and likely to be lost from the system.

Range health of monotypic medusahead communities may be considered less than that of the native plant community due to the loss of species diversity. Processes or functions of the system become un-linked as diversity decreases and the ecologic system is simplified. Ecosystem processes such as nutrient and hydrologic cycles, plant succession, and fire frequencies are disrupted and may result in negative feedback. The medusahead community exhibits a single period of physiologic activity, whereas different species of the native community tend to exhibit successional or overlapping growth periods. Hence, plant growth stages and processes are staggered throughout the season and provide a broader and more diverse base of support for consumer species.

The loss of understory vegetation associated with high densities of juniper may also impact range health through a loss of diversity and ecologic links. When understory growth is sufficiently inhibited and soils are exposed, hydrologic functioning of the system may be impaired through losses of precipitation inputs and increased erosion (Buckhouse and Mattison, 1980).

The present research was conducted in an effort to quantify results of general practices and theories that may be used to improve medusahead or juniper dominated rangelands. Competitive influences of western juniper were considered a primary factor inhibiting understory production, so trees were cut prior to the planting of three native bunchgrass species. Relatively limited planting experiments were also conducted in stands of uncut juniper. Control of annual grass competition has been considered necessary for successful rangeland reseeding efforts (Harris and Dobrowski, 1986; Young et al., 1969; McCell et al., 1962; Torell et al., 1961; Hull and Stewart, 1948). Planting experiments were therefore conducted with and without prior medusahead burning.

Plant litter has been shown to positively influence microclimate and resource conditions for plant establishment (Eddleman, 1996), so material from cut juniper trees, herein termed slash cover, was assessed in regards to its potential for improving planting success. In this study, success encompasses survival and reproductive effort by planted propagules.

Climate and soil conditions of the study area were considered very poor in regards to general requirements for successful re-seeding (Vallentine, 1989). Under relatively poor conditions, greater planting success has been obtained with transplants rather than direct seed (Bainbridge et al., 1995). All species introductions were therefore conducted with greenhouse transplants, herein termed tublings, versus direct seed propagules.

A second aspect of study involved measuring the response of existing understory vegetation to release of western juniper competition after cutting. Responses of the understory were measured by percent cover and density, and involved treatments of slash versus no-slash, and cut versus uncut juniper.

CHAPTER II. LITERATURE REVIEW

Efforts to improve understory forage production by control of juniper woodlands are somewhat controversial (Belskey, 1996). Woodland conversion projects have generally been driven by those with interests in livestock production, but benefits for wildlife, watershed function, biodiversity, and general range health are also cited (BLM, 1993; Johnson, 1987; Dalen and Snyder, 1987; Bedell, 1987). However, there is little actual evidence for increased hydrologic function as a result of juniper or pinyon control projects (Schmidt, 1987; Gifford, 1987; Clary et al., 1974). Claims of juniper's potential to effect widespread rangeland degradation (Bedell et al., 1993; Rumpel et al., 1991), can be countered by the natural role of juniper in climax woodland communities (West and VanPelt, 1987; Burkhardt and Tisdale, 1969). However, this does not take into account the disruption of natural fire frequencies and other perturbations that have allowed juniper to spread from shallow soils and rocky outcrops which afforded natural fire protection, to deeper more productive lowland soils (Burkhardt and Tisdale, 1969).

The earliest efforts to improve understory production were initiated in pinyon-juniper woodlands of the southwest during the 1950's (Stevens, 1987). Bulldozers were most often used to uproot and pile trees for burning or windrowing, and sites were reseeded with exotic or native cultivar species. Quantitative results were often not recorded (Clary and Wagstaff, 1987), but many re-seeding efforts were considered to have failed as a result of poor methodologies and improper matching of seeded species with site characteristics (Johnson, 1987; Stevens, 1987).

More recent woodland control projects have been conducted in the northern regions of the Great Basin and intermountain northwest. Benefits of leaving the cut and limbed tree material on site include conservation of soil moisture and amelioration of soil and microclimate temperatures (Eddleman, 1996; Miller, 1995; Everett and Sharrow, 1987; Stevens, 1987; Gifford, 1973;). As much as 18% of a sites nitrogen resources have been measured within juniper biomass (Tiedemann, 1987), so leaving this material on site to decay should enhance nutrient availability.

Several woodland conversion projects have indicated significant increases in perennial grass cover as a combined result of re-seeding and increased growth of the existing understory after canopy removal (Davis and Harper, 1989; Clary, 1987; Stevens, 1987; Evans and Sharrow, 1985; Barney and Frischknecht, 1974). In some cases, responses of the existing understory were equivalent to, or exceeded production of seeded perennial grasses (Bedell, 1987; Davis and Harper, 1989).

However, multiple entrance points for secondary succession following overstory removal are possible, depending on the Initial Floristic Composition (Egler, 1954) of the understory community. Seed bank diversity and the abundance of mid-seral perennial species has been observed to decrease with increasing maturity of pinyon-juniper woodlands (Koniak, 1985; Koniak and Everett, 1982; Everett and Ward, 1984; Barney and Frischknecht, 1974). Hence, the most favorable understory responses have occurred in relatively young and dense woodlands which still contained components of mid-seral shrub-steppe communities (Evans and Young, 1985; Clary and Jameson, 1981; Jameson, 1971).

In later seral woodlands, or those in which perennial plant propagules were sufficiently depleted, secondary succession began with early seral annual species. Annual forbs accounted for the greatest proportion of increased growth two years after western juniper control in central Oregon (Vaitkus and Eddleman, 1987). Annual grasses were the primary increasers and still maintained dominance several years after removal of juniper competition in northeast California (Evans and Young, 1987; 1985), and eastern Nevada (Everett and Ward, 1984).

The greatest increase in understory production has usually occurred in or around the area of accumulated duff beneath juniper and pinyon canopies (Vaitkus and Eddleman, 1987; Evans and Young, 1985; Everett and Sharrow, 1985; Everett and Ward, 1984; Bedell, 1977; Clary and Morrison, 1973; Arnold, 1964). Nitrogen availability in the duff zone has been observed to increase for 4-6 years after killing juniper with picloram herbicide, and cheatgrass production paralleled the increasing nitrogen content (Evans and Young, 1985; 1987).

The duff zone has also been associated with the greatest proportion of remnant perennial bunchgrasses in comparison to the intercanopy areas (Bedell, 1987; 1977; Vaitkus and Eddleman, 1987; Everett et al., 1983; Clary and Morrison, 1973; Arnold, 1964). This would appear to contradict observations of high density juniper roots within the duff zone (Evans and Young, 1987), which would maximize competition with the bunchgrass plants. However, sagebrush (*Artemisia* spp.) has been shown to increase moisture availability for perennial grasses through mechanisms of hydraulic lift (Richards and Caldwell, 1987), and similar processes may occur beneath juniper. The canopy does intercept significant portions of precipitation before it reaches the duff zone, but increased shading and nutrient resources beneath the canopy, as well as protection from large herbivores, may offset this disadvantage. General observations have suggested difficulty of bunchgrass seed establishment within the juniper duff (Everett and Sharrow, 1985). This could be the result of poor seed-soil contacts resulting from the coarse nature of the duff, but phytotoxic effects of juniper litter on seedlings of several range grasses have been noted (Lavin et al., 1969; Jameson, 1970).

Early efforts to reseed exotic annual grass communities occurred in eastern Washington during the 1940's (Robertson and Pearse, 1945; Hull and Stewart, 1948). Piemeisel (1951) described processes and mechanisms of secondary succession from annual forb to annual cheatgrass (*Bromus tectorum* L.) communities after agricultural abandonment. Continued succession was indicated by establishment of squirreltail (*Sitanion hystrix* (Nutt.) Smith), a short lived perennial grass. In a later study, increased dominance of squirreltail in the cheatgrass community was noted by Hironaka and Tisdale (1963), and further experiments indicated squirreltail had the ability to establish and reproduce when broadcast seeded into undisturbed stands of medusahead (Hironaka and Sindelar, 1973). The ability of squirreltail to establish within annual grass communities was attributed to its ability to maintain root growth and store carbohydrate reserves under the stress of competition (Hironaka and Sindelar, 1975). There have also been reports of Thurber needlegrass (*Stipa thurberiana* Piper) and Purple needlegrass (*Stipa pulchra* Hitchc.), invading annual grass communities in California (Heady, 1956).

However, these observations contrast with numerous studies and reseeding efforts that indicate annual grass communities are essentially closed to reinvasion by later seral species (Harris and Dobrowski, 1986; Harris and Goebel, 1976; Harris, 1967; Young and Evans, 1978; Young et al., 1972, Young et al., 1969; Torell et al., 1961; Hull and Stewart, 1948). These studies usually involved efforts to establish wheatgrass species (*Agropyron* spp.), both native and exotic, that represent a later seral stage than squirreltail. Greenhouse studies have indicated as few as 43 cheatgrass plants/m^2 can negatively influence establishment of wheatgrass, and cheatgrass densities of about 700 plants/m^2 prevented any wheatgrass establishment (Evans, 1961). However, it has been shown that if annual grasses can be controlled such that perennial grasses become established at 2-4 plants/m^2, the perennials are able to maintain dominance and inhibit annual grass expansion (Harris and Goebel, 1976; Young et al., 1969; Heady and Bartolome, 1977).

Field burns conducted under very exact conditions have been successful at reducing medusahead competition and preparing seed beds for planting (Mckell et al., 1962), but Young et al. (1972) found little influence of burning on medusahead populations. The loss of ground litter associated with burning may increase the difficulty for cheatgrass seedling establishment (Evans and Young, 1970; Young et al., 1976), but this may also effect the establishment of desirable species. Medusahead control has also been accomplished with atrazine herbicide (Young et al., 1969), and mechanical plowing and discing have been successful for reducing cheatgrass competition (Cook et al., 1967; Hull and Stewart, 1948). In general, reseeding efforts are more likely to be successful when seed is buried within the soil rather than broadcast seeded. Further increases in reseeding success are likely to occur with increasing intensity of site treatments (Clary and Wagstaff, 1987).

CHAPTER III. MATERIALS and METHODS

Study Area

The study area lies within the southern foothills of the Mutton Mountains at an elevation of about 725 m, in an area locally referred to as Charlie Canyon (T8S, R31E, southern boundary of sections 5 and 6). The Mutton Mountains trend roughly NE-SW, and attain an elevation of 1300 m approximately 2.5 km north of the study site.

Annual precipitation is relatively low, with primary air masses derived from the Pacific after crossing the Cascade Mountains. The 30 year average annual precipitation measured between 1961 and 1990 is 277 mm at Madras, Oregon (Oregon Climate Service, 1993). This station is located 25 km SSE of the study site and 45 m lower in elevation. About 65% of the annual precipitation is received between October and March, with December and January being the wettest months. The 30 year average annual temperature at Madras is 9.5 °C. The warmest months are July and August, with mean daily temperatures of 19.1 °C. Minimum temperatures occur in December and January, with daily means of about 0.7 °C. Extended periods of moderate to high velocity wind were common during the coarse of this study, especially during the spring months.

The foothills of the study area were moderately undulating and incised by numerous drainages. Most stream flow is intermittent and lost to deep percolation before crossing the foothill region. There were many springs in the study area, but relative drought conditions for several years prior to the study, changes in the rangeland vegetation system, and past and present grazing practices, are potential factors contributing to relatively xeric conditions.

Historically, the study area lies within the northern fringes of the shrub-steppe grassland system. However, as evidenced by the current dominance of non-native grasses, vegetative compositions have dramatically changed relative to pre-settlement conditions. Rangelands of the study area have been extensively used for grazing of horses and cattle. Recent stocking rates are greatly decreased relative to accounts of past use, but year-long grazing practices persist. Observations within areas inaccessible to livestock provide insight concerning the native plant community, and a list of species encountered during the course of study is located in Appendix A.

Remnant native vegetation consists of several perennial bunchgrass species - principally squirreltail (*Sitanion hystrix* (Nutt.) Smith), bluebunch wheatgrass (*Agropyron spicatum* (Pursh.) Scrib. & Smith), and Sandberg bluegrass (*Poa sandbergii* Vasey). Other bunchgrass species of relative scarcity include mountain brome (*Bromus carinatus* H. & A.), Thurber needlegrass (*Stipa thurberiana* Piper), basin wildrye (*Elymus cinereus* Scribn. & Merr.), Junegrass (*Koleria cristata* Pers.), and one-spike oatgrass (*Danthonia unispicata* (Thurb.) Munro).

Woody shrubs tend to be concentrated in localized patches and include bitterbrush (*Pursia tridentata* Pursh), sagebrush (*Artemisia tridentata* var. *vaseyana* Nutt.), rabbbitbrush (*Chrysothamnous nauseosus* (Pall.) Britt., and *C. viscidiflorus* (Hook.) Nutt.), horsebrush (*Tetradymia canescens* DC.) and slenderbush (*Eriogonum microthecum* var. *microthecum* Nutt.). The most abundant perennial forbs included *Achillea millefolium* L., *Agoseris grandiflora* (Nutt.) Greene, *Antennaria dimorpha* (Nutt.) T. & G., *Crepis occidentalis* Nutt., *Happlopappus acaulis* (Nutt.) Gray, *Eriogonum strictum* Benth., *Lupinus caudatus* Kell., *Lomatium* spp., *Allium* spp., and *Astragalus* spp.. Several annual forb species are common and listed in Appendix A.

As stated, current understory vegetation is dominated by medusahead, a non-native annual grass. Nearly monotypic stands of medusahead occur at densities of more than 1000 plants/m^2 across large areas on the eastern border of the reservation. Accumulated litter from medusahead dominates the structural composition of the ground surface, and is the primary influence of the soil seed bed environment. Other non-native annual grasses include cheatgrass (*Bromus tectorum*), and to a much lesser extent, *B. brizaeformis* Fisch. & Mey., *B. commutattus* Schrad., and *Festuca bromoides* L.. A native annual grass, *Festuca microstachys* Nutt., is also present.

Within the area of study, juniper trees appeared to be moving downslope from higher elevation stands in the Mutton Mountains. The largest and most vigorous trees tended to occur at relatively low densities on gentler slopes of red clay soil, with dense understories of medusahead. In terms of total acreage, this was the predominant community type in the foothill region.

A second community type involved drainage side slopes and ridgelines of gray gravelly clay and somewhat loamier surface soil. Juniper densities were much greater in these areas, but the understory was sparse and 90% bare ground was often found in the intercanopy areas. Understory species were more equally comprised by a mixture of annual grasses and forbs rather than monotypic medusahead stands, and Sandberg bluegrass often co-dominated the intercanopy understory. Several of the previously mentioned native bunchgrasses were also present, but generally of low vigor and confined to duff zones beneath juniper canopies.

