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Douglas E. Johnson

This research examined the biology of barb goatgrass (*Aegilops triuncialis* L.) a weedy annual grass that is invading the rangelands of California. Germination and root growth characteristics of barb goatgrass were compared to soft chess (*Bromis mollis* L.), medusahead rye (*Taeniatherum caput-medusae* (L.) Nevski), slender wild oats (*Avena barbata* L.), and subterranean clover (*Trifolium subterrraneum* L.) to determine what advantages barb goatgrass might have when establishing in a plant community. Barb goatgrass germinated under a wide range of temperatures, between 5 and 25 C. This was a wider temperature range than associated species. Root growth rates under greenhouse conditions that simulate spring conditions on California annual grasslands were greatest for barb goatgrass and slender wild oats. Rooting area observed in glass sided boxes was greatest for goatgrass.

Barb goatgrass populations increased with sheep grazing. Increasing grazing pressure resulted in increasing goatgrass density. Barb goatgrass invades both grazed and ungrazed pastures however higher density of this noxious weed was found in grazed pastures.

Barb goatgrass can be controlled with 1.12 kg ai/ha glyphosate (Roundup) but desirable plant species will likely need to be reseeded to occupy the site.

Biology and Control of Barb Goatgrass (*Aegilops triuncialis* L.)

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BIOLOGY AND CONTROL OF BARB GOATGRASS (*Aegilops triuncialis* L).

CHAPTER 1

INTRODUCTION

Barb goatgrass (*Aegilops triuncialis* L.) is an introduced noxious weed that is invading California. According to Crampton (1974) barb goatgrass is an annual grass with stiff, erect culms 20 to 40 cm tall. It has cylindrical spikes with 3 to 5 large spikelets and glumes which are "very tough, each ending in three stiff, stout and eventually spreading long awns". At maturity, the wheatlike fruits are armed with long, barbed awns (Talbot and Smith, 1929). Crampton (1974) also notes that "the whole spike falls away to the ground as a unit and remains so until the soaking rains in the fall break it up into joints. Seed germinates in a portion of the spike, and that blackish portion may be found among the roots of the barb goatgrass plant" (Figure 1.1).

In California, goatgrass "greens up" in February and begins to ripen in late June, depending on seasonal rainfall and other seasonal conditions for plant growth. The reddish or purplish heads, when immature, are easily distinguished from the drier associated grasses which mature earlier than goatgrass. The seeds may remain dormant for two or more seasons before germinating (Talbot and Smith, 1929).

Figure 1.1 Barb Goatgrass (*Aegilops triuncialis* L.). Mature barb goatgrass plant with seedhead and seeds.

Barb goatgrass was first reported being found in California in the early 1900s (Kennedy, 1928). It has become a serious range weed which not only crowds out desirable forage species (Crampton, 1974) but also causes mechanical injury to livestock because of its sharp, barbed awns (Talbot and Smith, 1929). Goatgrass is, therefore, not a preferred livestock feed. Livestock avoid this plant on rangeland (Munz and Keck, 1975) due to the "stiff stems, scarcity of foliage and the obnoxious spikes" (Crampton, 1974).

The common name, goatgrass, is used for several species of *Aegilops*, which are closely related to wheat (*Triticum spp.*) (Talbot and Smith, 1929). Species of both *Aegilops* and *Triticum* have contributed to the genetic makeup of the cereal crop, wheat (Crampton, 1974). *Aegilops* species resemble and are often referred to as wild wheat. Kennedy (1928) noted that a specimen of *Aegilops triuncialis* was identified as *Triticum triuncialis* by the United States Department of Agriculture indicating a close resemblance to wheat. A troublesome wheat-field weed, jointed goatgrass (*Aegilops cylindrica* L.), is a closely related plant (Munz and Keck, 1975). In California, the term goatgrass usually applies to *A. triuncialis* but may also refer to *A. ovata* (Talbot and Smith, 1929). *A. triuncialis* is also called barb goatgrass (Crampton, 1974). Comments on goatgrass in this paper refer to *Aegilops triuncialis.*

It has been reported by Talbot and Smith (1929) that goatgrass is an uninvited plant immigrant from Europe. Kennedy (1928) noted that two *Aegilops* species occur in the Mediterranean region and northern Africa, three species in

France, and in the United States, two species occur as alien immigrants. In 1917, a goatgrass sample was collected and sent to the Commission of Horticulture, Sacramento, California, with a note that stated that the grass was first noticed when cattle from Mexico had been pastured in-between Eldorado and Sacramento counties (Kennedy, 1928). Thus, *Aegilops* seems to be present in many countries.

Goatgrass is easily dispersed. The awns can be carried in the wool of sheep or hair of cattle and horses, transported by water, or windblown along bare ground where it will usually lodge when encountered by any obstruction (Talbot and Smith, 1929). Goatgrass could have arrived in the United States by being "carried in the wool of imported sheep, as an impurity in imported agricultural seed, or by other agencies" (Talbot and Smith, 1929).

Barb goatgrass is expanding its range annually (Barbe, 1993). New areas are being reported and existing infestations are increasing in size (Figure 1.2). Kennedy (1928) reported that goatgrass first appears as scattered plants which rapidly multiply into solid patches. Talbot and Smith (1929) added in their report on goatgrass that solid infestations of several acres may appear "in which goatgrass comprises from 50 to 70 percent, and upwards, of the thick carpet of vegetation." Foothill grazing ranges, on which forage is mainly composed of annual grasses and forbs, native-hay meadows, and grain fields, are all areas where goatgrass has invaded (Talbot and Smith, 1929). Kennedy (1928) reported that cultivated areas are also affected.

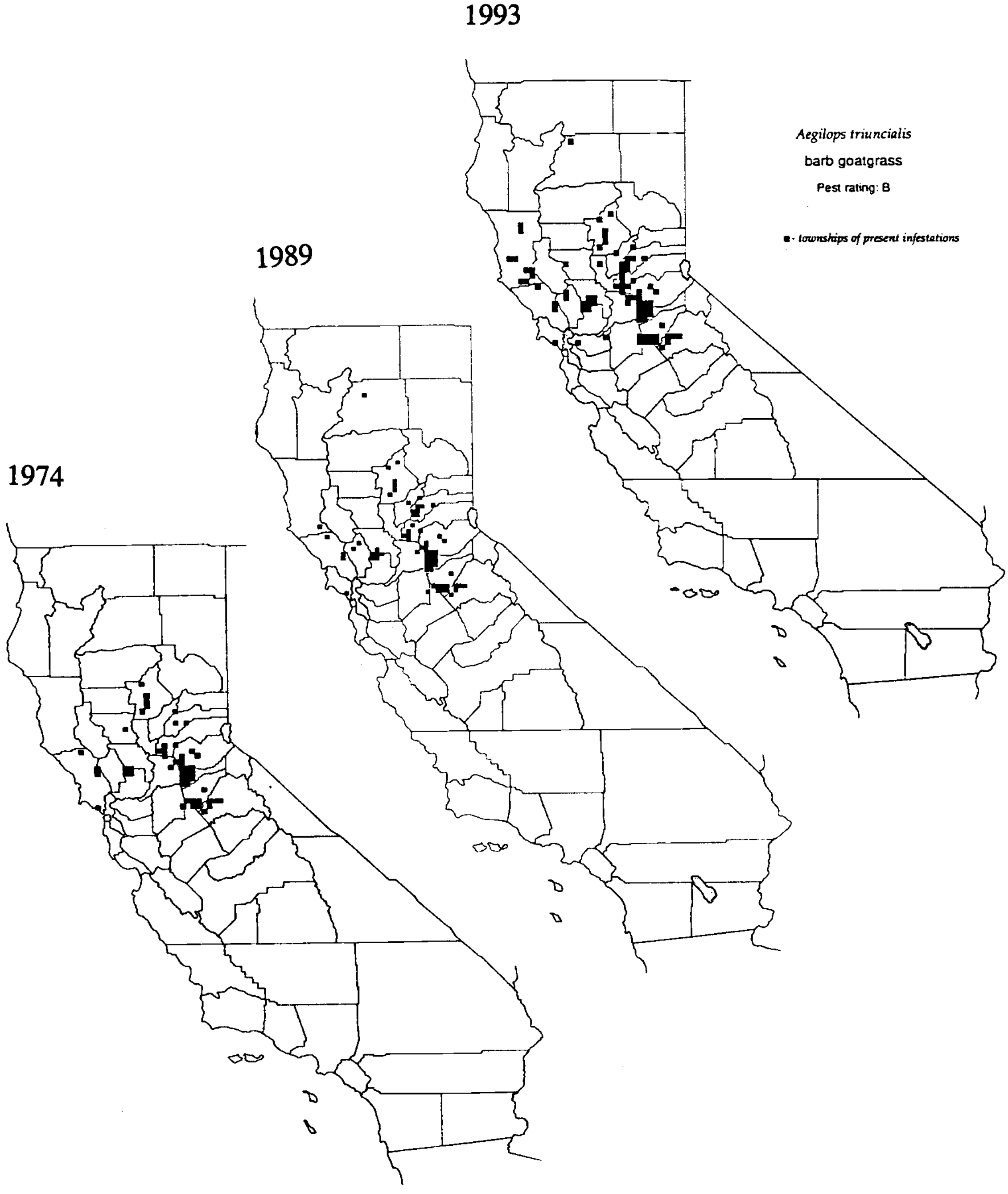


Figure 1.2. Expansion of Barb Goatgrass. Maps of California showing the expansion of barb goatgrass, by township, in the years 1974, 1989, and 1993.

The plant thrives in open grasslands as well as oak woodlands. It occurs in level, rolling, and rough country on various classes of soil and at various elevations. A high abundance of plants has also been observed on thin, gravelly soils (Talbot and Smith, 1929).

Goatgrass is an undesirable forage species due to its injuriousness to livestock, low forage value, and ability to crowd out desirable forage (Talbot and Smith, 1929; Crampton, 1974). The barbed seeds are reported to cause serious injury to sheep and hogs. A report from Calaveras County, California in 1927 stated that "the very pointed fruit entered the eyes of hogs, penetrating to the brain and causing death" (Kennedy, 1928). The forage value of the plant is negligible although horses may derive some nutritional value from goatgrass (Talbot and Smith, 1929) due to their feeding strategy. Kennedy (1928) noted that stock eat sparingly of the young grass and entirely avoid grazing the mature plant. "Evidence is clear that goatgrass under favorable conditions crowds out valuable associated forage plants" (Talbot and Smith, 1929). Goatgrass has been rated "B" ("A" being the most problematic) in the rating classification of noxious weed species in California. A "B" rating is defined as "intensive control or eradication, where feasible, at the County level. Quarantine or other holding action at the discretion of the Commissioner" (McCaskill, 1977). As a comparison of the goatgrass problem, yellow starthistle (*Centaurea solstitialis* L.) is on the "C" list.

There is not much published information on control methods for goatgrass. The related species, jointed goatgrass, (Aegilops cylindrica), however, has recently been studied and some control measures have been recommended. Hopefully, knowledge of control methods for one species of *Aegilops* may lead to control methods for other species.

Jointed goatgrass (*A. cylindrica*) is a weed that commonly infests roadsides, fencerows, and wastelands first and then migrates to cropland and ranges (Fenster et al., 1980). It is a serious problem in winter wheat producing areas of the United States (Fleming and Young, 1986), including Eastern Oregon. Research has focused on selective herbicides as a means of controlling jointed goatgrass although fire studies have also been conducted. Jointed goatgrass seeds remain dormant in the soil up to 5 years with nearly 100% germinability (Willis et. al., 1988). This is similar to barb goatgrass which has seeds that remain dormant for at least 2 years before germinating (Talbot and Smith, 1929). Willis et.al. (1988) noted that jointed goatgrass seeds germinate on the soil surface. They conducted a study to determine germinability of jointed goatgrass seed after 1) flaming and 2) oven burning to mimmick effects of field burning of grain stubble. Flaming of the seeds for 1 second reduced germination to 30%, 14 days after treatment. Yenne et al. (1986) found that the preemergence surface application of ethyl-metribuzin at 1.68 kg/ha plus metribuzin at 0.15 kg/ha controlled 86% of the jointed goatgrass. They also found burning, with a soil surface temperature of 249 C, reduced seed viability by 49%. Ethyl-metribuzin was also used by Westra (1988) to control jointed goatgrass. High application rates were needed for control and costs may, therefore, be too high for practical treatment. Rydrych (1986) also successfully controlled jointed goatgrass using ethyl-metribuzin when it was preplant surface applied. It was noted that jointed goatgrass is easier to control when herbicides are applied in the fall. Miller and Krall (1988) found that jointed goatgrass control with the herbicide SMY-1500 decreased as plant maturity increased. Buman et al. (1988) stated that SMY-1500 is the only herbicide that will selectively control jointed goatgrass in winter wheat. O'Bryan and Peeper (1985) determined that jointed goatgrass was succeptible to postemergence application of another herbicide, chlortoluron. Fenster et al. (1980) listed several herbicides that may be effective in controlling jointed goatgrass: atrazine, Princep (simazine), Pramitol (prometon), Telvar (monuron), or Hyvar (bromacil). Whitson et al. (1985) reported that of several herbicides tried, only Treflan (trifluralin), a foliar/soil active herbicide, was effective in controlling jointed goatgrass and it was at best "fair" (60-79%).

Grazing, mowing, burning, and herbicide treatments are potential control methods for goatgrass. Munz and Keck (1975) stated that although cattle generally avoid goatgrass on rangelands, if the goatgrass infested areas are heavily grazed, the infestation may be reduced. George (1991, unpublished) noted that mowing or grazing by sheep or cattle to ground level via high intensity/short duration grazing throughout the growing season may reduce vigor and seed set. He also suggested mowing to ground level near the end of the growing season but before seeding. Talbot and Smith (1929) found that mowing alone was ineffective since "very short or bent-over seed stalks are missed". Many mowed plants "stool out" and produce seed within a month after cutting. Mowing combined with other treatments may be effective, however. George (1991, unpublished) suggested mowing in late spring and then after a week, burning. The mowing would provide more tinder, especially in thinly grassed spots, and would, therefore, help to achieve a more uniform burn. Burning can be effective if a slow, hot fire is achieved to kill seed (George, 1991 unpublished). Talbot and Smith (1929) commented that burning may be the cheapest and most practical method of control on large areas of infested land that cannot be grazed sufficiently close to prevent goatgrass seeds from ripening. George (1991, unpublished) suggested a burn treatment while goatgrass is green and other plants are dry. He also suggested possibly burning in late spring/early summer when goatgrass is dry. Goatgrass control may be similar to medusahead rye (Taeniatherum caput-medusae Link.) control in that burning may reduce thatch and, thereby, open up the site to more desireable competitors (George, 1991 personal communication). Kennedy (1928) stated that burning when plants are dry is only a partial remedy since the beards may be singed without destroying the seed. Herbicide treatment in spring before seed set is suggested by George (1991, personal communication). He also suggested either a herbicide to kill everything such as glyphosate (Roundup) or a grass selective herbicide such as Post (sethoxydim) or Fusilade (fluazifop). Kennedy (1928) suggested using residual herbicides so that the seeds which are in the soil would not germinate.

There has not been much recent research conducted on controlling goatgrass even though the goatgrass problem is increasing each year (Barbe, 1993). Not much is known about the basic competitive nature of the plant. For example, we have little, if any, information on the palatability of goatgrass as a livestock feed. Perhaps palatability is related to a high silica content in the plant as is the case with medusahead rye. The plant's seed reservoir and how it functions is another possible area of study to be considered.

Although goatgrass has been documented as occuring mainly in California, it is quite likely that undiscovered or unreported infestations exist in other locations. The range of goatgrass is moving in north and west directions in California. Shasta County has been affected by goatgrass and the infestation continues to grow. In Mendocino County, the goatgrass population has spread rapidly and now exists in many parts of the county. Oregon will likely have a goatgrass problem if proven control measures are not found and put into effect in California.

The basic biological characteristics of goatgrass such as germination and growth rates are unknown. We also do not know optimal temperature for germination and growth. These parameters are important for determining goatgrass' relative competitiveness in the California annual grassland. Germination and early seedling growth dynamics are of special importance because they determine resource partitioning and subsequent reproductive success of annual plants.

One goal of this study was to quantify germination requirements and seedling root growth dynamics of barb goatgrass and four cohort species; slender wild oats (*Avena barbata*), medusahead rye (*Taeniatherum caput-medusae*), soft chess (*Bromis mollis*), and subterranean clover (*Trifolium subterraneum*). Another goal was to determine the response of barb goatgrass to sheep grazing. The third goal was to document the effects of glyphosate (Roundup), a non-selective herbicide, on barb goatgrass. In summary, the objectives of this research were to:

1. Determine physiological optimal temperatures and temperature ranges under which barb goatgrass and associated species germinate.
2. Determine root growth rates under greenhouse conditions that simulate spring conditions on California annual grasslands.
3. Determine the dynamics of barb goatgrass populations to sheep grazing at selected plant phenological stages.
4. Determine what rate of Roundup is necessary to control barb goatgrass in the field.

CHAPTER 2

GERMINATION AND EARLY DEVELOPMENT OF BARB GOATGRASS AND ASSOCIATED SPECIES

Abstract

Rate of germination and early root growth rates of five species of annual plants were investigated under five constant temperature regimes (5, 10, 15, 20, and 25 C). Barb goatgrass (*Aegilops triuncialis* L.) was compared to soft chess (*Bromis mollis* L.), medusahead rye (*Taeniatherum caput-medusae* (L.) Nevski), slender wild oats (*Avena barbata* L.), and subterranean clover (*Trifolium subterrraneum* L.) to determine what advantages it has when establishing in a plant community. A high percentage (90.8%) of bare barb goatgrass seed germinated quickly across all temperatures tested. Other species tested had a maximum percentage of their seed germinate at temperatures between 5 and 20 C, but had a lower percentage germinate at 25 C. Average number of days to germination was different ($P<0.001$) for all species. Bare barb goatgrass seed germinated faster than all other species tested at all temperatures. Barb goatgrass root growth penetrated to greater depth than all species except slender wild oat. Rooting area observed in glass-sided boxes was greater for barb goatgrass than other species except subclover. Barb goatgrass is, therefore, a rapidly-growing aggressive species.

Key Words: Barb Goatgrass, Germination, Root Growth.

Introduction

Developmental characteristics of plant species such as germination of seed, root growth rates, and establishment of seedlings are important when trying to determine environmental tolerances and control methods for weedy species. The ways in which plants develop and interact with each other and their environment also adds to the understanding of apparent plant competition within an area.

One aspect of germination is length of time needed to germinate and the effect of temperature on germination time. Plants that are able to germinate quickly and establish themselves in the community first, may be better able to occupy the site, acquire resources, and outcompete neighboring species. Percent of seeds that are actually viable and germinate is another aspect. Germination percent and seed yield together have implications for population dynamics and composition of future stands.

We investigated the percent germination, rate of germination, and early root growth rates of five species of annuals at various temperature regimes. We were interested in comparing barb goatgrass (Aegilops triuncialis L.) to several species to determine what advantages it potentially has when establishing in a plant community.

Materials and Methods

Plant Materials

Seed used for this study were obtained from plants growing on the Hopland Field Station, Mendocino County, California. Seed was collected from barb goatgrass, slender wild oats (*Avena barbata* Link.), medusahead rye (*Taeniatherum caput-medusae* L.), and soft chess (*Bromus mollis* L.) in May and stored under refrigeration until fall. Seed of a comparison species, subterranean clover (*Trifolium subterraneum* L.) was obtained commercially and represents the most widely seeded pasture plant in the area. Goatgrass seeds were measured and weighed to determine seed volume and density (Appendix Table 1).

Germination Study

A randomized complete block design was employed to examine both extent (percentage) of germination and rate of germination for the five species mentioned above. Goatgrass seed was tested both as found in the field, with intact seed heads, and as bare seed (exposed caryopsis). Fifty seeds of each species were placed in 10 cm by 10 cm plastic germination boxes on standard blotter paper. Tap water was added until the blotters were saturated and the excess water was removed. Moist white felt cloth was placed over the seeds to ensure seed contact with blotters. Boxes of seed were randomly assigned to one of five blocks.

Blocks were then randomly assigned to one of five constant temperatures (5, 10, 15, 20, and 25 C). Germinated seeds were counted daily for 28 days and those that germintaed were removed. Seeds were considered germinated when radicles were 2 mm long. Temperature in the germinators was monitored every 5 minutes for the duration of the experiment. Temperature in all chambers varied less than ±2 C of the assigned temperature for the duration of the experiment.

Root Growth Rates in the Greenhouse

The five species of annuals (as just germinated seed) were placed in the greenhouse in glass-sided boxes (30 cm by 60 cm by 2 cm) that had been filled with a potting soil mixture consisting of 1 part loamy soil, 1 part sand, 2 parts pumice, and 1 part peat moss. Each box held one plant. Each species was replicated five times. Seeds were placed 1 cm below the soil surface. A grid was attached to one side of the box to facilitate measurement of root growth. Each day, rooting depth was measured to the nearest mm using a ruler. Root spread was measured on each one cm horizontal grid line and was also measured to the nearest mm using a ruler. The study continued for 21 days, until roots reached the bottom of the box. Rooting area was calculated by multiplying lateral root spread (mm) at each 10 mm depth by 10 and summing.

Leaf area index of test species, which is a measure of photosynthetically active plant area, was measured using a Model LI-3100 Area Meter (LI-COR, Inc., Lincoln, NB).

Data analysis

Germination percent and rate averaged for each germination box were analyzed using a General Linear Model (GLM) procedure. Means that were significantly different were separated with a Fisher's Protected Least Significant Difference (LSD) test. All statistical analyses were performed using SAS procedures (Statistical Analysis Systems Institute, 1988). Null hypotheses for these experiments are as follows:

H_o: Germination percentage of barb goatgrass is similar to associated plant species.

H_o: Germination rate of barb goatgrass is similar to associated plant species.

H_o: Root growth rate (maximum depth) of goatgrass is similar to associated plant species.

H_o: Root growth rate (area) of goatgrass is similar to other associated plant species.

Statistical Model Statement:

$$Y_{ijk} = \mu + \text{Block}_i + \text{Species}_j + \text{Temperature}_k + (\text{Species by Temperature}) + \epsilon_{ijk}$$

Results and Discussion

Germination at Five Temperatures

Germination Percent

Temperature had a significant effect ($P<0.001$) on percent germination of all species except bare barb goatgrass (Table 2.1). Goatgrass seed was tested both as intact spikelets and as bare goatgrass seed. Table 2.1, Appendix Figures 3 and 4 demonstrate that the spikelet has an inhibiting effect on germination. Germination percentage was lower and variation was greater for intact spikelets. The spikelet probably slows the passage of water to the seed which in nature prevents light rains from inducing germination. Late establishment may be encouraged by the intact spikelet which needs to decompose somewhat prior to root and shoot development. Obviously, it is difficult to see newly germinated seeds within the spikelet and roots appear later than with bare seed.

An average of 40.8% of the goatgrass seed in spikelets germinated during the 28 day trial. Bare goatgrass seed had high germination percentages at all temperatures tested (avg = 90.8%).

The other four annuals tested had high germination percentages at all temperatures except at 25 C (Table 2.1, Appendix Figures 5 to 8). Soft chess had average germination percentages over 90% across temperatures from 5 to 20 C. At 25 C germination averaged 70%. Medusahead rye had greater variability than soft chess. The highest percentage (85%) of germinated medusahead rye seed was at 15 C (Table 2.1, Appendix Figure 6).

Slender wildoats had an average germination of 75.2% between 5 and 20 C but dropped off significantly ($P < 0.0001$) at 25 C to 20% (Table 2.1, Appendix Figure 7). Subclover the most common seeded pasture species in Mendocino County, California, had an 89.2% average germination overall. It showed more variability in germination at 25 C.

Table 2.1. Percent germination of barb goatgrass and associated species grown at constant temperature.

Temperature	Barb Goatgrass (Bare)	Barb Goatgrass (Intact)	Soft Chess	Medusahead Rye	Slender Wild Oats	Subterranean Clover	P-Value
5	91.2 AB,a	58.4 NS,c	89.6 A,a	70.8 A,bc	76.8 A,ab	86.8 A,a	0.0021
10	81.6 C,a	36.4 NS,b	93.6 A,a	80.4 A,a	78.8 A,a	84.4 A,a	0.0001
15	85.6 BC,ab	38.8 NS,c	94.4 A,a	87.2 A,ab	69.6 A,b	92.4 A,a	0.0001
20	100 A,a	45.6 NS,d	90.4 A,ab	71.6 A,c	75.6 A,bc	93.2 A,ab	0.0001
25	95.6 A,a	24.8 NS,c	72.4 B,b	32.8 B,c	24.4 B,c	74.0 B,b	0.0001
P-value	0.0037	0.2356	0.0015	0.0002	0.0001	0.0069	

Means within a column that are not different (P = 0.05) are immediately followed by the same upper case letter. Means within a row that are not different (P = 0.05) are followed by the same lower case letter. NS indicates non-significance at P = 0.05.

<u>Germination Rate</u>

Average number of days to germination differed ($P<0.001$) with differing temperatures for all species. Bare barb goatgrass seed germinated quickly at all temperatures (Table 2.2, Appendix Figure 10) but was most rapid between 10 and 20 C. It is impossible to directly compare seed within the spikelet to bare seed because we could not count seed as germinated until we could see the root. At lower temperatures the roots seem to be able to penetrate the spikelet relatively quickly (2 days) but at higher temperatures roots were not visible until 10 days later (Table 2.2, Appendix Figure 9). The variability in germination rate was increased for seed in intact spikelets.

Soft chess, medusahead rye, slender wild oats, and subterranean clover all germinated quickly at temperatures of 10 to 20 C (Table 2.2, Appendix Figures 11 to 14). However, bare goatgrass germinated faster at all temperatures and the range of time to germination was short. This shows one aggressive characteristic of goatgrass. It is able to germinate in a short time at a relatively wide range of temperatures. Other annuals took longer to germinate at higher and lower than optimum temperatures and had a lower percent of seeds germinate (Table 2.2).

Table 2.2. Average time in days to germination of barb goatgrass and associated species grown at constant temperature.