Specific study sites were located on the east and west facing slopes of a generally north-south trending ridge. These are henceforth referred to as the East and West Study Sites. The East Site was typical of the low density juniper - high density medusahead community type. Although juniper densities reached at least 75 trees/ha and 20%

canopy cover, there was no juniper cover directly within study plots of the East Site. Juniper densities within 10 m of the plots averaged about 40 trees/ha. Slopes on the East Site were 20-40%, with a general aspect of approximately N70E (70° east of north). As identified in preliminary studies by the Soil Conservation Service (SCS, 1994), soils were comprised of red clays and clay loams of the Day Complex. Rooting depths were reported to be at least 1.5 m, but when dry, soils below 15 cm were extremely hard. Shrinking and swelling was evidenced by the formation of surface cracks 25 cm deep and 2 cm wide.

The West Site is typified by relatively dense stands of western juniper. Thirty percent canopy cover was measured on the West Site with 165 trees/ha over 15 ft in height. Younger juniper trees tended to occur beneath the canopy of older trees. Ground cover was sparse and primarily comprised of cheatgrass, *Festuca* spp., and Sandberg bluegrass. Except for dense patches infringing into the corners of the West Site, medusahead formed a relatively minor component of the understory. Previously mentioned perennial grasses and forbs were more abundant on the West Site compared to the East, but the most abundant perennial grass - squirreltail, provided less than 1% cover. The general aspect of the West Site was about W20S, with slopes of 25-40%. Soils on the West Site consisted of grey to brown gravelly clays and loams of the Sorf-Simas Complex (SCS, 1994). Rooting depths are reported to be about 1 m. These soils became extremely hard with drying, but did not exhibit shrinking and swelling.

Climate Regime

Because the success of revegetation projects is primarily dependent on moisture availability after planting (Vallentine, 1989), a brief summary of annual precipitation is included for interpretation of planting results from two different years. Precipitation at the study site was measured with a standard USFS rain gage between the summer of 1992 and the end of 1994. Additional precipitation data for the period of 1989 to the summer of 1992, was obtained from a weather station on Mutton Mountain, approximately 7 km to the north and 350 m higher in elevation. Air temperature was estimated from measurements at the Agricultural Experiment Station at Madras. Bimonthly springtime measurement intervals of the study site rain gage were proportionally split into daily precipitation events based on records from Madras.

Precipitation and temperature during 1989-1994 are shown in Figure 1. Portions of the precipitation curve that exceed the temperature curve provide an indication of moisture availability during the growth season.

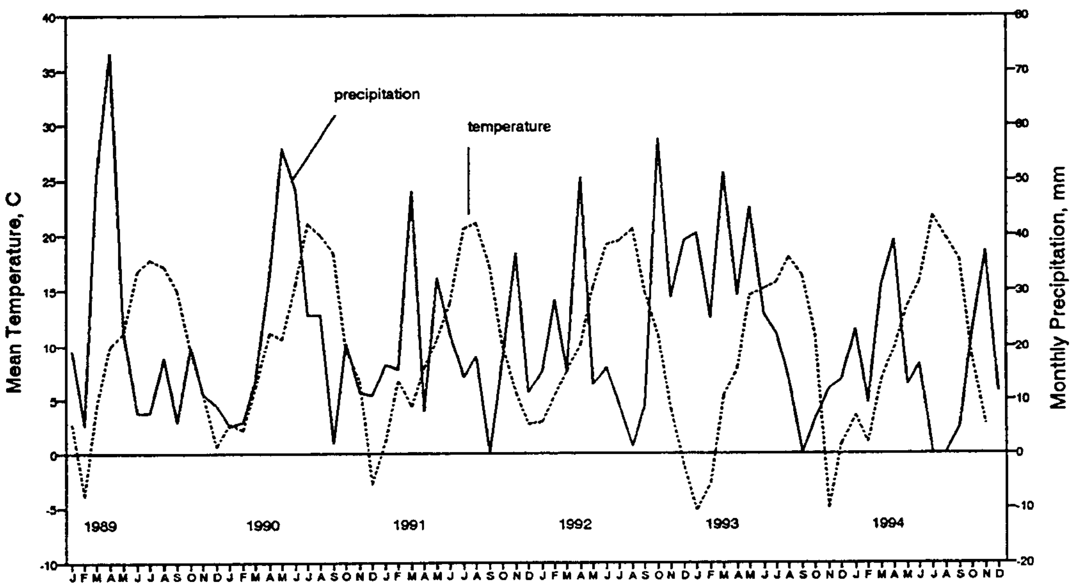

Figure 1. Monthly temperature and precipitation during 1989-1994. Vertical scales are after Walter (1963).

The 30 year Average Annual Precipitation (AAP) recorded at Madras is 277 mm (10.9 in). Based on a plant water year of October through September, about 220 mm, or 80% of the AAP was received during 1991 and 1992. Planting experiments of 1993 coincided with much wetter conditions, as almost 380 mm of precipitation was received (137% of AAP). Although rare in recent years, 20-30 cm of snow was observed on the study site during January, 1993. In contrast, only 168 mm of precipitation was received during the 1994 water year (61% of AAP), so planting experiments of 1994 were conducted under relative drought conditions.

Figure 2 compares precipitation received immediately prior and after planting was conducted in each year.

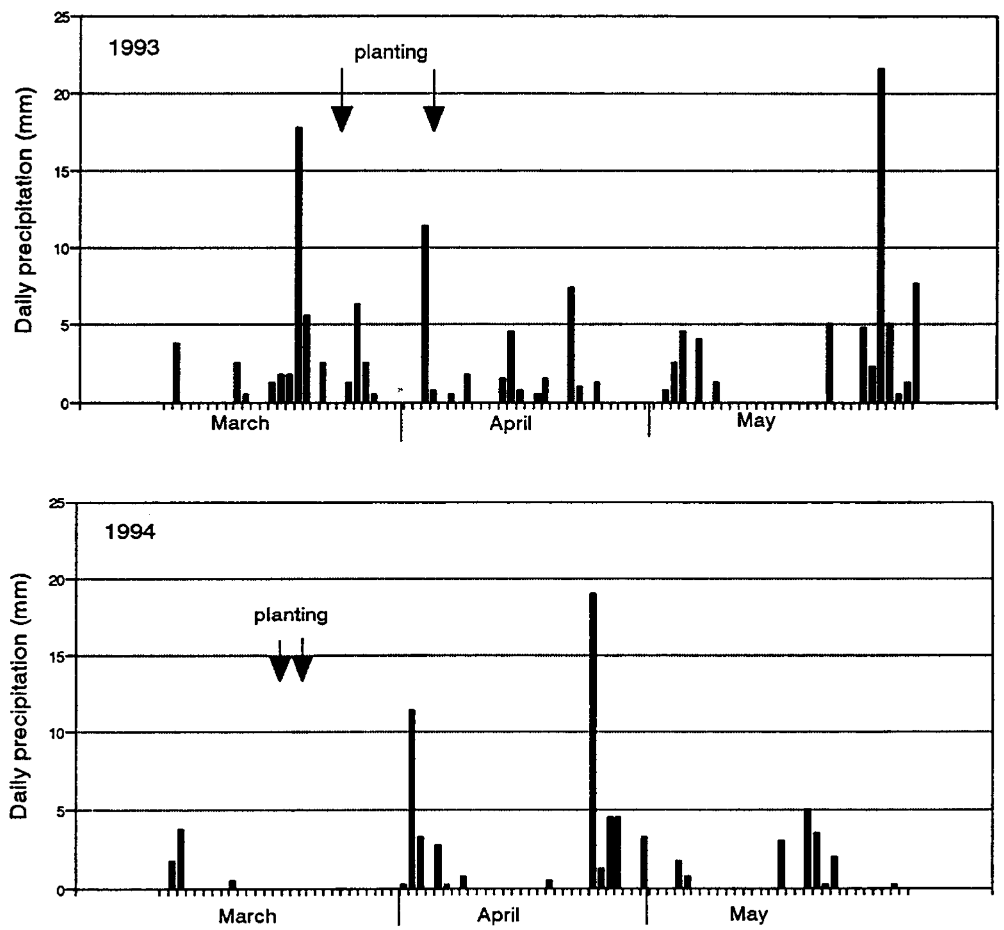

Figure 2. Estimated daily precipitation during March-May.

Planting in 1993 occurred during or immediately after significant rain events. Additional precipitation, although often less than 5 mm per event, tended to occur every 3-7 days through April and the first week of May. Almost 50 mm of precipitation was received during the last week of May. In contrast, planting in 1994 was conducted under very dry conditions. Precipitation of 15-20 mm was received ten days after planting, but the next significant rainfall was not received until one month later.

Experimental Treatments

The entire study area was fenced in the fall of 1992 to exclude grazing. Experimental sites are referenced to the year of planting and slope aspect, hence there are four sites - 1993 West, 1994 West, 1993 East, 1994 East. Sample plots measured 5 x 10 m, and plot locations within each site can be found in Appendix B. Table 1 provides a brief description of each experimental treatment, and abbreviations that are used in summary figures and tables. The sample size (N) for 1993 and 1994 planting treatments usually equaled 5 and 10 respectively. Exceptions involved BTJ on the 1993 West Site (N=4), BT and BS on the 1994 West Site (N=9), and STJ on the 1994 West Site (N=5).

Within blocks of cut juniper on the West Sites, species and treatments were randomly assigned to the allocated number of sample plots. Sample plots within stands of uncut juniper were located within available space along the margins of the cut juniper block, and were therefore not randomized. On the 1993 East Site, the experimental design was a randomized complete block, with the exception of the unburned medusahead treatment which was systematically located in the last sample plot of each block. This was done to facilitate proposed field burning operations by allowing the first four plots in each block to be burned as a single unit. The 1994 East Site involved a randomized assignment of burned and unburned blocks.

Table 1. Treatment descriptions and locations.

	Description	Location
ST	squirreltail tublings with slash[1]	All Sites (and years)
ST-	squirreltail tublings with no-slash	West Sites and 1993 East Site
ST*	squirreltail tublings with unburned medusahead[2]	East Sites
STJ	squirreltail tublings with uncut juniper	1994 West Site
SS	squirreltail direct seed with slash	All Sites
SS-	squirreltail direct seed with no-slash	West Sites and 1993 East Site
SS*	squirreltail direct seed with unburned medusahead[2]	East Sites
SSJ	squirreltail direct seed with uncut juniper	West Sites
BT	bluebunch wheatgrass tublings with slash	West Sites and 1993 East Site
BT-	bluebunch wheatgrass tublings with no-slash	1993 East Site
BS	bluebunch wheatgrass direct seed with slash	West Sites and 1993 East Site
BS-	bluebunch wheatgrass direct seed with no-slash	1993 East Site
TT	Thurber needlegrass tublings with slash	1993 West Site
TS	Thurber needlegrass direct seed with slash	1993 West Site

[1] unless otherwise indicated, treatments on the East Site involved medusahead burning.
[2] included no-slash in 1993, slash in 1994.

On 1993 sites, juniper trees were cut immediately prior to planting in late March. On 1994 sites, juniper was cut during September 1993, prior to planting in March 1994. Medusahead burn treatments on the East Sites were conducted prior to juniper cutting and placement of slash cover. Fall field burns on the 1993 East Site were unsuccessful as a result of excessive moisture, so burning was conducted with a propane torch the day before planting. On the 1994 East Site, the Warm Springs Fire Agency conducted a field burn during September 1993. Analysis of the seed bank indicated a mean of 11,275 *(s=1908)* germinable medusahead seed prior to burning, and 9,475 *(s=3500)* medusahead seed after burning (N=5).

Native bunchgrasses used for planting included squirreltail, bluebunch wheatgrass, and Thurber needlegrass. Seed sources for the three species were insufficient in the vicinity of the study site, so seed was collected from sites approximately 40 km to the south. Squirreltail and bluebunch wheatgrass seed were collected from a mixed community of perennial grasses and medusahead. Greenhouse tests indicated germination rates of about 80% for squirreltail and bluebunch wheatgrass, and 60% for Thurber needlegrass. The number of days required for germination was 2-4, 4-6, and 5-20 respectively.

Tublings were propagated in a greenhouse at Oregon State University in mid-December, about three months prior to out-planting in late March. Plastic tubling containers were 21 cm long, and tapered from 3.8 cm at the top to 2.5 cm at the bottom. Potting mixtures consisted of peat moss and vermiculite, and plants were generally well watered several days per week. Tublings generally exhibited 2-4 tillers at the time of out-planting, and root systems appeared moderately well to well developed.

All plantings were conducted in patches comprised of nine tublings or direct seed propagules, which were arranged in a 3 x 3 grid with 15-20 cm spacing between individual propagules. Plant patches were systematically located within each sample plot to ensure an equal area of slash or no-slash around each plant patch, and to assist potential measurements of reproduction by individual patches without interference from adjacent patches. Three patches were planted in each of the 1993 West Site sample plots, with each plot receiving only one propagule type.

Two plant patches of each propagule type were paired within sample plots of the 1994 West Site, and both East Sites. As discussed, planting in 1993 was conducted during relatively rainy weather between March 25 - April 10, while planting in 1994 was conducted during dry weather between March 18-25. To help alleviate the relatively long time frame of 1993 planting, propagules planted on the weekends of April 3 and 10 were supplied with 250 ml of water.

Individual wedge shaped holes measuring approximately 15 cm at the widest point, and 22 cm deep, were excavated for planting of each tubling. Native soils from each hole were backfilled and packed by hand around the transplanted tublings. Seed was planted in small holes formed by removing circular soil plugs measuring 6.3 cm in diameter and 2-4 cm in depth. Five or six seed of squirreltail and bluebunch wheatgrass, and about ten seed of Thurber needlegrass, were placed in each hole and lightly covered with soil. When necessary, excess seedlings emerging within each hole were thinned to 1 or 2 vigorous individuals about three weeks after planting.

The second phase of study involved measuring the response of the existing understory vegetation to the treatment of juniper cutting on the 1993 Study Sites. Experimental plantings had no influence on cover measurements because the plant patches were avoided and successful reproduction by the plantings was not observed during the period of study.

On the West Site, 34 sample plots received the treatment of slash, while 14 plots received no-slash (randomized design). There were 10 control plots of uncut juniper (and no slash), and as mentioned, these were not randomly located. On the 1993 East Site, two sample plots within each block of 5 plots were randomly assigned to slash, while the remaining 3 plots of each block were assigned to no-slash. Thus, a total of 10 plots received slash while 15 did not. Slash treatments provided approximately 50% cover. Percent cover of understory species and structural ground components was measured during the summer of 1992, prior to juniper cutting in March of 1993. Measurements were then repeated during the summer of 1993 and 1994. The 10 control plots of uncut juniper on the West Site were not established until 1993, so cover was measured only in 1993 and 1994.

Twenty cut and 10 uncut juniper trees were randomly selected from the 1993 West Site to measure the influence of juniper overstory removal, on remnant perennial bunchgrasses within the duff zone beneath the canopy. The 20 cut trees were randomly selected from the block of cut juniper, while the 10 uncut trees were randomly selected from the vicinity of the control plots. The duff zone was easily delineated from intercanopy areas by accumulated juniper litter, but the circular area of duff was not measured.

Data Collection

Plant survival was measured as the proportion of planted holes containing a live plant. Thus, measurements of direct seed survival were referenced to the number of planted holes, not the maximum number of holes with observed emergence, or the maximum number of seedlings that emerged. Holes exhibiting several emerged seedlings were thinned to 1 or 2 vigorous individuals, but this did not change the percent of holes with a live plant. Percent survival measurements were collected approximately 6 weeks after planting, and every 1-2 months thereafter during the active growth seasons. Fewer survival measurements were conducted on 1994 sites due to the dry planting year and difficulty of determining whether plants were dead or dormant. Only a single measurement was collected from the 1994 Sites during the second and wetter growth season.

For 1993 treatments, seed production was sampled from plant patches of squirreltail and bluebunch wheatgrass during late June and early July of the second growth season. Seed production was not sampled from Thurber needlegrass because seed culms had matured at an earlier date and seed was dispersed, and/or seed culms had been chewed by rodents.

Only one plant patch was usually sampled from each propagule type per sample plot. This allowed for maximum potential reproduction and expansion of the unsampled patches. However, seed production appeared highly variable among plant patches in a few of the sample plots, so two patches were sampled and the results were averaged. In most cases, only 30-40% of the seed culms were collected from each plant. This was partly due to time constraints involved in counting seed, but additionally, there was a high degree of variability in seed maturation among different plants of the same plant patch, as well as among different culms of the same plant. This was especially true for squirreltail, but also occurred among bluebunch wheatgrass. Relatively large and small sized seed heads were alternately collected from each plant in an effort to sample average production.

Seed culms from plants within the same patch were sampled together and placed in the same bag. Seed heads were cleaned by hand, and filled and empty seed were sorted and counted with the use of a light table, with the filled seed assumed to be germinable. The total number of filled and empty seed produced per plant patch was estimated by dividing the number of collected seed by the proportion of seed culms that were actually sampled from the plant patch. Thus, it is assumed that seed culms sampled were representative of all culms produced in the plant patch. Time did not permit sampling of seed production by 1994 treatments, but the number of seed culms were counted on all plants during the second year survival measurement.

Percent cover by species and structural ground components was visually estimated within each sample plot from ten randomly located and permanently marked transect frames measuring 40 x 50 cm. The transects were measured in 1992, and re-measured in 1993 and 1994 after juniper cutting. Cover measurements were grouped into life forms of annual and biennial forbs, annual grasses, perennial forbs, perennial grasses, and structural ground components of bare soil and gravel, and plant litter.

The density of squirreltail, bluebunch wheatgrass, and Thurber needlegrass plants were measured within each sample plot of the 1993 West Site. Measurements were conducted in 1992 and 1994, which correspond to zero and two years of competitive release from juniper. Within control plots of uncut juniper, bunchgrass density was measured only in 1994. Propagules from the planting experiments were not included in the density measurements. The three bunchgrass species, as well as their seed culms, were also counted within juniper duff zones during 1993 and 1994, which correspond to one and two seasons of competitive release from juniper.

Data Analysis

Statistical analysis was conducted for survival (the proportion of holes with live plants) and reproductive effort after two growth seasons. Statistical comparisons were made between directly contrasting treatments of each species, but were not conducted between species or different planting sites.

Statgraphics (STSC, 1992) software was utilized for all statistical analysis. Significance levels were set at 0.05, and reported p-values are one-sided. For planting experiments, two sample t-tests were used to compare survival and reproductive effort of slash versus no-slash, cut versus uncut juniper, and burned versus unburned medusahead. Paired t-tests were used for analysis of tubling versus direct seed propagules planted within the same sample plot, but this comparison was conducted with two sample t-tests on the 1993 West Site due to the non-pairing of propagule types. Despite the small sample sizes, basic assumptions of the t-tests were considered to be adequately met for most comparisons. Unequal variances were incorporated into confidence intervals when the ratio of standard deviations exceeded 2.0. Analysis of seed production was often conducted after transforming data to the square root scale in order to equalize sample variances. In a few cases where assumptions of the two sample t-tests were not met (uncut juniper), Rank Sum tests (Ramsey and Schafer, 1993) were utilized.

Changes in understory cover were analyzed with Repeated Measures ANOVA (STSC, 1991). For percent cover variables measured in the blocks of cut juniper, main effects involved slash versus no-slash, and the measurement year, which represented zero, one, and two years of competitive release from juniper. The interaction of the main effects was analyzed to determine if cover variables changed differently over time among the slash and no-slash treatments. If the interaction was not significant, the year effect was assessed to determine if percent variables significantly changed between years for either the slash or no-slash treatment. Significance of the slash effect with insignificance of the interaction, indicates cover was significantly different among the two slash and no-slash groups in at least one of the measurement years, but cover changed similarly among the two groups.

Because control plots of uncut juniper on the West Site were not measured in 1992, Repeated Measures ANOVA was conducted separately for cut (and no-slash) and uncut juniper treatments (1993-1994). Main effects involved cut versus uncut juniper, and the measurement year, which represented one and two years of competitive release from juniper. Significance for the main effects and interaction have the same meaning as discussed above.

Repeated Measures ANOVA was also conducted for measurements of bunchgrass density in sample plots, and bunchgrass plant and seed culm numbers within duff zones. Main effects involved the slash treatment and measurement year for bunchgrass density in sample plots, and juniper cutting and measurement year for plant and seed culm numbers in duff zones. The interaction was assessed to determine if bunchgrass numbers changed differently with slash and no-slash, or cut versus uncut juniper. Further analysis involved Paired t-tests between measurement years within treatments, and two sample t-tests between treatments within years.

Although sample distributions of percent cover variables analyzed with ANOVA were not always normal, data transformations which improved the distributions resulted in the same conclusions. Assumptions pertaining to linear trends of percent cover variables over the three measurement dates were not always met, but compared samples tended to exhibit similar trends. Sample distributions for bunchgrass plant and seed culm numbers were normally distributed and adequately met assumptions of ANOVA and t-tests.

CHAPTER IV. RESULTS

Planting Experiments

1993 West Site (wet year)

Summary and comparison analysis for measurements of survival and reproductive effort after two growth seasons are listed in Appendix C for each study site. The data is summarized in Figure 3 and Table 2 for the 1993 West Site.

Tubling survival for all species was significantly greater than direct seed survival. It should be noted from Figure 3 that the greatest proportion of direct seed mortality occurred on the first measurement date six weeks after planting. Further mortality during the first and second growth seasons was relatively small. An exception involved direct seed with uncut juniper that exhibited 95% emergence on the first measurement date, and high mortality throughout the first growth season. The high rate of emergence is attributed to water supplied when planting this treatment to help alleviate the late planting date.

Survival was significantly greater with slash versus no-slash for squirreltail tublings, but not for squirreltail direct seed. Squirreltail direct seed and bluebunch wheatgrass tublings, exhibited significantly greater survival when juniper was cut versus uncut.

The number of filled seed per plant patch was also significantly greater for tublings versus direct seed of squirreltail and bluebunch wheatgrass. Seed production was not significantly greater with slash versus no-slash for either type of squirreltail propagule. Squirreltail direct seed and bluebunch wheatgrass tublings exhibited greater seed production with cut versus uncut juniper.

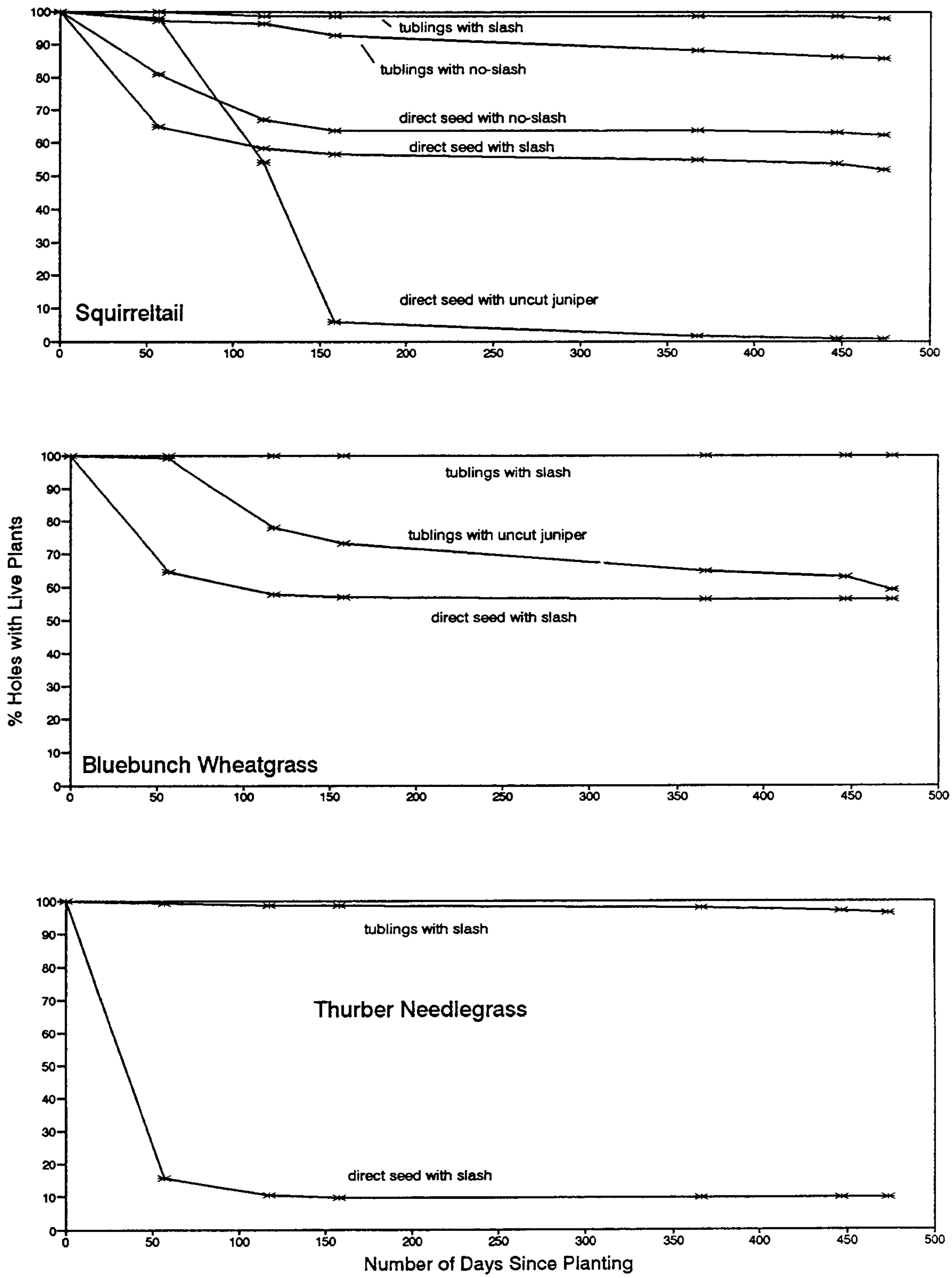

Figure 3. 1993 West Site. Percent of holes with live plants for the three species of planting. Mean planting date was March 27, 1993 (day = 0), while the last measurement date was July 10, 1994, (day = 470).

Table 2. 1993 West Site. Filled seed production per plant patch after two growth seasons.

	ST	ST-	SS	SS-	SSJ	BT	BTJ	BS
mean	3487	2698	652	738	0	1276	0.8	150
sd	*1328*	*2160*	*681*	*354*	-	*525*	*1.5*	*145*

1994 West Site (dry year)

Survival data are shown in Figure 4, while the number of seed culms/patch are listed in Table 3.

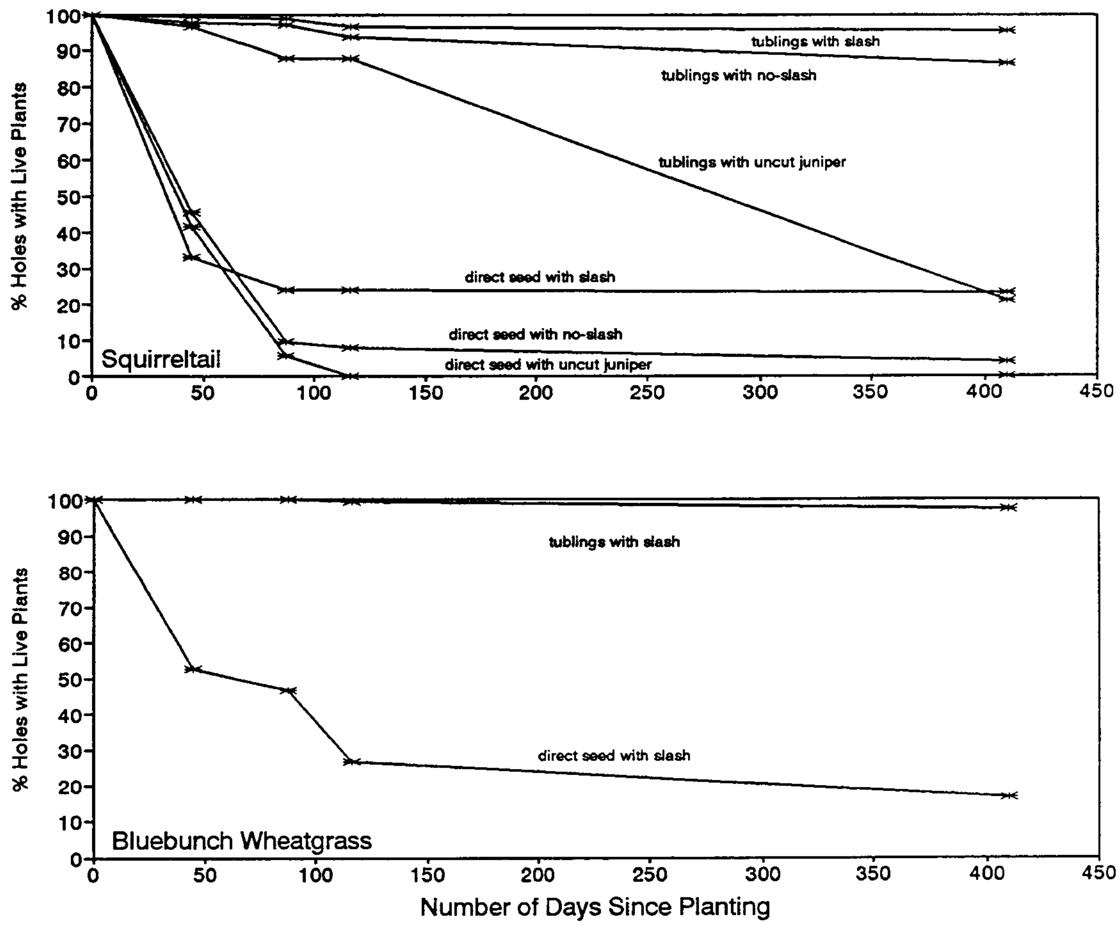

Figure 4. 1994 West Site. Percent of holes with live plants for the two species of planting. Mean planting date was March 22, 1994 (day = 0), while the last measurement date was June 19, 1995 (day = 454).