Temperature	Barb Goatgrass (Bare)	Barb Goatgrass (Intact)	Soft Chess	Medusahead Rye	Slender Wild Oats	Subterranean Clover	P-Value
5	6.0 A,d*	9.9 BC,c	11.4 A,b	13.3 B,a	11.9 A,b	6.1 A,d	0.0001
10	3.9 B,bc	7.1 BC,a	5.9 B,ab	6.6 C,a	6.0 C,ab	2.3 B,c	0.0051
15	3.5 B,bcd	5.6 C,ab	4.6 C,abc	2.6 D,cd	6.9 BC,a	1.4 B,d	0.0022
20	2.7 B,cd	10.7 B,a	4.1 C,bcd	5.8 C,b	5.2 C,bc	2.0 B,d	0.0001
25	6.7 A,d	19.1 A,a	6.6 B,d	16.3 A,b	9.7 AB,c	6.9 A,d	0.0001
P-value	0.0001	0.0001	0.0001	0.0001	0.0009	0.0001	

* Means within a column that are not different (P = 0.05) are immediately followed by the same upper case letter. Means within a row that are not different (P = 0.05) are followed by the same lower case letter. NS indicates non-significance at P = 0.05.

Root Growth

Greenhouse plantings help to illustrate potential plant competitive abilities as related to root and shoot growth strategies. Rooting depth characterizes a plant's niche and, therefore, its strategy to utilize available nutrients from the soil. Goatgrass and slender wild oats both had the deepest roots of all species examined, 375 and 341 mm, respectively ($P = 0.05$)(Table 2.3, Figures 2.1 - 2.5). Slender wild oats differed ($P < 0.05$) from medusahead rye and subclover, with the roots of slender wild oats being much deeper. Goatgrass and subclover rooting depths also differed ($P < 0.05$) as shown in Figures 2.1 and 2.5. Medusahead rye showed an average rooting depth of 219 mm, soft chess was 232 mm, and subclover was 155 mm after 22 days in the greenhouse.

The rate of root penetration was found to be linearly related in both goatgrass and slender wild oats (Figures 2.1 and 2.4). Rooting depth correlated well with time, as described by days since germination (Figure 2.1 to 2.5). Subclover rooting was not as deep and fast as the other species, but this is a plant that occupies space near the surface of the soil. Soft chess tends to grow more slowly and does not reach the depths of goatgrass and slender wild oats. Medusahead rye grows at a rapid rate but also does not reach the depths of goatgrass and slender wild oats ($P = 0.05$)(Table 2.3). Species with a fast growth rate combined with deep roots are able to occupy more area, capture more nutrients, and, therefore, be more competitive. Roots were difficult to see at times since the soil in the glass-sided boxes tended to shift. The roots did not always grow along the sides of the box, making measurement of root growth difficult.

Total area occupied by roots in the soil, i.e., observed rooting area, is also an indication of competitiveness. Goatgrass rooting area differed from slender wild oats, medusahead rye, and soft chess ($P<0.05$) (Figures 2.6 to 2.11). Goatgrass roots were observed to be deeper and they occupied a greater total area.

Shoot height differed among all species except slender wild oats and goatgrass. Goatgrass grew to an average height of 245 mm and slender wild oats was 221 mm. Both of these plants are relatively tall-growing species which compete for light and nutrients by occupying a significant portion of above-ground area as well as below-ground. Goatgrass and slender wild oats differed ($P<0.05$) from medusahead rye (165 mm), soft chess (143 mm), and subclover (39.5 mm). Medusahead rye differed from subclover ($P<0.0001$) as shown in Table 2.4.

Leaf area index of plants is a measure of photosynthetically active plant area. Slender wild oats had the highest leaf area index, 750 mm, and differed ($P=0.05$) from all species except goatgrass. Medusahead rye, soft chess, and subclover did not differ from one another (Table 2.4).

Table 2.3. Mean Daily Root Penetration of Test Plants. Mean maximum rooting depth measured 25 days after germination of five plants in the greenhouse.

Plant Species	Maximum Rooting Depth in mm	Std. Dev.	Mean Daily Root Penetration in mm	Std. Dev.
Barb goatgrass	341 ab*	93.5	14.2	3.3
Medusahead rye	219 bc	102.6	11.2	2.2
Soft chess	233 abc	70.5	10.8	3.1
Subclover	155 c	77.1	6.9	3.7
Slender wild oats	376 a	134.5	18.4	6.5

* Means within a column that are not different (P = 0.05) are followed by the same letter.

Table 2.4. Mean Shoot Height and Mean Leaf Area Index of Test Plants. Mean leaf area index of measured 25 days after germination of five plants grown in the greenhouse.

Plant Species	Shoot Height in mm.	Std. Dev.	Mean Leaf Area in mm.	Std. Dev.
Barb goatgrass	242 a*	14.2	532 b	61.5
Medusahead rye	165 b	16.2	86 c	11.8
Soft chess	144 b	28.1	82 c	15.7
Subclover	40 c	21.0	273 c	192.8
Slender wild oats	222 a	14.1	751 a	273.9

* Means within a column that are not different (P = 0.05) are followed by the same letter.

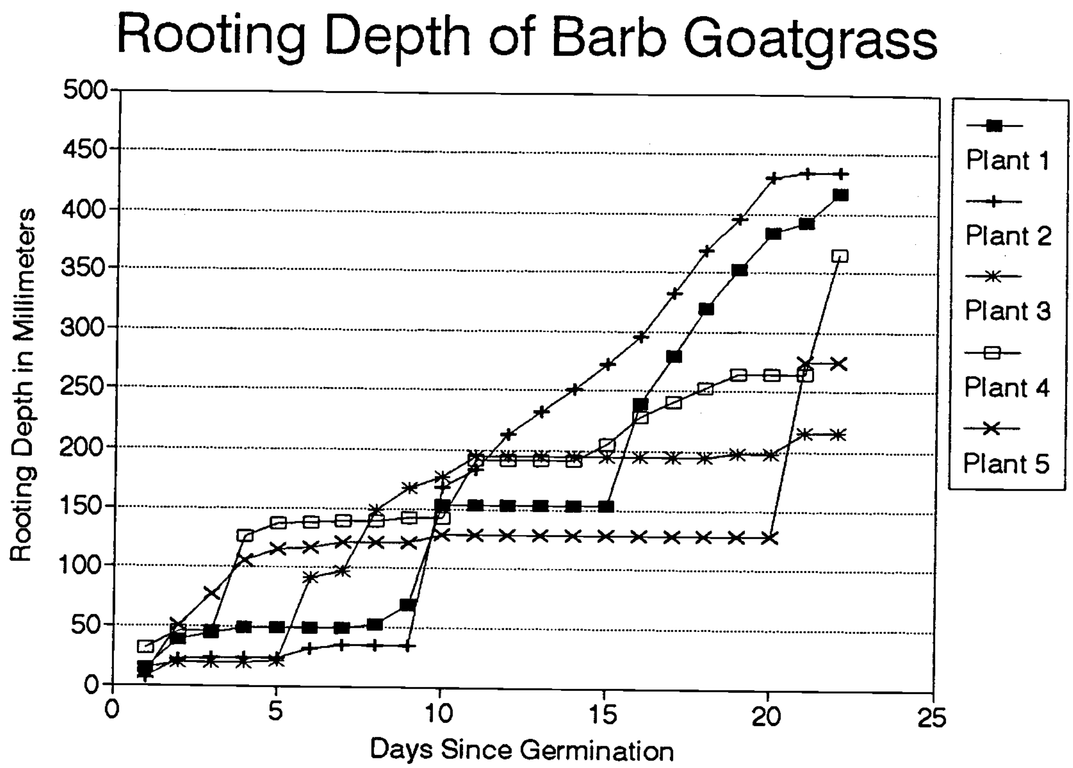


Figure 2.1. Maximum rooting depth of barb goatgrass (*Aegilops triuncialis* L.).

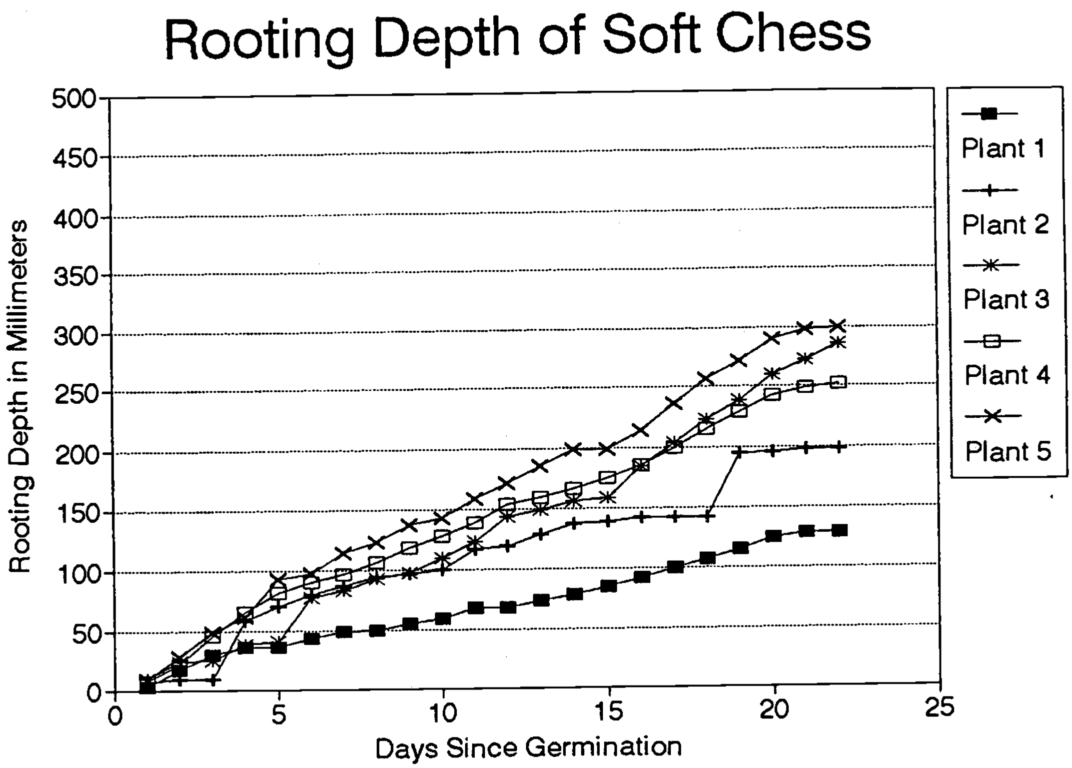


Figure 2.2. Maximum rooting depth of soft chess (*Bromus mollis* L.).

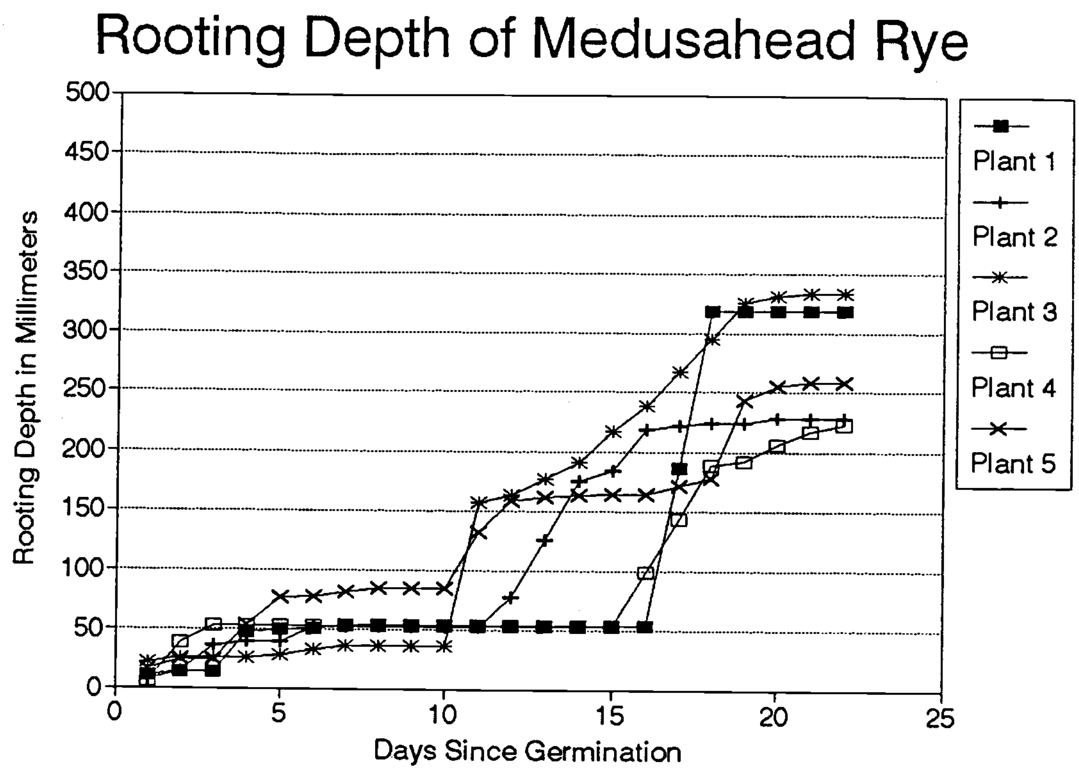


Figure 2.3. Maximum rooting depth of medusahead rye (*Taeniatherum caput-medusae* L. Nevski).

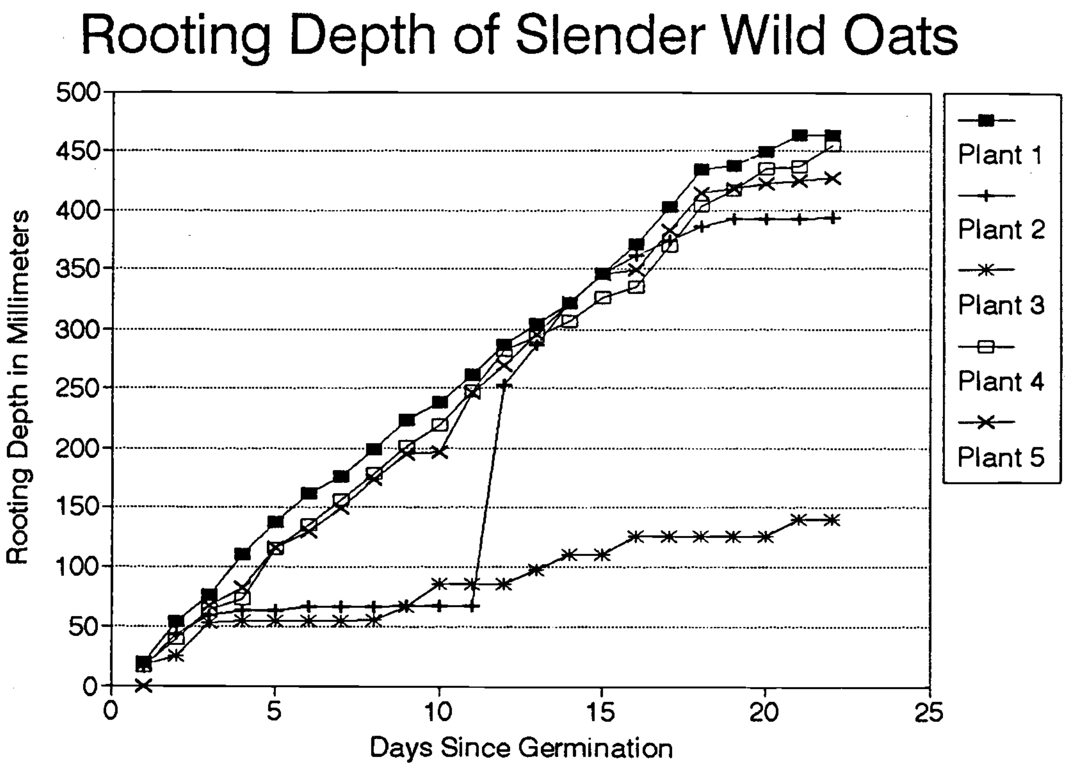


Figure 2.4. Maximum rooting depth of slender wild oats (*Avena barbata* Link.).

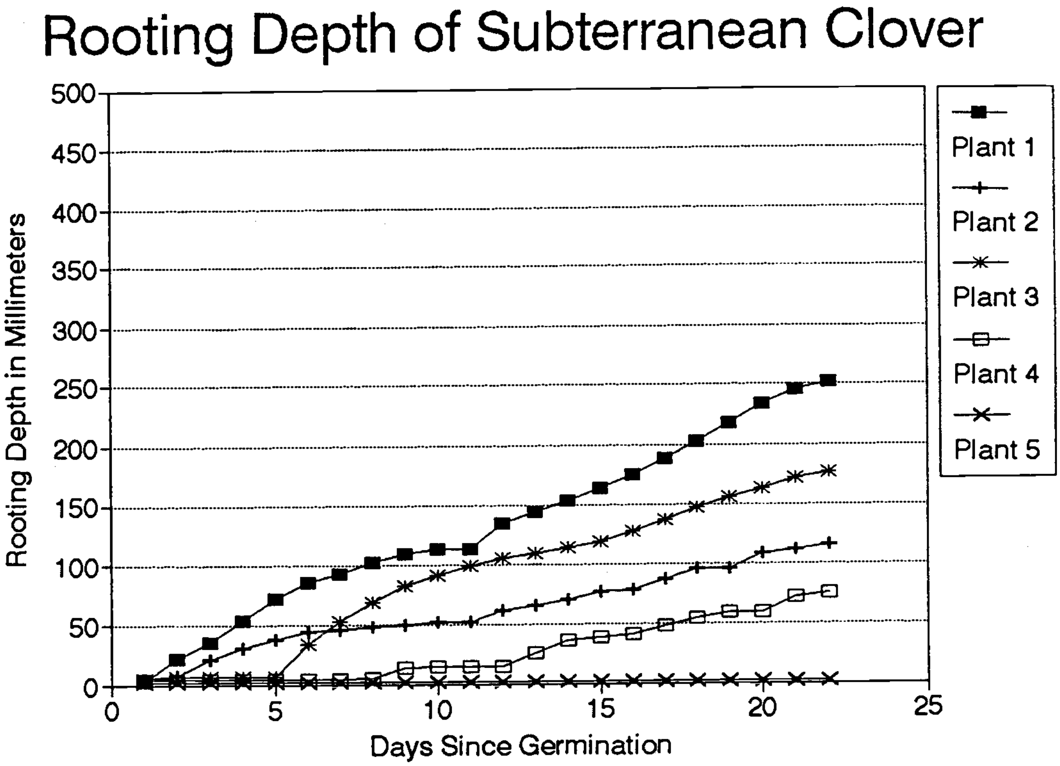


Figure 2.5. Maximum rooting depth of subterranean clover (*Trifolium subterraneum* L.).

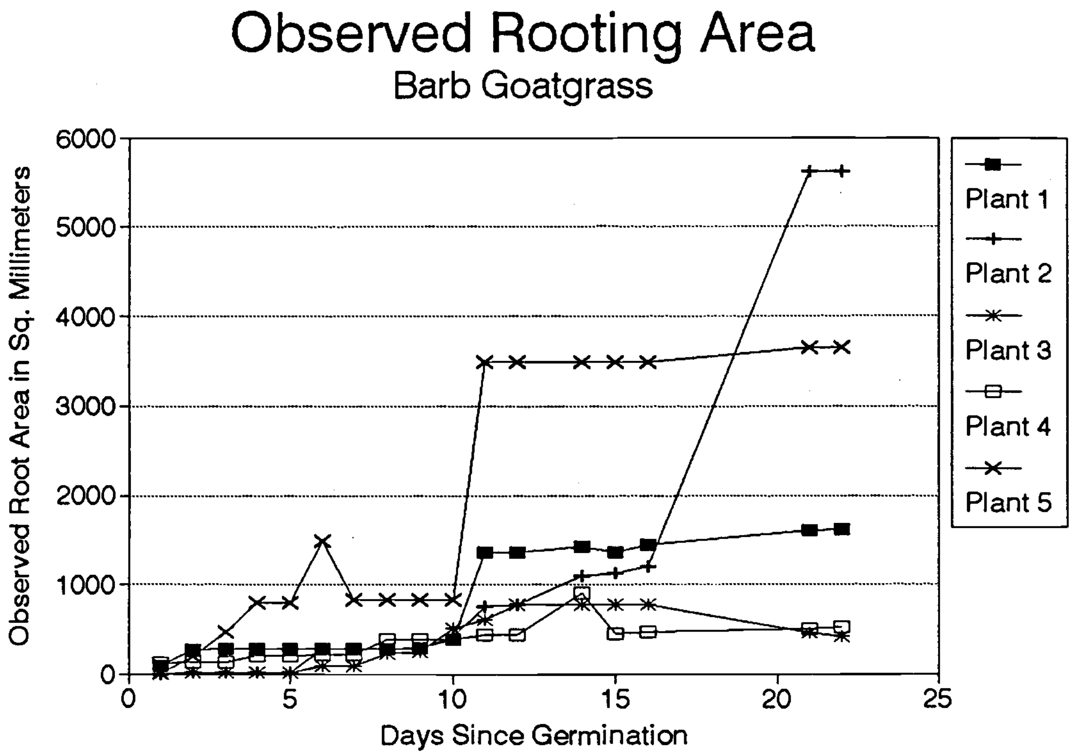


Figure 2.6. Observed rooting area of barb goatgrass (*Aegilops triuncialis* L.).

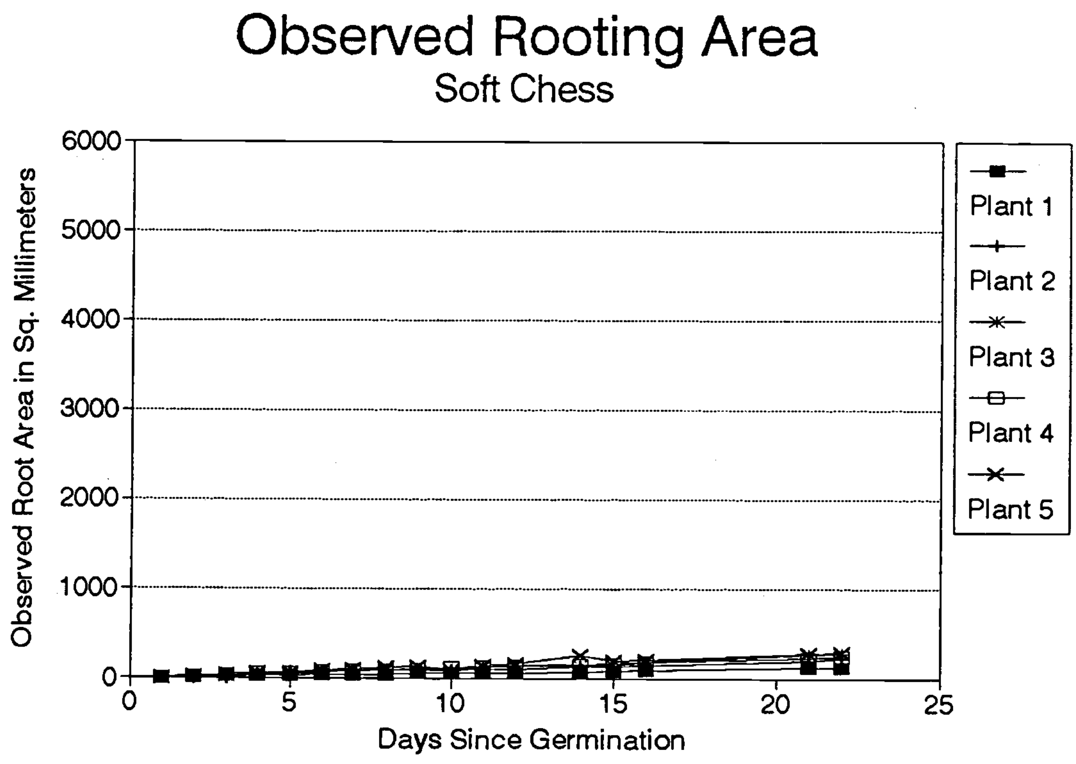


Figure 2.7. Observed rooting area of soft chess (*Bromus mollis* L.).

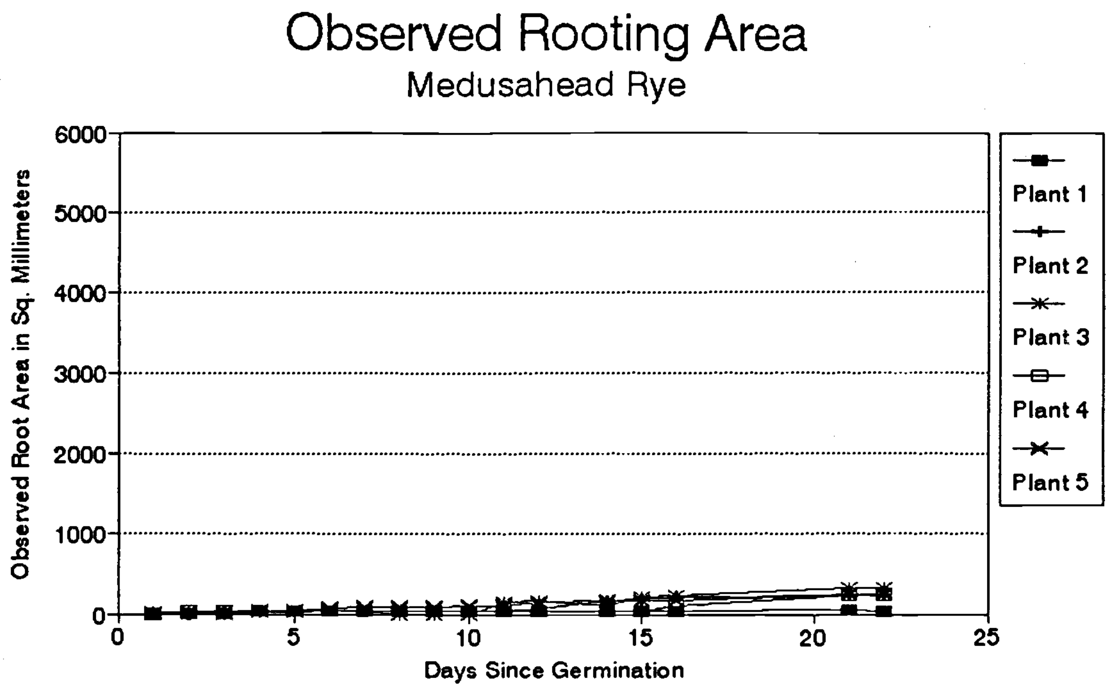


Figure 2.8. Observed rooting area of medusahead rye (*Taeniatherum caput-medusae* L.).