Table 3. 1994 West Site. Number of seed culms per plant patch after two growth seasons.

	ST	ST-	STJ	SS	SS-	SSJ	BT	BS
mean	40.0	118.	2.5	1.0	0	0	21.1	0
sd	*21.7*	*31.0*	*1.8*	*1.9*	-	-	*17.2*	-

Tubling treatments of squirreltail and bluebunch wheatgrass exhibited significantly greater survival than direct seed. Survival for squirreltail tublings was significantly greater with slash versus no-slash, and unlike 1993 plantings, the same was true for squirreltail direct seed. Squirreltail tublings and direct seed exhibited significantly greater survival when juniper was cut versus uncut, and in fact, direct seed exhibited complete mortality before the end of the first growth season when juniper was not cut.

Tublings also produced a significantly more seed culms/patch than direct seed. In contrast to 1993 where reproductive effort by squirreltail tublings was not significantly greater with slash versus no-slash, squirreltail tublings of 1994 produced significantly more seed culms/patch with no-slash versus slash. The number of seed culms/patch produced by squirreltail tublings was significantly and dramatically greater with cut versus uncut juniper. Seed culm production by squirreltail direct seed was very small with cut juniper and slash, but significantly greater than zero reproductive effort with cut juniper and no-slash, or uncut juniper and no-slash.

1993 East Site (wet year)

Survival and seed production data are shown in Figure 5 and Table 4 respectively. Most sample distributions of seed production exhibited a high degree of positive skewness, so the sample medians are also listed. Data were often transformed to the square root scale prior to statistical analysis.

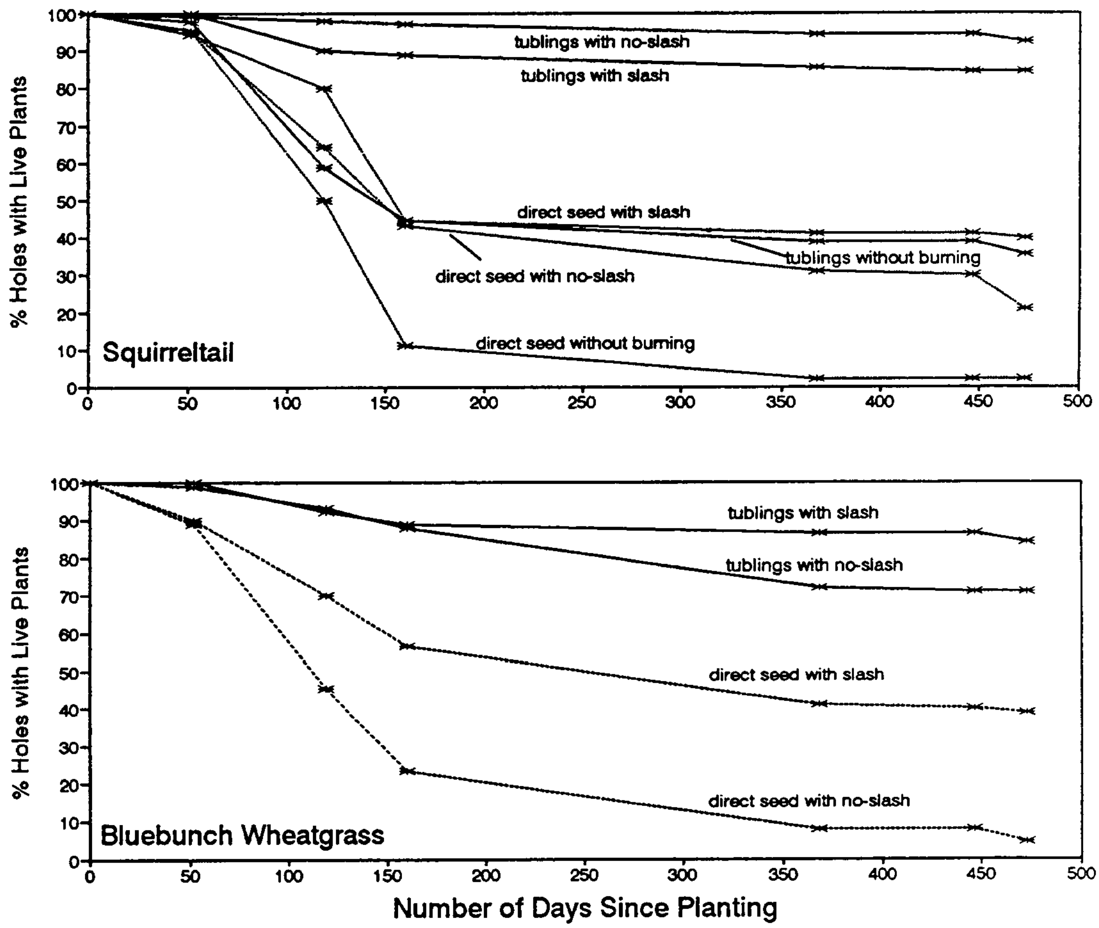

Figure 5. 1993 East Site. Percent of holes with live plants for the two species of planting. Mean planting date was April 1, 1993 (day = 0), while the last measurement date was July 10, 1994 (day = 465).

Table 4. 1993 East Site. Filled seed production per plant patch after two growth seasons.

	ST	ST-	ST*	SS	SS-	SS*	BT	BT-	BS	BS-
mean	2422	1639	472	327	75.0	4.4	349	33.0	3.6	1.5
median	2882	565	78	0	0	0	212	0	0	0
sd	*1981*	*1816*	*746*	*459*	*135*	*9.8*	*21.6*	*31.0*	*6.1*	*3.4*

Again, tubling survival for squirreltail and bluebunch wheatgrass was significantly greater than direct seed survival. Squirreltail survival was not significantly greater with slash versus no-slash for either propagule type, but survival for both bluebunch wheatgrass propagules was significantly greater with slash versus no-slash. Squirreltail tubling survival was significantly greater when medusahead was burned versus unburned, but greater mean survival by squirreltail direct seed with burned versus unburned medusahead was not quite significant.

Squirreltail tublings produced significantly more filled seed/patch than direct seed propagules when slash cover was provided. However, at least several fold greater mean seed production by tublings versus direct seed was not significant with the no-slash and unburned treatments. Filled seed production by bluebunch wheatgrass was significantly greater for tublings versus direct seed, with both the slash and no-slash treatments.

Seed production by squirreltail tublings and direct seed was not significantly greater with slash versus no-slash. Bluebunch wheatgrass tublings produced significantly more filled seed/patch with slash versus no-slash, but this was not true for bluebunch wheatgrass direct seed. Despite several fold greater mean seed production by squirreltail propagules with burned versus unburned medusahead, the differences were not significant.

1994 East Site (dry year)

Data of survival and seed culms/patch are shown in Figure 6 and Table 5 for squirreltail propagules planted with burned and unburned medusahead in 1994. All treatments received slash.

Tubling survival was significantly greater than direct seed survival. Survival was not significantly greater with burned versus unburned medusahead for either type of squirreltail propagule. Reproductive effort by tublings was significantly greater than direct seed, which did not exhibit reproductive effort after two seasons of growth. Tublings produced significantly more seed culms/patch with burned versus unburned medusahead.

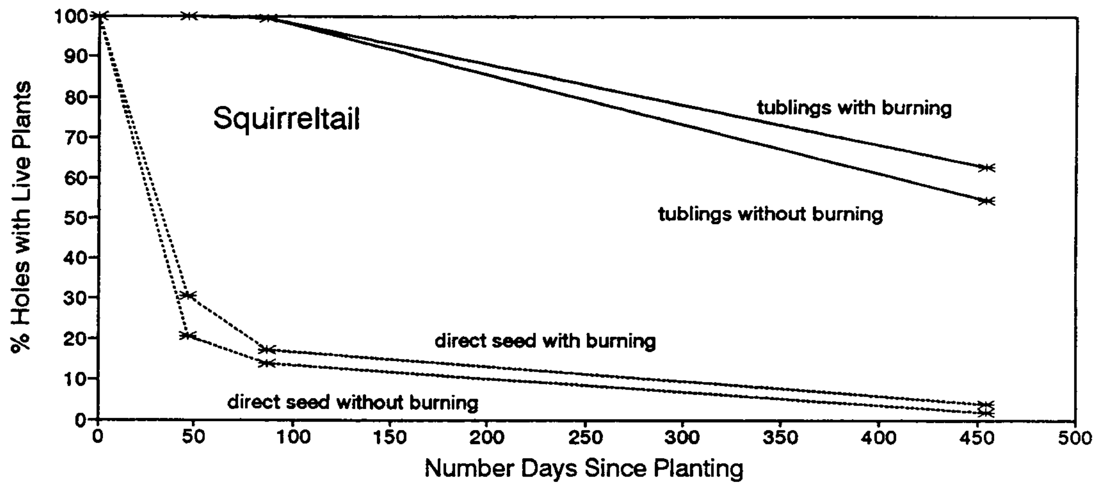

Figure 6. 1994 East Site. Percent of holes with live plants for squirreltail treatments. Planting was conducted on March 20, 1995 (day = 0), while the last measurement date was June 20,1995 (day = 457).

Table 5. 1994 East Site. Number of seed culms per plant patch after two growth seasons.

	ST	ST*	SS	SS*
mean	22.1	9.1	0	0
sd	*16.0*	*9.7*	-	-

Understory Response

1993 West Site

Measurements of percent cover during 1992-1994 are summarized in Table 6. As discussed in the Methodology, Repeated Measures ANOVA was conducted twice - once with three years of data (1992-1994) for the slash and no-slash treatments, and once with two years of data (1993-1994) for the no-slash and uncut control treatments. Significance for the interaction term indicates that percent cover changed differently among the slash versus no-slash treatments, or cut versus uncut juniper (and no-slash).

First year measurements of juniper canopy cover were not significantly different between treatment groups. After juniper cutting, slash treatments averaged about 44% cover in 1993 and slightly decreased to 41% in 1994.

Pre-treatment (1992) litter cover averaged 37.6% in sample plots that were eventually assigned to the slash and no-slash treatments. Most of the litter cover was derived from transect locations that fell beneath the canopy of juniper trees, where accumulated duff covered 100% of the ground surface. Intercanopy areas generally exhibited less than 10% litter cover in 1992.

Litter cover changed differently among the slash and no-slash treatments - there was a relatively minor increase in litter cover with no-slash, but a several fold increase in litter cover with slash. Litter cover also changed differently among the cut and uncut juniper groups - relatively small increases in litter cover with cut juniper were contrasted with decreases in litter cover with uncut juniper. The percent of bare ground exhibited trends inverse to that of litter cover among the three treatment groups, and significant changes in bare ground were identical to that of litter.

Table 6. 1993 West Site. Percent cover during 1992-1994, and results of Repeated Measures ANOVA. (-) indicates not measured. (* p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001).

		Percent Cover			p-values	
Parameter	Treatment	pre-juniper cutting (1992)	1 season of release (1993)	2 seasons of release (1994)	slash vs no-slash (1992-94)	cut vs uncut (1993-94)
Uncut Juniper	slash (N=34)	20.8	0.0	0.0	T = slash or cutting effect	
	no-slash (N=14)	15.7	0.0	0.0		
	uncut (N=10)	-	16.7	-	Y = year effect	
Slash Cover	slash	-	44.2	41.1	I = interaction	
	no-slash	-	-	-		
Litter	slash	38.0	63.0	77.0	T **	T
	no-slash	37.2	36.4	40.4	Y ****	Y
	uncut	-	57.8	49.3	I ****	I ***
Bare Ground (gravel and soil)	slash	61.0	35.0	20.6	T ***	T
	no-slash	61.3	61.2	56.7	Y ****	Y
	uncut	-	40.1	47.1	I ****	I ***
All Annual Grasses	slash	1.3	1.7	6.6	T ***	T
	no-slash	2.3	2.8	11.0	Y ****	Y ****
	uncut	-	5.8	5.6	I ****	I ****
Medusahead	slash	0.35	0.42	1.4	T	T
	no-slash	1.2	1.1	2.9	Y ****	Y
	uncut	-	4.4	3.1	I	I *
Cheatgrass	slash	0.34	0.74	4.1	T	T *
	no-slash	0.42	1.0	4.4	Y ****	Y ***
	uncut	-	0.74	1.5	I	I *
Annual & Biennial Forbs	slash	0.48	0.46	0.89	T	T **
	no-slash	0.41	0.66	0.62	Y ***	Y *
	uncut	-	0.33	0.04	I *	I
Perennial Forbs	slash	0.25	0.98	1.6	T	T *
	no-slash	0.26	1.2	1.6	Y ****	Y
	uncut	-	0.43	0.15	I	I
All Perennial Grasses	slash	1.0	0.92	1.6	T	T
	no-slash	1.1	0.74	1.6	Y **	Y
	uncut	-	0.76	0.96	I	I
Squirreltail	slash	0.08	0.19	0.95	T	T
	no-slash	0.26	0.21	0.67	Y ***	Y
	uncut	-	0.10	0.17	I	I
Sandberg Bluegrass	slash	0.92	0.73	0.59	T	T
	no-slash	0.72	0.54	0.43	Y ***	Y
	uncut	-	0.66	0.78	I	I

Mean annual grass cover was less with slash versus no-slash prior to implementing any treatments. Although the interaction term was significant, annual grass cover exhibited proportionally similar increases of about 500% between the first and third measurement years for both the slash and no-slash treatments.