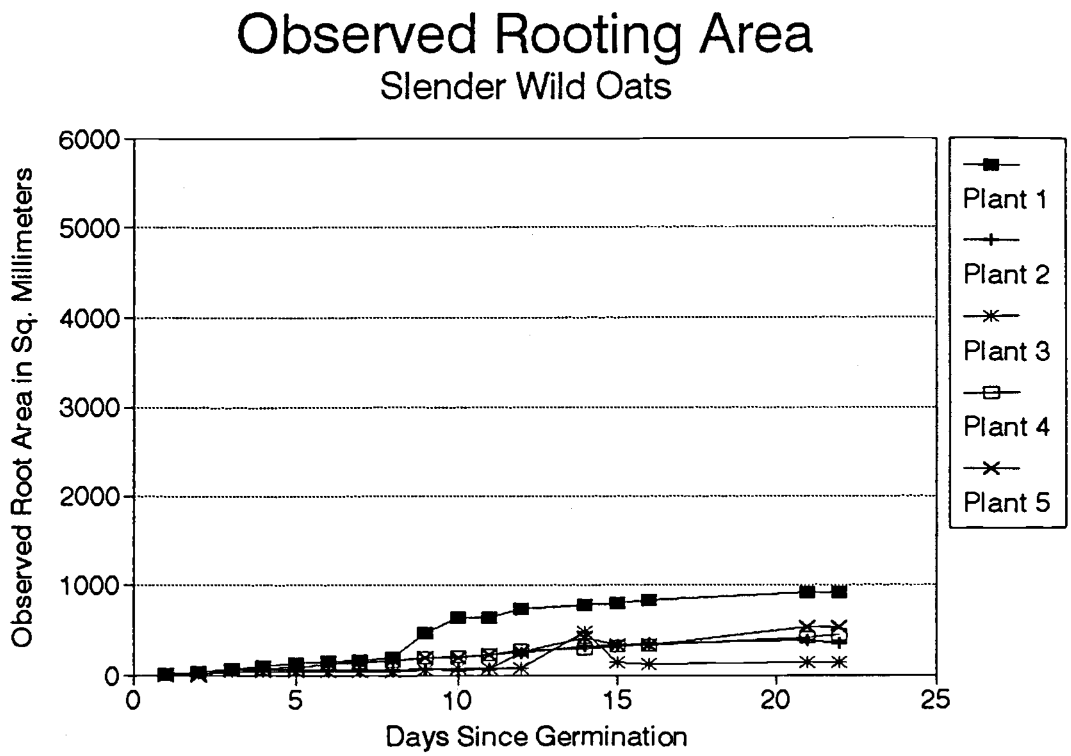


Figure 2.9. Observed rooting area of slender wild oats (*Avena barbata* Link.).

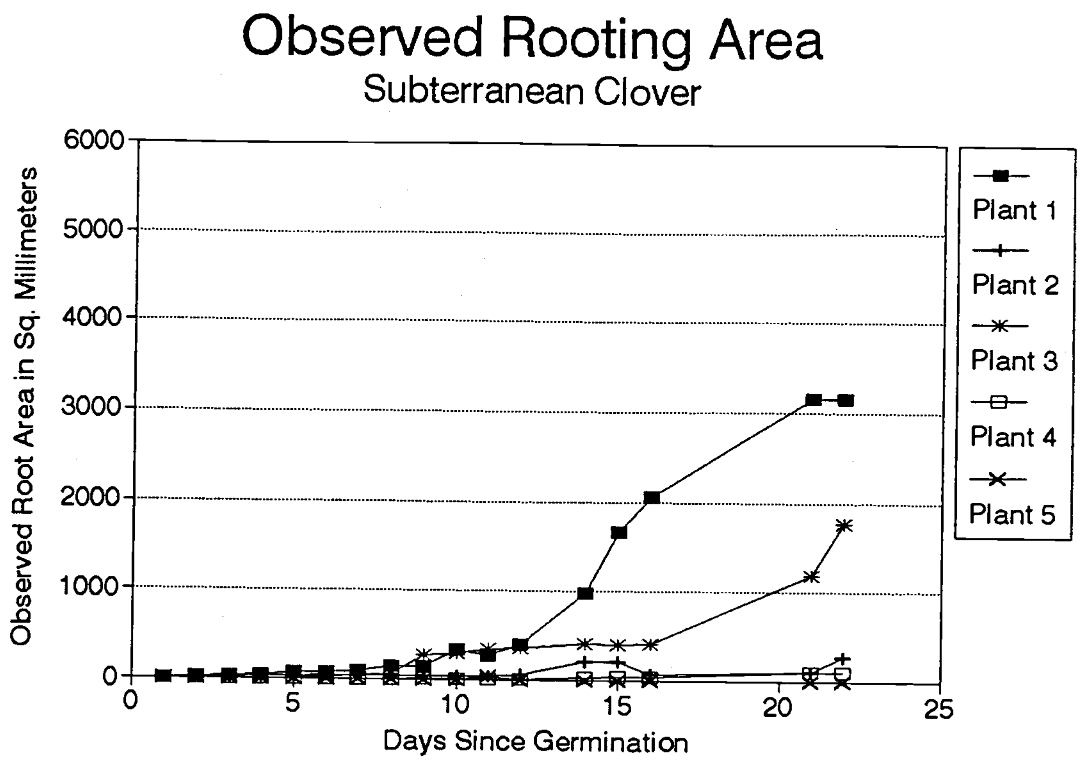


Figure 2.10. Observed rooting area of subterranean clover (*Trifolium subterraneum* L.).

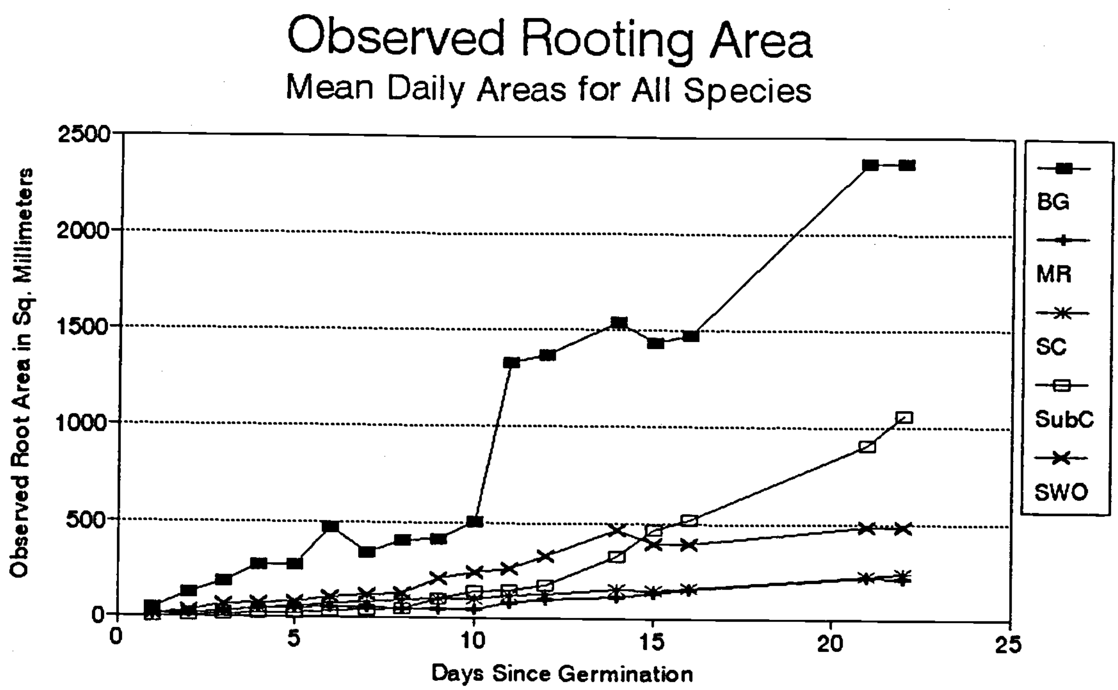


Figure 2.11. Observed mean daily rooting area for all test species.

Conclusions

These results suggest that bare barb goatgrass seed germinates and develops rapidly across a wide range of temperatures. Our experiments were conducted under conditions similar to those found on rangelands of the North Coast Region of California, in the fall when germinating rains first occur. Bare barb goatgrass seed would be relatively independent of temperature and, therefore, timing of "breaking" fall rains.

Barb goatgrass seed heads typically will break into sections in late summer and early fall. The spikelets burrow into the soil because of the recurved spines on the awns. Decomposition of the spikelet begins with first fall rains. The spikelet appears to delay and prolong seedling development which sequesters a portion of the seedbank for later growth.

Because barb goatgrass roots develop rapidly and spread widely, they can occupy the soil profile. This helps explain the observed competitive nature of the plant on annual grasslands. The rapid germination rate, high percent germination, and deep penetrating root system together with its late maturation, give this weedy species a dominant place in the plant community.

CHAPTER 3

CONTROL OF BARB GOATGRASS ON RANGELANDS

Abstract

This study was designed to begin to determine satisfactory control methods for the noxious weed, barb goatgrass (*Aegilops triuncialis* L.). Although goatgrass is invading new areas each year, little work has been reported on possible control methods. Biological control using high intensity/short duration sheep grazing and chemical control using glyphosate (Roundup) were examined. The grazing treatments consisted of an early season graze, an early + mid-season graze, and grazing whenever plant height reached 20 cm. Glyphosate treatments consisted of rates of 0.28 kg/ha, 0.56 kg/ha, and 1.12 kg/ha. Results from grazing treatments showed that the more the pastures were grazed, the higher the goatgrass density. Glyphosate applied at 1.12 kg/ha is able to control goatgrass but reseeding with desirable plant species is recommended.

Key Words: barb goatgrass, subterranean clover, annual grassland, range rehabilitation, glyphosate, sheep grazing

Introduction

Rangelands could be more productive and less injurious to grazing animals if noxious weeds were controlled. Weeds tend to establish on a site and then begin to outcompete more desirable species. Many of these weeds were accidently introduced into North America at or before the turn of the century.

In the early 1900s, barb goatgrass began to invade parts of California and has continued to establish in many areas (Kennedy,1928). When this plant matures, its rough obnoxious spikes may cause abscesses in livestock and wildlife who graze in areas infested with the plant. Barb goatgrass is undesirable as a forage, especially at the later phenological stages, causing grazing animals to avoid it. This promotes the spread of this noxious weed since areas that are not grazed continue to expand in size and it becomes dominant in the plant community. Understanding plant dynamics of this alien species aids in developing satisfactory control programs.

The purpose of this study was to begin to determine practical methods to control the noxious weed, barb goatgrass (*Aegilops triuncialis* L.). Biological control, using sheep grazing, and chemical control, using glyphosate (Roundup), were tested to determine barb goatgrass' response to these control methods.

Materials and Methods

Study Site

The field study site is located in Mendocino County, California at the University of California Hopland Field Station. It is located in the Russian River drainage of southeastern Mendocino County, 6.6 km (4 mi.) east of Hopland, California and approximately 165 km (100 mi.) north of San Francisco and 65 km (40 mi.) from the coast (Appendix Figure 1).

The Mediterranean climate in this area is characterized by hot, dry summers and mild, rainy winters. Annual precipitation averages 932 mm (36.71 in) at 243 m (800 ft) elevation and 1144 mm (45.05 in) at 610 m (2,000 ft). Rainfall (75%) generally occurs between November and February. Snow usually lasts for no more than a few days. July is the hottest month with maximum temperatures reaching 46 C (115 F). Night-time temperatures are generally cool, however. The frost-free growing season averages 250 days.

Rainfall is the most limiting factor for rangeland vegetation and the growing season lasts from the "breaking" fall rains through spring or for about 180 days, from November through April.

Vegetation Sampling and Monitoring

Biological Control of Goatgrass with Sheep - Experiment #1

Three permanent grazing areas 25 m by 15 m (81 ft. by 50 ft.) were fenced using typical sheep fencing consisting of woven wire and T-posts. Plots were established at three locations of varying elevation at the Hopland Field Station (Foster 1 = 275 m (900 ft.), Foster 2 = 305 m (1000 ft.), Middle = 457 m (1500 ft.)). These were subdivided into 3 m by 11 m (10 ft. by 37.5 ft.) paddocks representing the three grazing treatments (early season graze, early + mid season graze, graze whenever grass height reached 20 cm), the control (no grazing), and one chemically treated (glyphosate @ 1.12 kg ai/ha or 1.0 lb. ai/A) paddock (Appendix Figure 2).

On 16 September 1992, each paddock was broadcast seeded with 750 goatgrass seeds per paddock. Seeds were collected at the Hopland Field Station and distributed to ensure an even distribution of goatgrass within the study area. Rhizobium innoculated subterranean clover (*Trifolium subterraneum* L.) variety Karridale, was also broadcast seeded at a rate of 22.4 kg/ha (20 lbs./A).

Prior to introducing the animals to the paddocks, forage samples were taken to determine percent utilization using double sampling techniques. Plots were sampled with 15 randomly located 0.093 m^2 (1ft.^{2}) square quadrats in each treatment paddock and on average, one out of three quadrats were clipped. Climatic data were collected from the Hopland Field Station weather station at elevations of 244 m (800 ft.) and 518 m (1700 ft.). Monthly average precipitation and temperature readings are given in Appendix Tables 2 and 3.

During the growing seasons of 1992 and 1993, four or five ewes were allowed to heavily graze the paddocks using high intensity/short duration grazing. Biomass and percent species cover were determined for each paddock before and after grazing to determine utilization. Vegetation samples were then oven dried at 60 C (140 F) for 3 days to determine dry matter conversion factors. Species composition of each paddock was determined at the end of the growing season using a 10 cm plot with 100 samples taken in each paddock. A listing of plant species encountered on field plots is given in Appendix Table 3.