The uncut juniper treatment contained more than twice the mean annual grass cover as the cut treatment (no-slash) in 1993. However, in contrast to several fold increases in annual grass cover with cut juniper, the uncut treatment exhibited a slight decrease in annual grass cover between 1993 and 1994. The interaction was significant and the relative percent of annual grass cover was reversed among cut and uncut juniper - cut juniper contained more than twice the annual grass cover as uncut juniper.

Table 6 also lists contributions of medusahead and cheatgrass to the total annual grass cover. Despite differences in mean percent medusahead cover between slash and no-slash treatments, only increases across measurement years were significant. Cheatgrass cover was similar among slash and no-slash treatments, and mean increases across years were significant and greater than increases of medusahead.

Annual forb cover remained less than 1% during the course of study for all treatments. This is at least partially attributed to the relatively late season measurements when most forbs were dead and desiccated, and the remains potentially dispersed. Increases in annual forb cover were slightly greater for the slash versus no-slash treatments, and the interaction term was significant. Although decreases in mean annual forb cover between 1993 and 1994 were much greater with uncut versus cut juniper, the interaction term was not significant. Significance for the cutting and year effects most likely reflects the decrease observed among annual forbs with uncut juniper.

There was a striking change in the composition of annual forbs within plots of cut juniper during the course of study. In 1992, early season species such as *Draba verna* L., *Stellaria nitens* Nutt., *Cryptantha ambigua* (Gray)

Greene, and *Holosteum umbellatum* L., dominated the annual forb cover. These species gradually decreased in 1993 and 1994, while larger and later season annuals and biennials increased, including *Epilobium paniculatum* Nutt., *Lactuca serriola* L., and *Tragapogon dubious*, Scop.. These species also appeared to increase in areas of uncut juniper during the wet year of 1993, but were nearly absent during 1994.

Perennial forb cover remained nearly identical among slash and no-slash treatments, and only increases across years were significant. Perennial forb cover was significantly greater with cut versus uncut juniper in at least one of the measurement years, but despite opposite trends in mean perennial forb cover between treatments, the interaction was not significant.

The greatest increases in perennial forb cover with cut juniper involved *Eriogonum strictum, Achillea millifolium, Crepis occidentalis,* and species of *Astragalus* and *Lupinus*. Three previously unrecorded species were also noted during 1994 - *Gnaphalium microcephalum* Nutt., *Anaphalis margaritacea* (L.) B. & H., and *Hieracium albiflorum* Hook.. These species were not observed in stands of uncut juniper, either in or outside the fenced exclosure. *Antennaria dimorpha* (Nutt.) T. & G., a mat forming species, was one of the few perennial forbs to decrease in cover within the block of cut juniper.

Changes in perennial grass cover were similar among slash and no-slash treatments, and only the year effect was significant. Mean perennial grass cover increased from about 1% in 1992, to 1.6% in 1994. Although mean perennial grass cover increased by a greater relative amount with cut versus uncut juniper, neither the interaction or main effects was significant.

Squirreltail and Sandberg bluegrass comprised the majority of the bunchgrass cover, but neither exceeded 1% cover during the course of study. Greater mean increases in squirreltail cover with no-slash versus slash was not significant, but increased squirreltail cover across years was significant for at least one of the treatment groups.

In contrast to squirreltail, Sandberg bluegrass cover decreased in the slash and no-slash treatments. Decreases were similar among both treatments, and only the year effect was significant. Sandberg bluegrass cover was not significantly different between cut and uncut juniper.

Table 7 summarizes the mean bunchgrass density occurring in 5 x 10 m sample plots (excluding Sandberg bluegrass). Squirreltail comprised about 98.5% of the total bunchgrass plants counted, while bluebunch wheatgrass and Thurber needlegrass comprised 0.5% and 1.5% respectively. The year of 1992 is pre-treatment, while 1994 represents two seasons of release from juniper competition. Control plots of uncut juniper were measured only in 1994.

Table 7. 1993 West Site. Mean bunchgrass density per 5 x 10 m sample plot. (-) indicates not measured. Different letters indicate significance ($p < 0.05$) between measurement years, while different numbers indicate significance between treatments.

		Number of Plants			
		1992 pre-juniper cutting		1994 2 seasons after cutting	
(N)	Treatment	x	s	x	s
(34)	slash	11.2 [a1]	*(9.8)*	18.8 [b1]	*(13.2)*
(14)	no-slash	7.9 [a1]	*(7.6)*	16.6 [b1]	*(15.2)*
(10)	uncut	-	-	9.4 [1]	*(7.2)*

The year of measurement was a significant factor of bunchgrass density when juniper was cut, but neither the slash treatment or interaction of year and slash treatment were significant. With the slash and no-slash treatments combined, a 95% confidence interval for the mean increase in bunchgrass density with cut juniper is from 6 to 10 plants per 5 x 10 m sample plot. The mean bunchgrass density of 9.4 plants/plot with uncut juniper in 1994, was not significantly less than the average of 17.7 plants/plot with cut juniper.

Table 8 lists the mean number of bunchgrass plants and seed culms within the duff zone of cut and uncut juniper. When squirreltail, bluebunch wheatgrass, and Thurber needlegrass were counted within sample plots during 1992, 96% of the plants were located within the duff zone beneath juniper. Measurement years in Table 8 correspond to the first and second seasons of competitive release from juniper.

Table 8. 1993 West Site. Mean number of bunchgrass plants and seed culms in the duff of cut and uncut juniper trees (N = 20 and 10 respectively). Different letters indicate significance ($p < 0.05$) between measurement years, while different numbers indicate significance between treatments.

	Number of Plants				Number of Seed Culms			
	1993		1994		1993		1994	
	x	s	x	s	x	s	x	s
Cut	21.7 ^{a1}	*(16.6)*	21.8 ^{a1}	*(15.9)*	40.8 ^{a1}	*(35.2)*	233 ^{b1}	*(131.)*
Uncut	19.9 ^{a1}	*(15.7)*	16.3 ^{a1}	*(13.2)*	28.2 ^{a1}	*(23.3)*	20.0 ^{b2}	*(18.2)*

The mean number of bunchgrass plants per duff zone remained nearly constant when trees were cut, but plant numbers in the duff of uncut trees slightly decreased. The interaction of measurement year and cutting treatment was significant.

The interaction was also significant for the number of seed culms per duff zone - decreases in seed culm numbers between years with uncut juniper, were contrasted with a dramatic increase in seed culm numbers with cut juniper. With 95% confidence, the mean increase in seed culm numbers between the first and second seasons after juniper cutting is estimated to be from 144 to 241 per duff zone.

1993 East Site

Percent cover measurements are summarized in Table 9. Slash cover was not subject to Repeated Measures ANOVA, but provided about 48% cover in 1993, and 45.5% in 1994.

Table 9. 1993 East Site. Percent cover during 1992-1994, and results of Repeated Measures Analysis. (* p < 0.05; ** p < 0.01; *** p < 0.001; **** p < 0.0001).

		Percent Cover			
Parameter	Treatment	pre-Juoc cutting 1992	1 season of release 1993	2 seasons of release 1994	p-values
Slash cover	slash (N=10) no-slash (N=15)		48.1	45.5	T = slash effect Y = year effect I = interaction
Litter	slash no-slash	43.5 46.9	84.4 63.3	94.2 65.8	T ** Y **** I ****
Bare Ground (gravel & soil)	slash no-slash	53.7 51.4	15.6 36.4	5.3 32.2	T ** Y **** I ****
Annual Grasses	slash no-slash	15.3 13.6	15.0 17.1	25.9 31.1	T Y **** I
Annual & Biennial Forbs	slash no-slash	0.10 0.11	0.28 0.54	0.53 0.65	T Y ** I
Perennial Forbs	slash no-slash	0.17 0.23	0.22 0.23	0.30 0.19	T Y I
Perennial Grasses	slash no-slash	0.04 0.02	0.01 0.03	0.04 < 0.01	T Y I

The predominant litter component consisted of medusahead plant fragments. In 1992 this material was nearly equally distributed among all sample plots and averaged about 45% cover. However, increases in litter cover were greater with slash versus no-slash treatments, and the interaction was significant. With slash, mean litter cover nearly doubled during the first year of treatment in 1993, but increased to a lesser degree with the no-slash treatment. Additional increases in litter cover were observed with the slash treatment in 1994, but little change occurred with the no-slash treatment. The percent of bare ground changed inversely to that of litter, and the interaction of the slash group and measurement year was also significant.

Annual grass cover, mostly medusahead, exhibited similar increases among the slash and no-slash treatments. The interaction was not significant, but the effect of measurement year was. Most of the increase in annual grass cover occurred during 1994, rather than the first year of juniper release in 1993.

Annual forb cover averaged about 0.1% in 1992, but increased during the successively wet and dry years of 1993 and 1994. By 1994, annual forb cover was 0.53% and 0.65% among the slash and no-slash treatments. Again, the measurement year was significant, but the interaction was not. Changes in annual forb composition were similar to those discussed for the West Site, but also included increases of *Madia citriodora* Greene. Larger and later season annual and biennial forbs were extremely vigorous and produced seed during 1993. In 1994, patch densities of *E. paniculatum* reached 500 plants/m^2, while *L. serriola* occurred at 50 plants/m^2. However, as a result of the dry growth season, mortality of these plants was high and only a small portion were observed to flower.

Perennial forbs comprised less than 0.2% cover in 1992. Relatively minor changes were observed during the course of monitoring, and treatment effects were not significant. *Crepis occidentalis* and *Agoseris grandiflora* were the most common perennial forbs. Early spring visits in 1993 indicated increased abundance of *Lithofragma bulbifera* and several species of *Lomatium* and *Allium* in areas of cut as well as uncut juniper. However, only scattered fragments (including seed bearing appendages) of these species were present at the time of summer measurements. These species were relatively scarce during 1994, and although a few plants were observed early in the season, most of these quickly became dormant without flowering.

Perennial grasses were scarce and never exceeded more than 0.05% cover in either the slash or no-slash treatment. Squirreltail comprised the majority of this cover, followed by rather equal amounts of bluebunch wheatgrass and Sandberg bluegrass.

CHAPTER V. DISCUSSION

Tublings exhibited significantly greater survival and reproductive effort relative to direct seed. Furthermore, treatments hypothesized to decrease planting success appeared to have the greatest influence on direct seed. For instance, tubling survival decreased about 40% when juniper was not cut, but direct seed survival decreased by more than 1000%. Planting in a dry year had little influence on tubling survival, but resulted in 250-3000% less survival for direct seed when compared to planting in a wet year.

Tubling survival was always greater than 50%, and was usually greater than 85%. With cut juniper, direct seed survival ranged from 2-62% among the various treatments and planting years. Mean reproductive effort by tublings was at least several times greater than reproductive effort by direct seed. However, sample variances of seed production were large, and several fold greater mean seed production by tublings versus direct seed was not always significant on the East Study Site. Small sample sizes and relatively large variances may have contributed to type II errors for comparisons of reproductive effort, as well as for some of the other analysis on the East Site.

Greater survival and reproductive effort by tublings relative to direct seed increases the potential for more rapid growth or regeneration of the patch populations. This could be advantageous if site treatments or other factors assist invasion of less desirable and competing species, such as was observed with annual grasses in this study. Tublings were also better able to survive the dry planting conditions of 1994, thus providing some insurance for revegetation success. The use of tublings may be especially warranted if propagules of a desired species are limited, or conditions are such that establishment is very difficult.

However, despite greater success by tublings, direct seed treatments on the 1993 West Site with cut juniper appeared adequate for establishment of the bunchgrass species studied. Sharply decreased success of direct seed treatments planted in 1994, substantiates the importance of conducting seeding operations during years of normal or above normal precipitation (Vallentine, 1987). Plantings of 1993 remained green and apparently non-dormant until at least early September, while most plantings of 1994 appeared dormant by mid-July.

Although comparisons of direct seed survival between this and other studies are complicated by differences in methodology, analysis, and species, other reseeding projects with less than 5% establishment rates were sufficient for establishment and growth of the seeded populations (Davis and Harper, 1989; Heady and Bartolome, 1977; Cook et al, 1967). Hironaka and Sindelar (1973) observed successful reproduction by squirreltail 18 months after broadcast seeding into unmanipulated medusahead stands. On the 1993 West Site, 700 filled seed/patch were produced by squirreltail direct seed treatments 15 months after planting. This suggests a high potential for successful reproduction and expansion of the plant patches within relatively low density (but increasing) cheatgrass populations.

On the other hand, it appears that squirreltail and bluebunch wheatgrass densities of 2-4 plants/m^2 could have been relatively easily obtained across the entire West Site if it had been evenly seeded. Based on findings of others (Heady and Bartolome, 1977; Harris, 1967; Young and Evans, 1968), this could be expected to inhibit the increase of annual grass cover that was observed on the West Site. Hence, planting by direct seed might actually be more desirable than tublings because greater areas of perennial grass dominance could be established before annual grasses are able to increase.

The potential for regeneration of bunchgrass plantings on the East Site is less certain. Measurements of survival and reproductive effort were both less, and more variable, than observed on the West Site. Successful reproduction is considered more difficult due to medusahead competition and litter barriers to the seed bed. Although it was possible to establish patches of squirreltail and bluebunch wheatgrass, they essentially exist as islands within the medusahead community. Medusahead cover almost doubled during the course of study, and burned litter appeared to be replaced fairly quickly and before perennial grass plantings were able to reproduce.

All reported reseeding projects involving wheatgrass species have failed when extensive cheatgrass or medusahead competition was not controlled (Robertson and Pearse, 1945; Hull and Stewart, 1948; Torell et al., 1961; Harris, 1967; Evans et al., 1970; Harris and Goebel, 1976; Heady and Bartolome, 1977; Young and Evans, 1978). Even the long term success of squirreltail broadcast seeded into medusahead communities by Hironaka and Sindelar (1973) was less than suggested by early observations (Young, 1992). Further monitoring is especially necessary on the East Site to determine if the patch populations are able to regenerate, but rather than relying on greater apparent success of tubling versus direct seed propagules, further studies of medusahead control should be implemented.