Barb Goatgrass Control With Glyphosate (Roundup) - Experiment #2

A randomized complete block design was utilized with three replications. The plots consisted of non-fenced pasture areas, 3 m by 11 m (10 ft. by 37.5 ft.), with heavy barb goatgrass infestations. Four treatments were applied to each of the three replicated sites. Glyphosate (Roundup) was applied at 0.00, 0.28, 0.56, and 1.12 kg ai/ha (0.00, 0.25, 0.50, and 1.00 lb. ai/A). The herbicide was initially applied on May 22, 1992 to the fenced plots, which constituted the first year treatment. Unfenced chemically treated plots were then established and both fenced and non-fenced plots were sprayed December 14,1992, the beginning of the 1993 grassland crop. Goatgrass was in an immature developmental stage at this point. A CO_2 backpack was the power source for four Fanjet 38002-LP nozzles, spaced 50 cm (20 in.) apart on a 1.5 m (5 ft.) hand wand boom applied at a rate of 0.703 kg/cm^2 (10 psi). An average of 516 ml (20 gal./A) were delivered per test area.

Environmental data were collected on the day of application. Air temperature, relative humidity, soil temperature, and wind speed were determined (Tables 3.1 and 3.2).

Species composition was determined after the growing season using a 10 cm^2 square quadrat with 100 samples taken in each paddock. A listing of the plant species encountered on field plots is given in Table 3.5. Above ground biomass was estimated by double sampling techniques on 15 randomly located 0.093 m^2 (1 $ft.^2$) square quadrats in each treatment subplot. On average, one plot of three was clipped.

Data Analysis

Species composition, percent cover and utilization percentage averaged for each treatment were analyzed using a General Linear Model (GLM) procedure. A Fisher's Protected Least Significant Difference (LSD) test was performed to identify significant differences. All statistical analyses were performed using SAS procedures (Statistical Analysis Systems Institute, 1988).

Table 3.1. Weather conditions during the herbicide application of 22 May 1992.

Parameter	Reading
Air Temperature	33 C (92 F) dry bulb 20 C (68 F) wet bulb
Relative Humidity	39%
Soil Temperature	28 C (83 F) at 20 cm (8 in.)
Wind Speed	0 - 8 km/hr (0 - 5 mi./hr.) gusts to 11 km/hr (7 mi./hr.)

Table 3.2. Weather conditions during the herbicide application of 14 December 1992.

Parameter	Reading
Air Temperature	11 C (51 F) dry bulb 14 C (57 F) wet bulb
Relative Humidity	60%
Soil Temperature	*
Wind Speed	0 - 8 km/hr (0 - 5 mi./hr.) gusts to 11 km/hr (7 mi./hr.)

* Data not collected

Results and Discussion

Biological Control of Goatgrass with Sheep

There was a difference ($P < 0.001$) in species composition between 1992 and 1993, after two seasons of treatment. The frequency of barb goatgrass did not differ ($P = 0.05$) by either plot or treatment in 1992. In 1993, however, treatment differences were found. Paddocks grazed whenever grass height reached 20 cm were different ($P = 0.05$) than paddocks grazed only in the early season and those treated with glyphosate (Table 3.3). Plots grazed whenever grass height reached 20 cm showed a higher percentage of goatgrass plants. Observations indicate that high intensity/short duration grazing throughout the growing season may cause barb goatgrass plants to tiller and, therefore, produce more seedheads. Glyphosate (Roundup) sprayed plots showed the least density of goatgrass plants, 1.2 plants/paddock compared to 19.6 plants/paddock for the heavily grazed plots. The control plot (no grazing), had a mean number of 3.5 plants/paddock. Even the moderately grazed paddock, which was grazed early and mid-season, had an average of 12.0 barb goatgrass plants/paddock. These results indicate that heavily grazing pastures containing this noxious weed throughout the growing season may actually aid in its spread.

Desirable forage species in the California annual grassland such as slender wild oats (*Avena barbata* L.) and soft chess (*Bromis mollis* L.) both

Table 3.3. Frequency of Plants Found on the Grazing Plots. Mean plant frequency at the end of the growing season (1993) on the grazing plots at the Hopland Field Station, Hopland, California.

Species	Early Season Graze	Early + Mid Season Graze	Grazed 20 cm Grass Height	Roundup @ 1.12 kg a.i/ha	Control
Barb Goatgrass	3.5 b*	12.0 ab	19.6 a	1.2 b	10.6 ab
Soft Chess	93.5 a	91.2 a	80.6 b	35.6 c	92.8 a
Medusahead Rye	79.2 a	75.2 a	32.2 b	1.2 c	70.5 a
Slender Wild Oat	93.8 a	92.2 a	59.2 b	1.8 c	95.0 a
Subterranean Clover	8.6 a	7.8 a	12.2 a	1.2 a	4.2 a
Filaree spp.	24.2 c	16.0 c	73.3 a	56.6 b	23.6 c
Dogtail	24.8 b	37.8 a	24.3 b	2.3 c	28.6 ab
Hairgrass	19.3 a	21.0 a	8.6 b	12.8 ab	18.2 a
Turkey Mullein	0.6 c	6.2 b	0.0 c	12.2 a	1.2 bc
Common Centaury	0.5 b	4.5 b	0.0 b	32.3 a	1.5 b
Lamarck's Bedstraw	7.0 b	4.6 bc	0.0 c	28.8 a	7.8 b
Chickweed	1.5 b	0.5 b	0.0 b	15.6 a	0.6 b

* Means within a row that are not different (P = 0.05) are followed by the same letter.

showed differences ($P<0.0001$) due to treatments. Slender wild oats decreased in frequency ($P=0.05$) in the glyphosate sprayed plots compared to other treaatments including grazing at 20 cm height, no grazing, early season grazing, and early-mid-season grazing. We found that only 1% of samples contained slender wild oats in the Roundup sprayed plots. Plots grazed every 20 cm resulted in 59% of samples containing slender wild oats. Over 90% of samples in the control, early season graze, and early + mid-graze contained slender wild oats. Frequency of soft chess was similar to slender wild oats (Table 3.3).

Subterranean clover (*Trifolium subterraneum* L.) did not differ significantly in any of the treatments. This was due to poor stand establishment. Subterranean clover was chosen to reseed these plots because it is a good forage species and has been successfully established in the area. Since subclover has similar patterns of initial growth as barb goatgrass, it may make it more difficult to establish this species in areas infested with barb goatgrass.

Barb Goatgrass Control With Glyphosate (Roundup)

Percentage of vegetative cover differed ($P<0.0001$) between all plots and between all treatments (Table 3.4). The difference between plots is due to the difference in the amount of dead material at each site. Two of the plots had much more dead material, mainly goatgrass, whichmay have decreased the amount of Roundup that contacted the plant leaves. The higher concentration of

Table 3.4. Mean Cover and Mean Above Ground Dry Phytomass on Glyphosate (Roundup) Plots.

Parameter	Control	Roundup @ 0.28 kg a.i./ha	Roundup @ 0.56 kg a.i./ha	Roundup @ 1.12 kg a.i./ha
Percent Cover	83.4 a*	57.4 b	39.6 c	31.9 d
Dry Phytomass (g/m^2)	403.1 a	176.7 b	131.8 c	118.2 c

* Means within a row that are not different (P = 0.05) are followed by the same letter(s).

Roundup, 1.12 kg ai/ha (1.0 lb. ai/A), showed different ($P=0.05$) percentages of cover compared to plots sprayed at all other rates. The amount of cover was reduced ($P<0.05$) after the plots had been sprayed with all three Roundup concentrations but best control was achieved at the highest rate (Table 3.5). The average percent cover for control plots was 83%, 0.28 kg ai/ha (0.25 lb. ai/A) was 57%, 0.56 kg ai/ha (0.50 lb. ai/A) was 39%, and 1.12 kg ai/ha (1.00 lb. ai/A) was 31%. The frequency of barb goatgrass was reduced by Roundup application (Table 3.5).

Total dry weight phytomass (g/m^2) differed ($P<0.0001$) between plots and treatments (Table 3.4). The control treatment had a higher dry weight phytomass and differed ($P<0.0001$) from all rates of Roundup. The rate of 0.28 kg ai/ha (1.0 lb. ai/A) differed ($P<0.05$) from 0.56 kg ai/ha (0.50 lb. ai/A) and 1.12 kg ai/ha (1.00 lb. ai/A). The rate of 0.56 kg ai/ha (0.50 lb. ai/A) did not differ ($P<0.05$) from 1.12 kg ai/ha (1.00 lb. ai/A).

Roundup is able to significantly decrease the amount of barb goatgrass. Other desirable species such as soft chess did not show any treatment effect. It may be beneficial to reseed barb goatgrass infested areas after chemical control with a non-selective herbicide such as glyphosate. This would halt seed production of the barb goatgrass plants establishing that season and possibly result in remaining seed being outcompeted for nutrients by more aggressive and desirable perennial grasses. It was suggested by Crampton (1974) that reseeding with hardinggrass

(*Phalaris tuberosa* L.) and clovers (*Trifolium spp.*) and applying fertilizers may reduce goatgrass density. More work needs to be completed in this area.

Table 3.5. Frequency of Plants Found on the Glyphosate (Roundup) Plots. Mean plant frequency at the end of the growing season (1993) on the glyphosate (Roundup) plots at the Hopland Field Station, Hopland, California.

Species	Control	Roundup @ 0.28 kg ai/ha	Roundup @ 0.56 kg ai/ha	Roundup @ 1.12 kg ai/ha
Barb Goatgrass	98.6 a*	72.0 ab	52.6 bc	31.3 c
Soft Chess	9.0 a	24.0 a	33.3 a	19.0 a
Medusahead Rye	0.0 a	0.0 a	0.0 a	0.0 a
Slender Wild Oat	1.3 a	0.3 b	0.0 b	0.0 b
Subterranean Clover	0.0 a	0.0 a	3.0 a	4.0 a
Filaree spp.	0.0 a	0.0 a	0.0 a	0.0 a
Dogtail	0.0 a	0.6 a	0.0 a	0.3 a
Hairgrass	4.0 a	0.6 a	1.0 a	0.0 a
Turkey Mullein	1.0 a	15.0 a	6.3 a	25.3 a
Common Centaury	5.6 a	17.0 a	28.6 a	0.0 a
Lamarck's Bedstraw	0.0 a	0.0 a	0.0 a	0.0 a
Gastridium	6.0 b	28.6 ab	26.3 ab	48.0 a
Salsify	15.0 a	18.0 a	26.0 a	6.0 a
Chickweed	0.0 a	0.0 a	0.0 a	0.0 a

* Means within a row that are not different (P = 0.05) are followed by the same letter.

Conclusions

These results suggest that high intensity/short duration grazing regimes throughout the growing season help increase barb goatgrass density. Treatments consisting of heavy grazing multiple times throughout the season showed a higher goatgrass density than those grazed fewer times or not at all.

Roundup treatments reduced frequency, cover, and biomass of goatgrass. The highest concentration of Roundup tested, 1.12 kg ai/ha (1.0 lb. ai/A), was found to be most effective. At this point, it may be best for land managers to chemically treat barb goatgrass infestations and then reseed with a perennial grass/clover mixture. More work needs to be completed on desirable species that are able to replace barb goatgrass.

CHAPTER 4

INVASION OF BARB GOATGRASS INTO GRAZED AND UNGRAZED AREAS

Abstract

We investigated the rate of barb goatgrass invasion into two neighboring pastures, one grazed by domestic livestock and the other grazed only by wildlife. Barb goatgrass increased in density in both sheep grazed ("grazed") and wildlife grazed ("ungrazed") pastures. The sheep grazed pasture had more goatgrass plants further away from the fenceline and goatgrass distribution was shown to be patchy. The ungrazed pasture showed more plants near and fewer further from the fenceline. In the grazed pasture, there was a mean density of goatgrass plants of 189.4 plants/m^2 in 1992 and 237.8 plants/m^2 in 1993, an increase of 125% where no control measures have been attempted. The ungrazed pasture showed an increase in goatgrass density as well with a mean of 4.3 plants/m^2 in 1992 and 11.8 plants/m^2 in 1993, an increase of 274%.

Key Words: Barb Goatgrass, Sheep Grazing, Weed Spread, *Aegilops triuncialis* L.

Introduction

Barb goatgrass (*Aegilops triuncialis* L.) is an undesirable alien weed that causes serious mechanical harm to animals in its late phenological stages because of its sharp, barbed awns (Talbot and Smith,1929). The awns of barb goatgrass may be carried in the coats of animals, both domestic and wild, or may be carried by other means such as wind or water (Talbot and Smith,1929).

The spread of the noxious weed, barb goatgrass, may be influenced by domestic livestock grazing. The rate at which barb goatgrass invades into grazed pastures compared to ungrazed pastures is important background information when developing successful weed control programs.

We investigated the rate of barb goatgrass invasion into two neighboring pastures, one grazed by domestic livestock and the other grazed only by wildlife. We were interested in gathering background information on the rate of spread of barb goatgrass.

Materials and Methods

Expansion of barb goatgrass was determined from five 22.5 m (75 ft.) line transects, 4.5 m (15 ft.) apart, placed parallel to a fenceline dividing the two pastures. The "ungrazed" pasture has been grazed by wildlife but not domestic livestock for more than forty years. Vehicular and human traffic is minimal. Improved grazing management has been practiced in the sheep grazed pasture. Barb goatgrass plants were counted in a 0.093 m^2 (1 $ft.^2$) square quadrat regularly placed every 0.9 m (3 ft.) along the transects.

Data Analysis

Barb goatgrass density was analyzed using a General Linear Model (GLM) procedure and a Fisher's Protected Least Significant Difference (LSD) test was performed to identify significant differences. All statistical analyses were performed using SAS procedures (Statistical Analysis Systems Institute, 1988).