Burn treatments of this study did not appear very effective at reducing live medusahead seed, but further experiments could involve burning at an earlier plant stage before seed development is complete. Studies by Young et al. (1972) and Torell et al. (1961), indicated little success of burning for medusahead control, but success was reported by McKell et al. (1962). Spring burn treatments of 1993 with a propane torch appeared to be more effective at reducing medusahead competition compared to the fall field burn. This may suggest the use of propane burning equipment such as used for agricultural purposes to control weeds. A major drawback observed with the 1993 field burn involved the fact that the only consistent hot spots occurred in the areas of juniper duff beneath the canopy. Unfortunately, this resulted in complete mortality of remnant bunchgrasses and other perennial plants that were concentrated in these microsites. Hence, the primary areas of perennial grass dominance were destroyed and opened to invasion by annual grasses.

Squirreltail propagules did tend to exhibit significantly greater success when the medusahead understory was burned versus unburned. However, general observations indicated that digging holes for planting of tublings was nearly as effective at reducing medusahead competition as the burn treatment. Hence, greater success exhibited with burned versus unburned medusahead might be attributed to an increase in nutrient availability. Increased reproductive effort by squirreltail after controlled burns has been noted by Young and Miller (1985).

Less disturbance associated with direct seed planting appeared to result in greater medusahead competition than occurred with tublings. Additionally, many medusahead seed were dispersed into the direct seed planting holes during the first growth season, and competition appeared exceptionally high during the second growth season.

The results of squirreltail planting with slash versus no-slash were somewhat inconsistent, but overall success tended to be greater with slash. Squirreltail tubling survival was significantly greater with slash versus no-slash on the 1993 West Site. Survival of squirreltail direct seed, and reproductive effort by both propagule types, was not significantly different with slash versus no-slash. However, under drier conditions of the 1994 West Site, survival of both squirreltail propagule types was significantly greater with slash versus no-slash. Reproductive effort by direct seed was also greater with slash versus no-slash, but this pattern was sharply reversed for tublings, where reproductive effort was dramatically greater with no-slash versus slash.

On the 1993 East Site, squirreltail success was not significantly greater with slash versus no-slash, but both survival and reproductive effort were significantly greater with slash versus no-slash for tublings and direct seed of bluebunch wheatgrass. Slash treatments were not contrasted on the 1994 East Site.

Other studies have indicated lower soil temperature and greater soil moisture with juniper or pinyon slash (Gifford and Shaw, 1973; Everett and Sharrow, 1985), and similar results were measured on this site (Eddleman, 1996). Amelioration of temperature extremes and increased organic litter inputs measured with slash cover, should promote microfaunal activity, nutrient availability, and soil development (Facelli and Pickett, 1991). Extended periods of plant growth beneath slash cover were evidenced by green vegetation and delayed reproductive stages, while vegetation in adjacent open areas was brown and had obviously ceased growth.

The major exception to greater success with slash versus no-slash involved squirreltail tublings planted on the 1994 West site, where patches with slash produced 66% fewer seed culms than patches with no-slash. Shade provided by the slash may have contributed to lower soil temperatures during the relatively cool and wet spring of the 1995 sampling year, which has been shown to decrease reproductive effort later in the year for other grass species (Weaver and Rowland, 1952; Rice and Parenti, 1978). Other possible influences of greater reproductive effort with no-slash versus slash could involve moisture stress triggering earlier seed production, or differences in the light spectrum. However, this does not agree with observations from other treatment contrasts.

The lowest planting success was observed with uncut juniper on the West Site. There was little or no direct seed survival, and reproductive effort by tublings was minimal. Nearly complete mortality of direct seed with uncut juniper suggest further difficulties for successful reproduction by the tubling patches. This and poor growth characteristics of tublings with uncut juniper (Appendix D), suggest that these patches will not successfully regenerate.

Preliminary evidence for succession towards a perennial herbaceous plant community on the West Site was indicated by decreases in early season annual forbs, and increases in larger biennial and perennial forbs, including three species not observed outside the treated study area. Cover of existing perennial grasses increased 60% on the West Site two years after juniper cutting. This is less than 300-700% increases commonly reported 3-6 years after juniper or pinyon control projects (Miller, 1995; Davis and Harper, 1989; Barney and Frischknecht, 1974; Everett and Sharrow, 1985; Bedell, 1987; Sedgewick and Ryder, 1987; Clarey, 1971; Clarey and Johnson, 1981; Stevens, 1987). However, dramatic increases in reproductive effort by remnant squirreltail plants suggest a high potential for further increases in perennial grass cover.

A few direct seed plant patches were located in duff zones of cut juniper. Seed emergence appeared to be lower in duff zones compared to intercanopy areas, and similar observations were reported by Everett and Sharrow (1985). Annual grass cover within duff zones was very low at the beginning of study, but has been increasing since juniper cutting. On the other hand, a few tubling patches planted in or near the duff zones exhibited very high reproductive effort during the first growth season, while this was rather rare for tubling patches in the intercanopy areas.

Annual grass cover increased about 5 fold on the West Site after juniper cutting, but this has commonly been observed in other juniper and pinyon control projects when annual grasses were present in the understory (Evans and Young, 1985; 1987; Barney and Frischknecht, 1974; Bedell, 1987). Without re-seeding of perennial grasses, medusahead has been observed to gain dominance over cheatgrass within 3-5 years after juniper cutting (Evans and Young, 1985), so this is likely to occur on the West Site due to the relatively small areas of perennial grass planting. As mentioned, this could potentially be alleviated by more extensive perennial grass seeding prior to juniper cutting. However, continued monitoring of the West Site could provide valuable information concerning the lateral rate of expansion by bunchgrass patches into the surrounding areas of increasing annual grass.

Medusahead was the primary species of increase on the East Site. Most of the increase in medusahead cover occurred during 1994, and this is presumed to be the result of high seed production during the wet year of 1993, as well as release from juniper competition. Similar results were obtained on juniper/medusahead rangelands in northeast California, but herbicide treatments were used to control medusahead prior to successful reseeding (Evans and Young, 1985). It should be mentioned that the East Study Sites were situated in some of the lowest density juniper areas. Hence potential release from juniper competition was less than obtained on the West Site. Furthermore, fewer juniper equate to fewer duff zones with remnant perennial bunchgrasses and forbs. More favorable changes in understory composition were observed in other study areas near the East Site, with denser juniper but similar medusahead cover in the intercanopy areas (Eddleman, 1996).

CHAPTER VI. CONCLUSIONS

There are both positive and negative effects associated with juniper cutting. When perennial grasses and forbs are present in the understory, removal of juniper competition allows these plants to increase in vigor and reproductive effort, and hence, they are likely to increase in cover and density. On the other hand, release of juniper competition also allowed annual grasses to increase, so this must be incorporated into management decisions of juniper control and revegetation efforts. It is evident that the vast majority of existing desirable perennial plants are located within the duff zones of juniper. Removal of juniper without management directed towards the maintenance of these species could result in their being lost from the system, while simultaneously assisting increased dominance of annual grasses. Thus, retaining patches of juniper could provide a reserve of remnant native species, as well as providing for landscape diversity.

Planting success and favorable increases in perennial grass and forb cover after juniper cutting on the West Site, suggest that revegetation projects could be worthwhile in areas of similar soil, understory composition, and juniper density. Increased remnant perennial plant growth would contribute to increased understory production and diversity, but extensive planting within the intercanopy areas is strongly suggested to rapidly establish perennial plants before annual grasses are able to gain dominance.

Although reproductive success by plantings of this study need to be verified, it appears that perennial grasses could be readily established in areas similar to the West Site by direct seed. This is true for squirreltail as well as bluebunch wheatgrass and more palatable forage species. Dramatically decreased success observed for planting in a dry year substantiates the need to conduct planting operations only during favorable precipitation years. Use of slash material provides some insurance against unfavorable weather conditions and is likely to enhance long term productivity. Increased litter cover from the slash material decreases bare ground surfaces, but may also assist establishment of annual grasses (Young et al., 1976).

Without additional monitoring, planting success is less certain in areas similar to the East Site. Tubling propagules exhibited a greater potential for patch expansion, but unless adequate reproductive success can be verified, further studies should be undertaken concerning control of medusahead. There were indications from adjacent medusahead sites that suggest better planting results and understory response with greater juniper densities.

Changes in the understory composition on the West Site could be valued solely in regards to increased plant diversity and maintenance of a semi-native community, to which several tribal members may have an interest (root gathering etc.). As discussed by Young and Evans (1978), high condition shrub-grass systems have become increasingly scarce due to numerous disturbances and exotic plant invasions. Thus, there is reason to maintain these systems when the opportunity arises. Due to the more limited aerial extent of communities similar to the West Site, restored areas would exist as patches within the juniper/medusahead landscape, but could enhance mid-summer or fall forage if carefully managed. With continued season long grazing, these areas would probably regress to annual grass communities and nothing would be gained from juniper control.

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APPENDICES

Appendix A. Species List

Appendix 1. Plant species encountered during 1992-1994.

Site Presence			
East	**West**	**Botanical Name**	**Common Name**
		Perennial Forbs	
E	W	*Achillea millefolium*	common yarrow
E	W	*Agoseris grandifolora*	false dandelion
E	W	*Allium spp.*	wild onion
	W	*Anaphalis margaritacea*	pearly everlasting
	W	*Antennaria dimorpha*	low pussytoes
E		*Asclepias fascicularis*	mexican milkweed
E	W	*Astragulus conjunctus*	longleaf milkvetch
E	W	*Astragulus curvicarpus*	curepod milkvetch
	W	*Boltonia asteoides*	white boltonia
E	W	*Calochortus macrocarpus*	star tulip
E		*Cirsium undulatum*	wavyleaf thistle
E		*Convolvulus arvensis*	field morningglory
E	W	*Crepis occidentalis*	western hawksbeard
E		*Delphinium andersonii*	anderson larkspur
E	W	*Eriogonum strictum*	strict buckwheat
E		*Eriogonum umbellatum*	sulfurflower buckwheat
E	W	*Fritillaria pudica*	yellow bell
	W	*Gnaphalium microcephalum*	slender cudweed
	W	*Haplopappus acaulis*	stemless goldenweed
E	W	*Helianthus cusickii*	Cusick sunflower
	W	*Hieracium albertinum*	western hawkweed
	W	*Hydrophyllum capitatum*	ballhead waterleaf
E	W	*Lithophragma bulbifera*	bulbet woodstar
E	W	*Lithospermum ruderale*	stoneseed
	W	*Leptodactylon pungens*	prickly phlox
E	W	*Lomatium canbyi*	canby biscuitroot
E	W	*Lomatium cous*	cous biscuitroot
E		*Lomatium nudicaule*	barestem lomatium
E		*Lomatium triternatum*	nineleaf biscuitroot
E	W	*Lupinus caudatus*	tailcup lupine
	W	*Phacelia hastata*	silverleaf phacelia
	W	*Phlox hoodii*	Hood's phlox
	W	*Phoenicaulis cheiranthoides*	dagger pod

Site Presence			
East	**West**	**Botanical Name**	**Common Name**
		Annual Forbs	
E	W	*Agoseris heterophylla*	annual agoseris
E	W	*Amsinckia lycopsoides*	tarweed fiddleneck
	W	*Arenaria pusilla*	small sandwort
E	W	*Athysanus pusillus*	sandweed
E	W	*Belpharipappus scaber*	blepharipappus
E	W	*Collinsia parviflora*	blue-eyed Mary
E	W	*Cryptantha ambigua*	obsure cryptantha
	W	*Claytonia megarhiza*	alpine spring beauty
E	W	*Collinsia rattanii*	
E	W	*Collomia grandiflora*	big flower collomia
E	W	*Descurainia richardsonii*	Richardson tansymustard
E	W	*Draba verna*	whitlow-grass spring draba
E	W	*Epilobium paniculatum*	autumn willow-weed
	W	*Eriogonum vimineum*	broom eriogonum
E	W	*Holosteum umbellatum*	jagged chickweed
E	W	*Idahoa scapigera*	scalepod
E	W	*Lagophylla ramosissima*	rabbitleaf
E		*Lotus purshiana*	Spanish clover
E	W	*Madia citriodora*	lemon-scented tarweed
	W	*Madia exigua*	little tarweed
E	W	*Microsteris gracilis*	pink annual phox
	W	*Montia spathulata*	pale montia
E	W	*Plagiobothrys tenallus*	bristly popcornflower
E	W	*Plectritis macrocera*	longhorn plectrites
E	W	*Polemonium micranthum*	littlebells polemonium
E		*Polygonum majus*	wiry knotweed
	W	*Stephanomeria paniculata*	skeletonweed
E	W	*Thysanocarpus curvipes*	fringepod
E	W	*Ranunculus testiculatus*	bur buttercup
E	W	*Rigiopappus leptocladus*	bristlehead
E	W	*Stellaria nitens*	shining chickwed
		Ephytes	
E		*Orobanche uniflora* var. *minuta*	broom rape
		Biennial Forbs	
E	W	*Lactuca serriola*	prickly lettuce
E	W	*Tragapogon dubius*	yellow salsify

Site Presence			
East	**West**	**Botanical Name**	**Common Name**
Perennial Grasses			
E	W	*Agropyron spicatum*	bluebunch wheatgrass
E	W	*Bromus carinatus*	mountain brome
E		*Danthonia unispicata*	onespike oatgrass
E		*Elymus cinerius*	basin wildrye
E	W	*Sitanion hystrix*	squirreltail
	W	*Stipa thurberiana*	Thurber needlegrass
E	W	*Poa sandbergii*	Sandberg's bluegrass
	W	*Poa bulbosa*	bulbous bluegrass
Woody Plants			
E	W	*Artemisia tridentata* subsp. *vaseyana*	mountain big sagebrush
E	W	*Chrysothamnus viscidiflorus*	green rabbitbrush
E	W	*Chrysothamnus nauseosus*	gray rabbitbrush
E	W	*Purshia tridentata*	bitterbrush
E	W	*Eriogonum spalerocephalum*	rock eriogonum
E	W	*Tetradymia canescens*	gray horsebrush
E	W	*Juniperus occidentalis*	western juniper
Annual Grasses			
E	W	*Bromus commutattus*	hairy brome
E	W	*Bromus tectorum*	cheatgrass
E	W	*Bromus mollis*	soft brome
E	W	*Elymus caput-medusae*	medusahead
E	W	*Festuca bromoides*	brome fescue
E	W	*Festuca microstachys*	small fescue

Appendix B. Sample Plot Location Maps for Each Study Site.