Results and Discussion

Barb goatgrass density differed ($P=0.0019$) with distance from the fenceline. The pasture with grazing, wildlife, and vehicular traffic ("grazed" pasture) had more goatgrass plants further away from the fenceline yet goatgrass distribution was shown to be patchy. The biological area ("ungrazed" pasture) showed more plants near and fewer further from the fenceline (Figure 4.1). Grazed and ungrazed pastures differed ($P=0.0001$) in their density of goatgrass plants. The density of goatgrass differed ($P=0.0220$) from 1992 to 1993 (Figure 4.1). In the grazed pasture, there was a mean density of goatgrass plants of 189.4 plants/m^2 (17.6 plants/ft^2) in 1992 and 237.8 plants/m^2 (22.1 plants/$ft.^2$) in 1993. This shows an increase of barb goatgrass plants of 125% in areas where no control measures have been attempted. The ungrazed pasture showed an increase in goatgrass density as well with a mean of 4.3 plants/m^2 (0.4 plants/$ft.^2$) in 1992 and 11.8 plants/m^2 (1.1 plants/$ft.^2$) in 1993 or an increase of 274%. These data suggest that barb goatgrass does indeed spread by means other than grazing of domestic livestock. Grazing may, however, enhance the spread of barb goatgrass by reducing competition from associated species, and by causing barb goatgrass to tiller and, therefore, produce more seed.

Conclusions

These results indicate that barb goatgrass can invade both grazed and ungrazed pastures. Animal movements play a major role in the spread of barb goatgrass. Both domestic stock and wildlife can be carriers of the seeds. Animal handling activities such as trailing, vehicular movement, checking pastures, and water hauling all tend to increase the rate of spread.

Pastures that are not open to vehicular traffic or livestock will most likely be invaded from their perimeters. Detection and control efforts should focus on boundry areas.

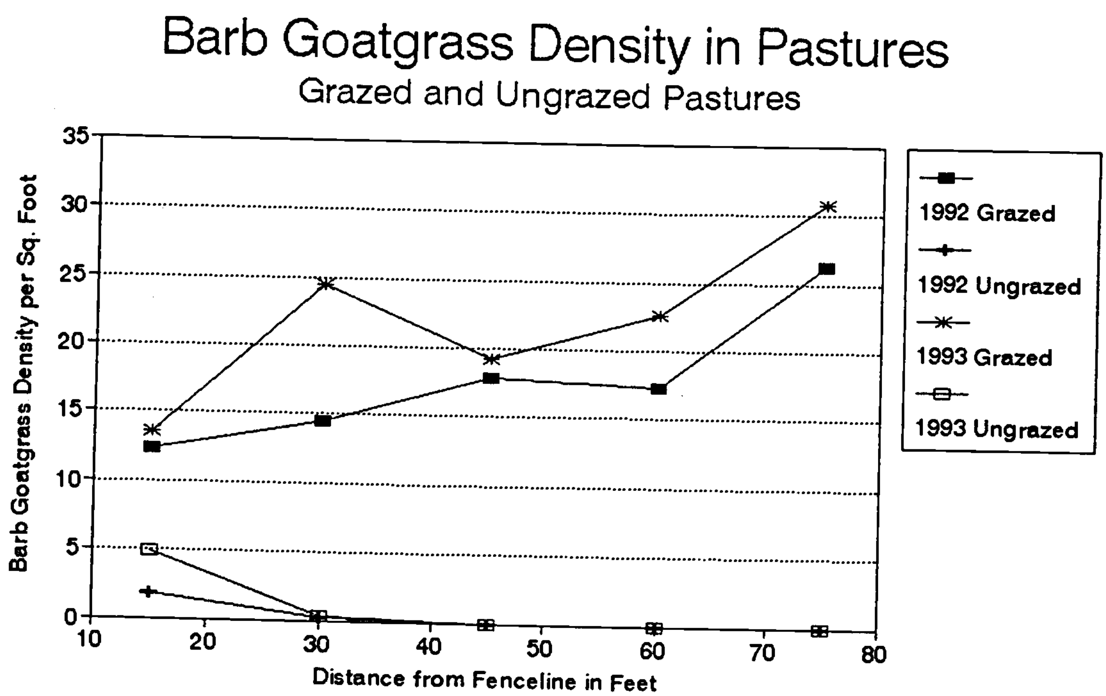


Figure 4.1. Barb Goatgrass Density in Grazed and Ungrazed Pastures.

BIBLIOGRAPHY

Barbe, G.D. 1993. Weed Detection Manual for the State of California. State of California Dept. of Food and Agriculture. Sacramento, CA.

Buman, R.A., D.R. Gealy and A.G. Ogg, Jr. 1988. Inhibition of net photosynthesis in downy brome and jointed goatgrass protoplasts by metribuzin and its ethylthio analog. Proc. Western Soc. Weed Sci. 41:76.

Crampton, B. 1974. Grasses in California. U.C. Press, Berkeley and Los Angeles, California. The Regents of University of California. p. 50.

Fenster, C.R., H.I. Owens and F.E. Westbrook. 1980. Fact sheet jointed goatgrass how to control it. USDA Science and Education Administrtion, Office of Governmental Public Affairs, Washington, D.C. 20250.

Fleming, G.F. and F.L. Young. 1986. Effect of winter wheat (*Triticum aestivum* planting geometry on the interference of jointed goatgrass (*Aegilops cylindrica*). West. Soc. Weed Sci. Proc. 39:175-176.

George, M.R. 1991. Personal communication. Range Extension Specialist, Univ. of Calif., Davis, CA 95616.

George, M.R. 1991. Goatgrass control study notes. Unpublished information.

Kennedy, P.B. 1928. Goatgrass or wild wheat (*Aegilops triuncialis*). Journal of the American Soc. of Agronomy. 20:12.

McCaskill. 1977. California Noxious Weeds. State of Calif., Dept. of Food and Agriculture, Division Plant Industry.

Miller, S.D. and J.M. Krall. 1988. Jointed goatgrass control in winter wheat. West. Soc. Weed Sci. Res. Prog. Rep. 38:240-243.

Munz, P.A. and D.D. Keck. 1975. A California Flora. Univ. of Calif. Press Ltd., Berkeley and Los Angeles. pp. 49-50.

O'Bryan, K.A. and T.F. Peeper. 1985. Investigations of chlortoluron and metoxuron for cheat control and phytotoxicity to winter wheat. Southern Weed Sci. Soc. Proc. 38:105.

Rydrych, D.J. 1986. Ethyl metribuzin for jointed goatgrass control in winter wheat. West. Soc. Weed Sci. Proc. 39:244.

SAS Institute Inc. 1988. SAS/STAT User's Guide. Release 6.03. Edition. Cary, N.C.

Talbot, M.W. and L.S. Smith. 1929. The goatgrass situation in California. USDA annual report.

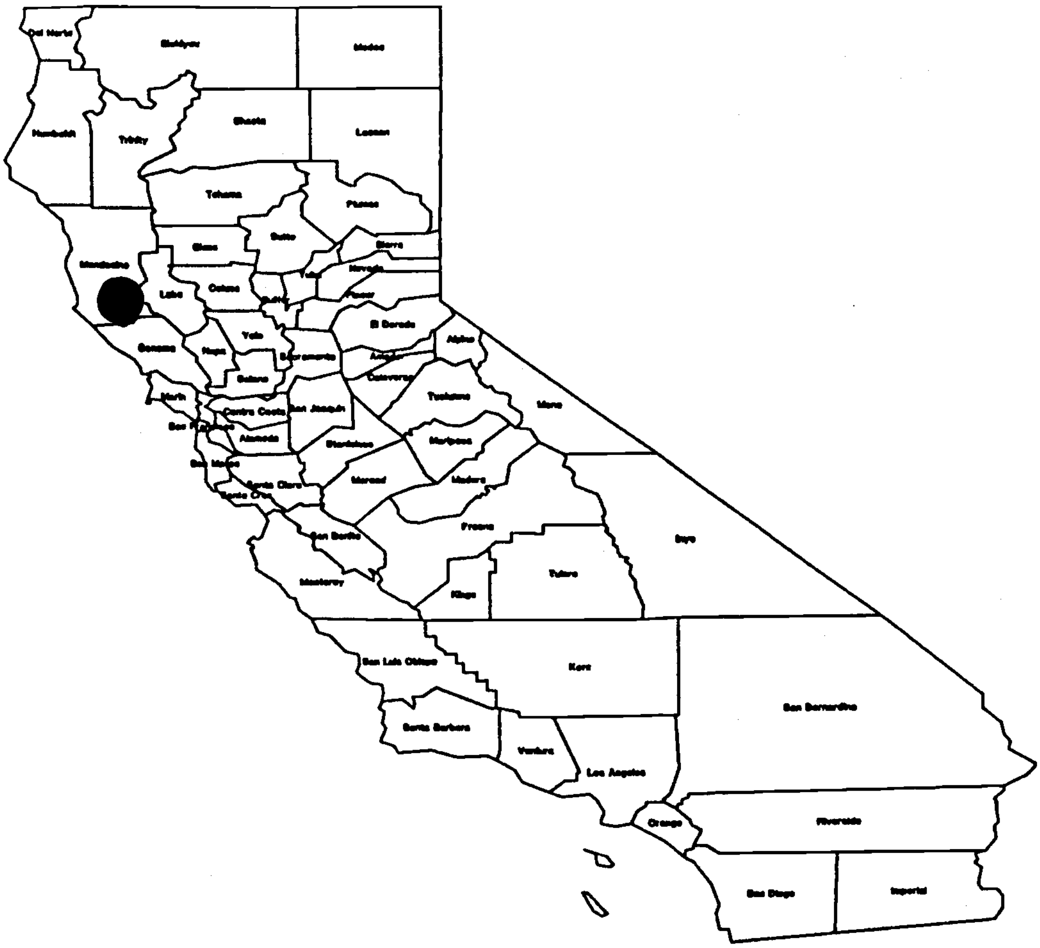
Westra, P. 1988. Use of ethyl-metribuzin for selective control of volunteer rye (*Secale spp.*), downy brome (*Bromus tectorum*), and jointed goatgrass (*Aegilops cylindrica*) in winter wheat (*Triticum aestivum*). Proc. West. Soc. Weed Sci. 41:145-146.

Whitson, T.D., R.D. William, R. Parker, O.G. Swan, and S. Dewey. 1985. Pacific Northwest Control Handbook. p. 32. Extension Services, Oregon State Univ., Washington State Univ., and Univ. of Idaho. Oregon State Univ., Corvallis Oregon 97331.

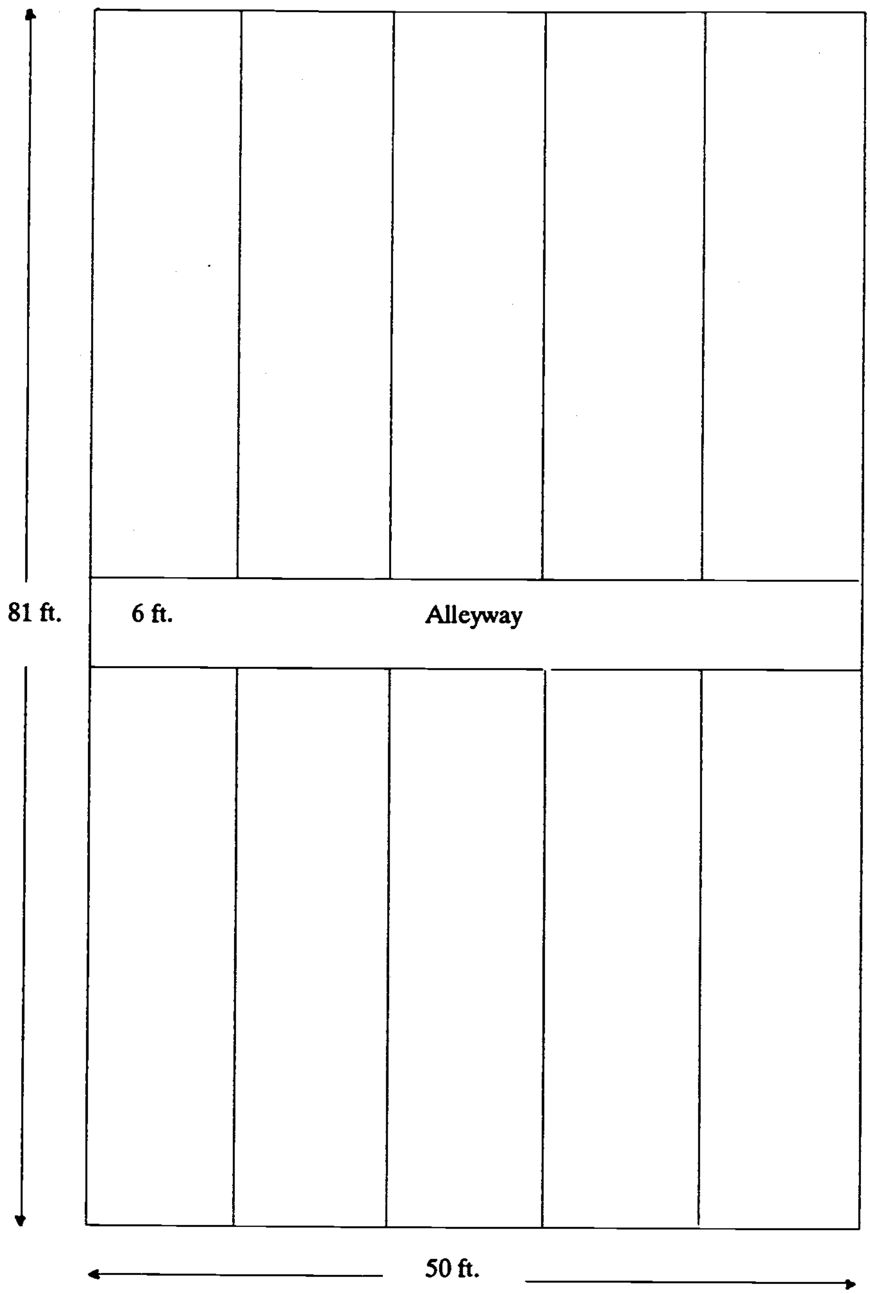
Willis, B.D., J.O. Evans and S.A. Dewey. 1988. Effects of temperature and flaming on germinability of jointed goatgrass (*Aegilops cylindrica*) seed. Proc. West. Soc. Weed Sci. 41:49-54.