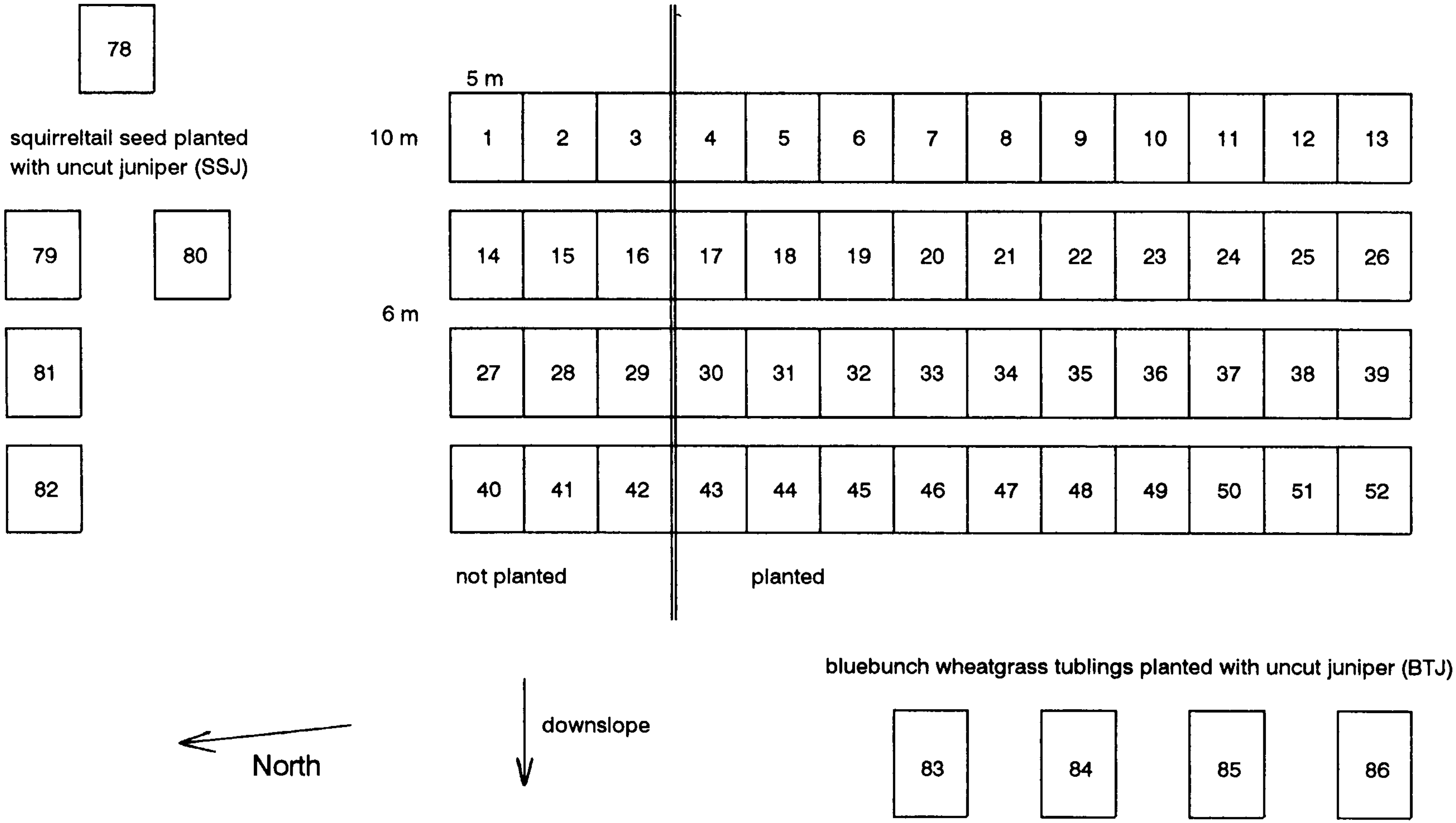

Figure B1. 1993 West Site sample plot locations.

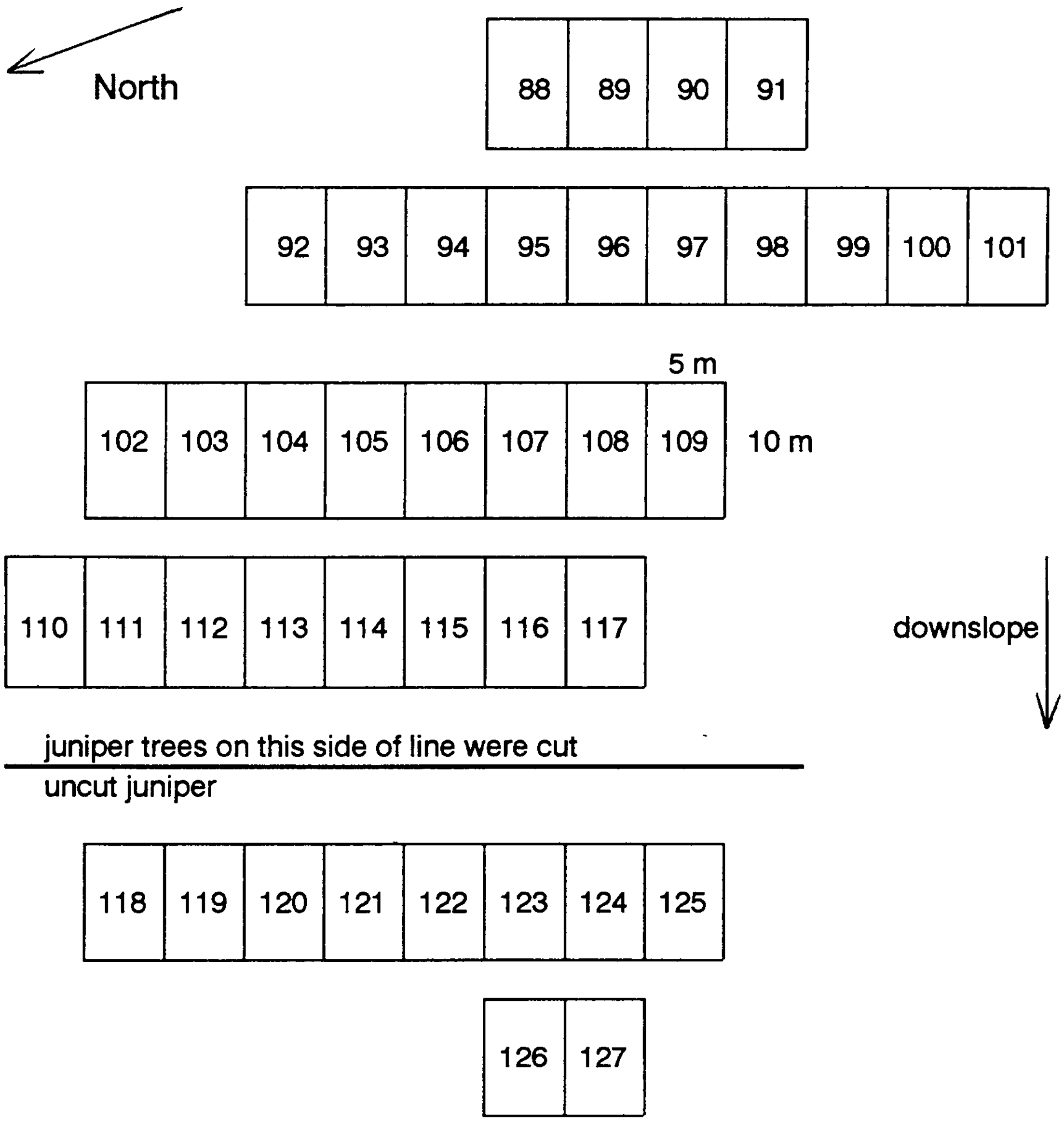

Figure B2. 1994 West Site sample plot locations.

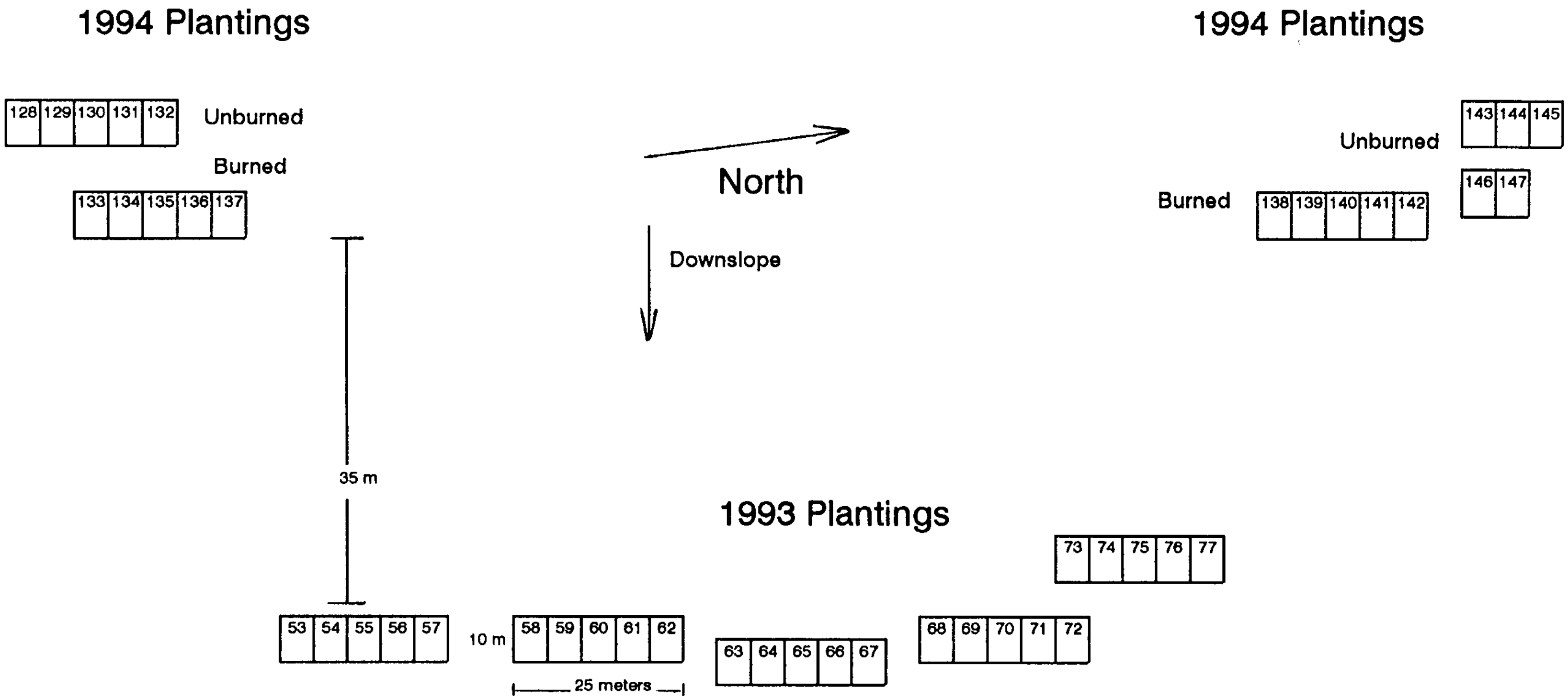

Figure B3. 1993 and 1994 East Site sample plot locations.

Appendix C. Summary and Comparison Analysis for the Percent of Holes With Live Plants, and Reproductive Effort, After Two Growth Seasons. (See Table 1, page 17, for key to abbreviations and treatment descriptions).

Table C1. 1993 West Site. Summary analysis for the percent of holes with live plants. N=5 except for BTJ, where N=4.

Species & Treatment	Sample Distribution	Percent Survival	Median	Range (hi-low)	Standard Deviation	95% CI (% survival)
ST	slight neg skew	97.8	100.0	7.4	3.3	93.7 - 101.9
ST-	sl pos skew w/high OL	85.6	83.3	14.8	6.2	77.9 - 93.3
SS	app normal	51.8	50.0	18.6	8.0	39.1 - 64.6
SS-	low and high OL's	62.2	66.7	51.9	18.8	38.9 - 85.6
SSJ	pos skew w/high OL	0.7	0.0	3.7	1.7	-1.3 - 2.8
BT	no variance	100.0	100.0	0.0	0.0	-
BTJ	long tailed	59.3	64.8	63.0	26.6	17.0 - 101.5
BS	gross low OL	56.3	63.0	40.8	15.8	36.7 - 76.0
TT	app normal	96.3	96.3	7.4	3.7	91.7 - 100.9
TS	app normal	9.6	11.1	11.1	4.2	4.4 - 14.9

Table C2. 1993 West Site. Comparison analysis for the percent of holes with live plants.

Treatment Factor	Sample Comparison	t - test	% Difference in Mean Survival	P - Value (one sided)	95% CI for Difference
propagule type	ST vs SS	Student	45.9% > w/tubling	< 0.0001	33.8 - 58.1%
	ST- vs SS-	Student	23.2% > w/tubling	0.0150	0.4 - 46.3%
slash cover	ST vs ST-	Student	12.2% > w/slash	0.0023	5.0 - 19.5%
	SS vs SS-	Student	10.4% > wo/slash	0.1703	-12.8 - 33.5%
juniper cutting	SS- vs SSJ	Rank Sum	61.5% > wo/juniper	0.0047	33.2 - 85.2%
propagule type	BT vs BS	Rank Sum	43.7% > w/tubling	0.0036	29.6 - 70.4%
juniper cutting	BT vs BTJ	Rank Sum	40.7% > wo/juniper	0.0054	14.8 - 77.8%
propagule type	TT vs TS	Student	86.7% > w/tubling	< 0.0001	80.9 - 92.5%

Table C3. 1993 West Site. Summary analysis for the number of filled seed per plant patch. N=5 except for BTJ where N=4.

Species & Treatment	Sample Distribution	Mean Number Filled Seed per Patch	Median	Range (hi-low)	Standard Deviation	95% CI
ST	app normal	3487	3852	3247	1328	1838 - 5136
ST-	app normal	2698	2587	4931	2160	14 - 5381
SS	pos skew	652	563	1378	681	-432 - 1735
SS-	pos skew	738	520	786	354	298 - 1178
SSJ	none	0	-	-	-	-
BT	neg skew	1226	1386	1412	525	575 - 1878
BTJ	pos skew	0.8	0	3	1.5	-1.6 - 3.1
BS	app normal	150	115	374	145	-30 - 329

Table C4. 1993 West Site. Comparison analysis for the number of filled seed per plant patch.

Treatment Variable	Sample Comparison	t-test	Difference in Mean Seed Production	P-value (one-sided)	95% CI for Difference
propagule type	ST vs SS	Student	2835 > w/tubling	0.0032	1093 - 4578
	ST- vs SS-	(T) Student	423 > w/tubling	0.0527	87 - 2544
slash cover	ST vs ST-	Student	789 > w/slash	0.2531	-1827 - 3405
	SS vs SS-	Student	87 > wo/slash	0.4054	-738 - 911
juniper cutting	SS- vs SSJ	rank sum	738 > wo/juniper	0.0038	456 - 1242
propagule type	BT vs BS	(T) Student	528 > w/tubling	0.0004	161 - 1109
juniper cutting	BT vs BTJ	rank sum	1225 > wo/juniper	0.0090	426 - 1838

Table C5. 1994 West Site. Summary analysis for the percent of holes with live plants. N=10 except for STJ where N=5, and BT and BS where N=9.

Species & Treatment	Sample Distribution	Percent Survival	Median	Range (hi-low)	Standard Deviation	95% C.I. (% survival)
ST	pos skew	95.6	100.0	22.2	7.3	90.3 - 100.8
ST-	pos skew	86.7	88.9	38.9	11.2	78.7 - 94.7
STJ	app normal	21.1	27.8	38.9	15.4	2.0 - 40.3
SS	long tailed	23.3	22.2	50.0	16.3	11.7 - 35.0
SS-	neg skewed	3.9	0.0	16.6	5.9	-0.3 - 8.1
SSJ	none	0.0	-	-	-	-
BT	short tailed	97.5	100.0	5.6	2.9	95.3 - 99.8
BS	long tailed	16.7	16.7	38.9	11.8	7.6 - 25.7

Table C6. 1994 West Site. Comparison analysis for the percent of holes with live plants.

Treatment Factor	Sample Comparison	t-test	Difference in Percent Survival	P - Value (one sided)	95% CI for Difference
propagule type	ST vs SS	Paired	72.2% > w/tubling	< 0.0001	62.1 - 82.3%
	ST- vs SS-	Paired	82.8% > w/tubling	< 0.0001	74.5 - 91.0%
	STJ vs SSJ	Paired	21.1% > w/tubling	0.0188	2.0 - 40.3%
slash cover	ST vs ST-	Student	8.9% > w/slash	0.0248	0.01 - 17.8%
	SS vs SS-	Student	19.4% > w/slash	0.0012	7.4 - 31.5%
juniper cutting	ST- vs STJ	Student	65.6% > wo/juniper	0.0001	40.7 - 59.7%
	SS- vs SSJ	Rank Sum	3.9% > wo/juniper	0.0174	0 - 5.6
propagule type	BT vs BS	Paired	80.9% > w/tubling	< 0.0001	72.3 - 89.4%

Table C7. 1994 West Site. Summary analysis for the number of seed culms per plant patch. N=10 except for STJ where N=5, and BT and BS where N=9.

Species & Treatment	Sample Distribution	Mean # Seed culms per Patch	Median	Range	Standard Deviation	95% CI (culms/patch)
ST	app normal	40.0	41.0	54.0	21.7	24.4 - 55.5
ST-	app normal	118.2	115.0	83.0	31.0	96.0 - 140.3
STJ	short tailed	2.5	3.0	4.5	1.8	0.3 - 4.7
SS	short tailed	1.0	0.0	6.0	1.9	-0.3 - 2.4
SS-	none	0.0	-	-	-	-
SSJ	none	0.0	-	-	-	-
BT	sl pos skew	21.1	14.5	53.0	17.2	7.9 - 34.3
BS	none	0.0	-	-	-	-

Table C8. 1994 West Site. Comparison analysis for the number of seed culms per plant patch.

Treatment Factor	Treatment Comparison	t-test	Difference in Mean # Seed Culms/Patch	P - Value (one-sided)	95% CI for Difference
propagule type	ST vs SS	Paired	38.9 > w/tublings	0.0001	23.7 - 54.1
	ST- vs SS-	Paired	118.2 > w/tublings	< 0.0001	96.0 - 140.3
	STJ vs SSJ	Paired	2.5 > w/tublings	0.0170	0.3 - 4.7
slash cover	ST vs ST-	Student	78.2 > wo/slash	< 0.0001	53.1 - 103.3
	SS vs SS-	Rank Sum	1.0 > w/slash	0.0175	0 - 1.5
juniper cutting	ST- vs STJ	Rank Sum	115.7 > wo/juniper	0.0013	76.5 - 156
	SS- vs SSJ	-	0	-	-
propagule type	BT vs BS	Paired	21.1 > w/tublings	0.0031	7.9 - 34.3

Table C9. 1993 East Site. Summary analysis for the percent of holes with live plants. N=5.

Species & Treatment	Sample Distribution	Percent Survival	Median	Range (high-low)	Standard Deviation	95% C.I. (% survival)
ST	gross low OL	84.4	94.4	66.7	28.7	48.8 - 120
ST-	app normal	92.6	94.4	16.7	5.7	86.5 - 98.6
ST*	app normal	35.6	33.3	83.3	33.0	-5.4 - 76.6
SS	app normal	40.0	38.9	88.9	38.4	-7.7 - 87.7
SS-	mild high OL	21.1	5.6	66.7	27.6	-13.2 - 55.4
SS*	gross high OL	2.2	0.0	11.1	5.0	-3.9 - 8.4
BT	high and low gross OL's	84.4	88.9	33.3	13.3	68.0 - 101
BT-	app normal	71.1	72.2	27.7	10.7	57.8 - 84.4
BS	long tailed	38.9	27.8	77.8	36.9	-6.9 - 84.7
BS-	gross high OL	4.4	0.0	22.2	9.9	-7.9 - 16.8

Table C10. 1993 East Site. Comparison analysis for the percent of holes with live plants.

Treatment Variable	Comparison	t-test	Difference in Percent Survival	P-value (one sided)	95% C.I. for Difference
propagule type	ST vs SS	Paired	44.4 > w/tublings	0.0466	-11.8 - 100.7
	ST- vs SS-	Paired	71.5 > w/tublings	0.0041	31.0 - 113.2
	ST* vs SS*	Paired	33.3 > w/tublings	0.0314	-2.9 - 69.5
slash cover	ST vs ST-	Student	8.1 > wo/slash	0.2550	-27.2 - 43.5
	SS vs SS-	Student	18.9 > w/slash	0.1989	-29.9 - 67.7
burning	ST- vs ST*	Student	57.0 > w/burning	0.0012	16.3 - 97.8
	SS- vs SS*	Student	18.9 > w/burning	0.0853	-15.1 - 52.9
propagule	BT vs BS	Paired	45.6 > w/tublings	0.0230	1.3 - 89.8
	BT- vs BS-	Paired	66.7 > w/tublings	< 0.0001	55.8 - 77.6
slash cover	BT vs BT-	Student	13.3 > w/slash	0.0591	-4.2 - 30.9
	BS vs BS-	Student	34.4 > w/slash	0.0392	-10.7 - 79.6

Table C11. 1993 East Site. Summary analysis for the number of filled seed per plant patch. N=5.

Species & Treatment	Sample Distribution	Mean Number Filled Seed per Patch	Median	Range (hi-low)	Standard Deviation	95% C.I.
ST	app normal	2422	2882	4404	1981	-39 - 4882
ST-	pos skew	1639	565	3881	1816	-267 - 3546
ST*	pos skew	472	78	1751	746	-454 - 1399
SS	pos skew	327	0	961	459	-243 - 897
SS-	pos skew	75	0	312	135	-93 - 243
SS*	pos skew	4.4	0	22	9.8	-7.8 - 16.6
BT	pos skew	349	212	482	216	81 - 617
BT-	pos skew	33	16	66	31	-5.5 - 71
BS	pos skew	3.6	0	14	6.1	-3.9 - 11.1
BS-	pos skew	1.5	0	7.5	3.4	-2.7 - 5.7

Table C12. 1993 East Site. Comparison analysis for the number of filled seed per plant patch.

Treatment Variable	Sample Comparison	t-test	Difference in Mean Seed Production	P-value (one-sided)	95% C.I. for Difference in Production
propagule type	ST vs SS	Paired	2095 > w/tubling	0.0220	90.5 - 4099
	ST- vs SS-	Paired	1564 > w/tubling	0.0581	-691 - 4240
	ST* vs SS*	Paired	468 > w/tubling	0.1166	-458 - 1393
slash cover	ST vs ST-	Student (T)	782 > w/slash	0.2559	-1809 - 3373
	SS vs SS-	Student (T)	40 > w/slash	0.2228	-169 - 655
burning	ST- vs ST*	Student (T)	399 > w/burning	0.0638	-48 - 2199
	SS- vs SS*	Student (T)	17 > w/burning	0.1413	-29 - 188
propagule type	BT vs BS	Paired	345 > w/tubling	0.0117	77 - 614
	BT- vs BS-	Paired	31.4 > w/tubling	0.0372	-4.9 - 68
slash cover	BT vs BT-	Student (T)	166 > w/slash	0.0009	42 - 373
	BS vs BS-	Student	2.1 > w/slash	0.2586	-5.0 - 9.2

Table C13. 1994 East Site. Summary analysis for the percent of holes with live plants. N=10.

Species & Treatment	Sample Distribution	Mean % Survival	Median	Range (hi-low)	Standard Deviation	95% C.I. (% survival)
ST	sl neg skew	62.8	66.7	50.0	16.4	51.1 - 74.5
ST*	app normal	54.4	55.6	66.7	19.9	40.2 - 68.7
SS	short tailed	3.9	0.0	16.7	5.9	-0.3 - 8.1
SS*	short tailed	1.7	0.0	5.6	2.7	-0.3 - 3.6

Table C14. 1994 East Site. Comparison analysis for the percent of holes with live plants.

Treatment Factor	Sample Comparison	t-test	Difference in Percent Survival	P - Value (one sided)	95% CI for Difference
propagule type	ST vs SS	Paired	58.9% > w/tubling	< 0.0001	47.6 - 70.2%
	ST* vs SS*	Paired	52.8% > w/tubling	< 0.0001	37.5 - 68.0%
burning	ST vs ST*	Student	8.3% > w/burning	0.1601	-8.8 - 25.5%
	SS vs SS*	Student	2.2% > w/burning	0.1458	-2.2 - 6.7%

Table C15. 1994 East Site. Summary analysis for the number of seed culms per plant patch. N=10.

Species & Treatment	Sample Distribution	Mean # Seed Culms/Patch	Median	Range	Standard Deviation	95% CI (culms/patch)
ST	long tailed	22.1	22.8	45.5	16.0	10.6 - 33.6
ST*	gross hi OL	9.1	7.2	33.0	9.7	2.2 - 16.0
SS	none	0	-	-	-	-
SS*	none	0	-	-	-	-

Table C16. 1994 East Site. Comparison analysis for the number of seed culms per plant patch.

Treatment Factor	Treatment Comparison	t-test	Difference in Mean # seed culms/patch	P - Value (one-sided)	95% CI for Difference
propagule type	ST vs SS	Paired	22.1 > w/tublings	0.0009	10.6 - 33.6
	ST* vs SS*	Paired	9.1 > w/tublings	0.0078	2.2 - 16.0
burning	ST vs ST*	Student	13.0 > w/slash	0.0206	0.6 - 25.4

Appendix D. Measurements of Growth and Reproductive Effort Referenced to the Individual Plant (See Table 1, page 17, for key to abbreviations and treatment descriptions).

Table D1. 1993 West Site. (-) indicates not measured.

Treatment	Number of Live Plants	Mean Basal Area sq cm		% Plants Exhibiting Rep Effort		#Seed Bearing Culms/Plant		#Filled Seed/Culm		#Filled Seed/Plant		% of Seed Filled	
		x	sd	x	sd	x	sd	x	sd	x	sd	x	sd
ST	131	32.8	6.1	97.0	4.8	22.0	4.4	23.2	10.0	401	155	80.3	3.8
ST-	108	18.3	9.6	92.1	7.8	16.8	9.9	14.2	4.8	323	196	78.4	5.6
SS	56	8.4	7.2	71.2	26.4	5.1	5.0	14.6	6.3	121	124	64.8	17.6
SS-	81	11.2	6.5	87.9	14.5	9.1	4.0	13.5	2.0	130	39	74.6	9.7
SSJ	1	0.7	n=1	0		0		0		0		0	
BT	135	20.0	5.2	96.3	5.2	17.9	4.4	6.4	1.5	136	58	37.0	11.3
BTJ	64	2.7	0.7	2.8	5.6	0.03	0.06	1.5	n=1	0.04	0.08	13.0	n=1
BS	76	6.0	2.0	65.7	7.4	5.1	4.3	4.2	1.9	28	22	20.0	9.6
TT	130	16.7	3.5	79.6	21.7	11.9	4.3	-		-		-	
TS	13	6.0	4.5	66.7	40.8	3.2	1.8	-		-		-	

Table D2. 1993 East Site.

Treatment	Number of Live Plants	Mean Basal Area sq cm		% Plants Exhibiting Rep Effort		#Seed Bearing Culms/Plant		#Filled Seed/Culm		#Filled Seed/Plant		% of Seed Filled	
		x	sd	x	sd	x	sd	x	sd	x	sd	x	sd
ST	76	14.4	11.2	97.6	5.3	11.0	8.1	23.6	8.6	281	218	78.9	15.4
ST-	92	15.8	8.8	77.7	21.6	9.8	6.4	16.7	6.5	185	200	80.4	6.6
ST*	32	7.9	2.9	75.6	29.3	5.8	2.8	13.4	9.9	74.9	82.4	73.0	12.5
SS	36	1.6	1.6	35.3	33.4	1.5	1.7	15.4	13.5	50.7	58.8	50.3	44.0
SS-	19	2.2	2.2	29.6	34.2	1.5	2.1	9.1	6.3	18.7	29.7	52.3	15.7
SS*	2	0.3	n=1	50.0	n=1	1.0	n=1	11.0	n=1	11.0	n=1	66.6	n=1
BT	76	11.8	4.5	93.8	7.7	12.2	3.9	4.1	1.4	43.1	27.5	19.7	6.7
BT-	58	6.5	1.8	36.5	13.0	2.5	1.8	2.6	3.4	4.6	4.2	16.3	11.0
BS	35	0.7	0.3	19.6	22.9	0.5	0.6	1.5	0.7	0.6	0.7	5.0	2.5
BS-	4	2.7	n=1	50.0	n=1	3.2	n=1	0.8	n=1	2.5	n=1	17.2	n=1