Yenne, S.P. , D.C. Thill and R.H. Callihan. 1986. Jointed goatgrass control in winter wheat. West. Soc. Weed Sci. Res. Prog. Rep. 39:240-243.

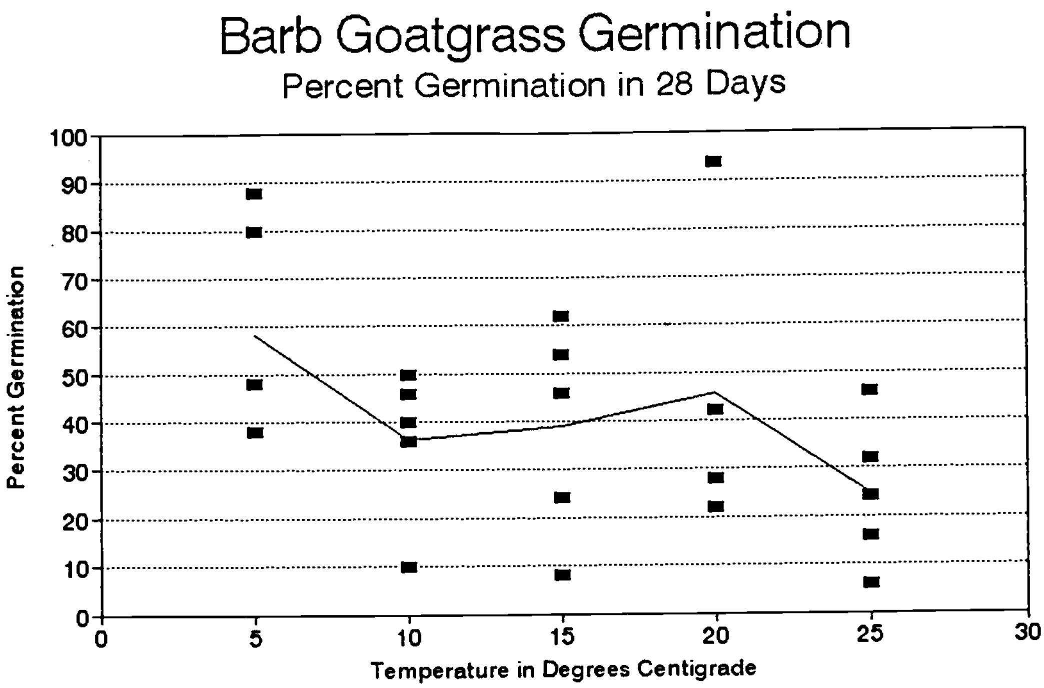
APPENDIX



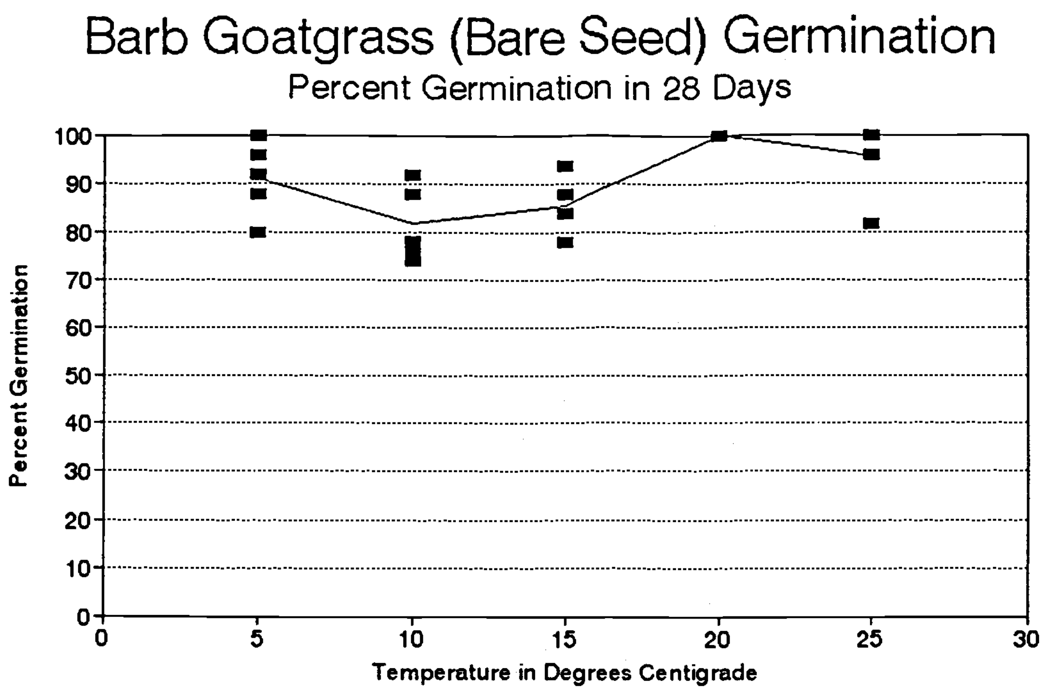
Appendix Figure 1. State Map - Location of the Hopland Field Station in Mendocino County, California.



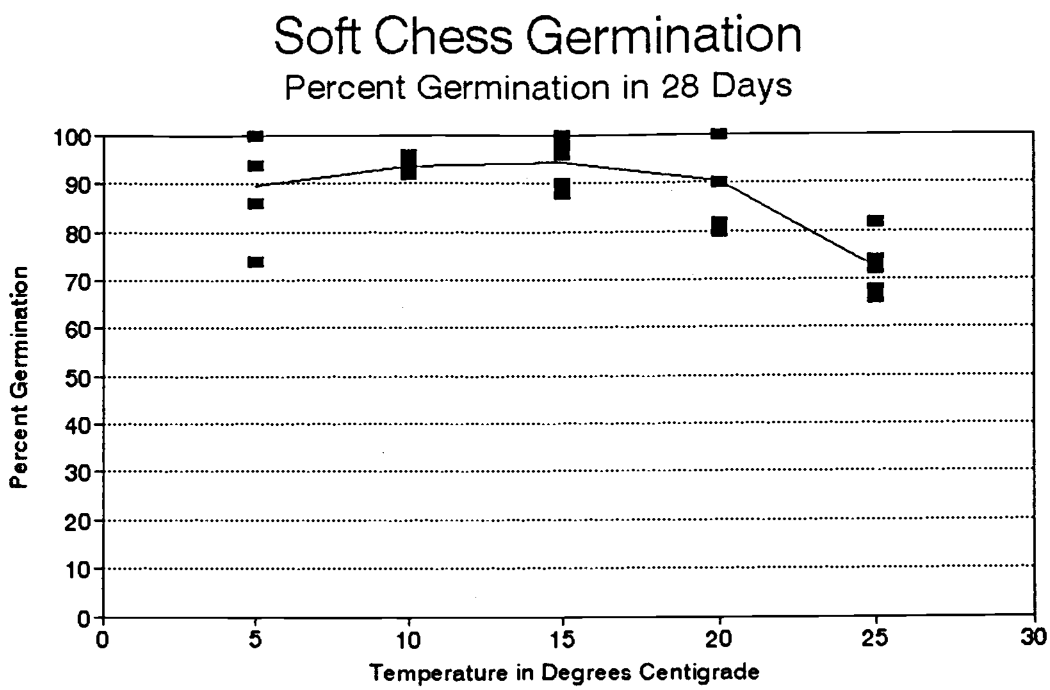
Appendix Figure 2. Experimental Grazing Plot Layout - Hopland Field Station, Hopland, California.



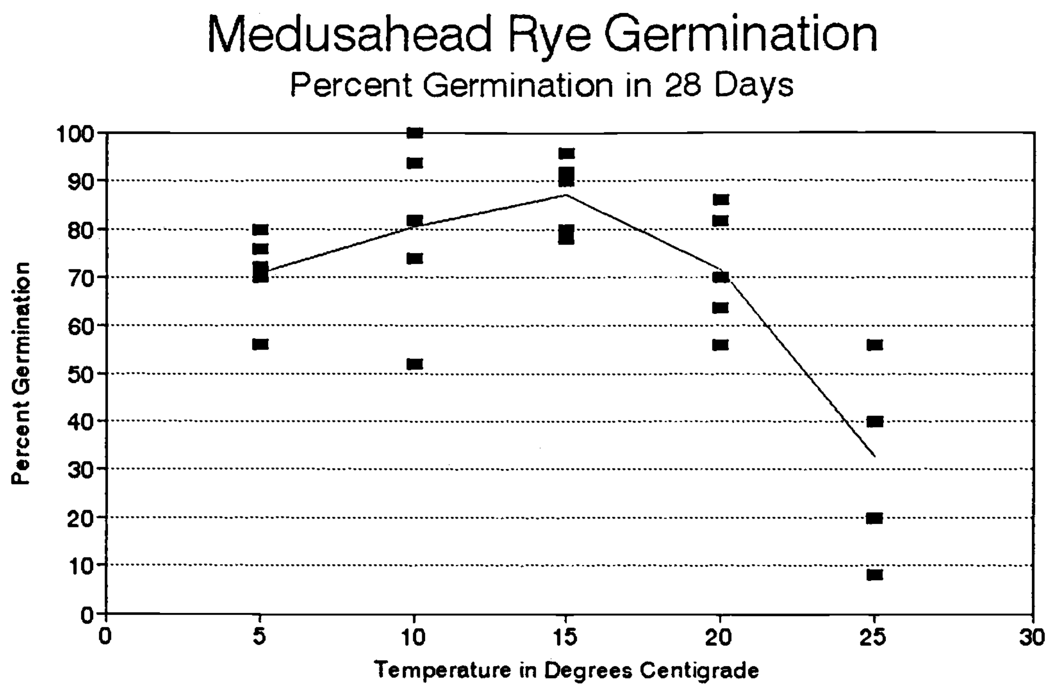
Appendix Figure 3. Percent Germination of Barb Goatgrass in the Spikelet. Percent germination of intact barb goatgrass (*Aegilops triuncialis* L.) at five temperatures.



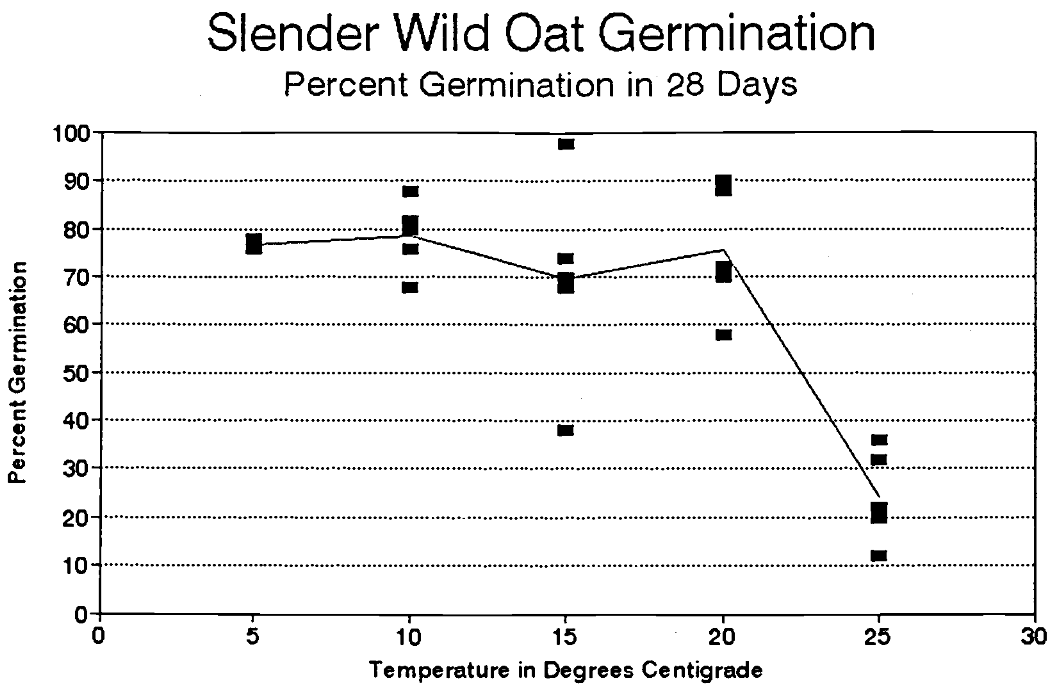
Appendix Figure 4. Percent Germination of Bare Barb Goatgrass. Percent germination of bare barb goatgrass (*Aegilops triuncialis* L.) at five temperatures.



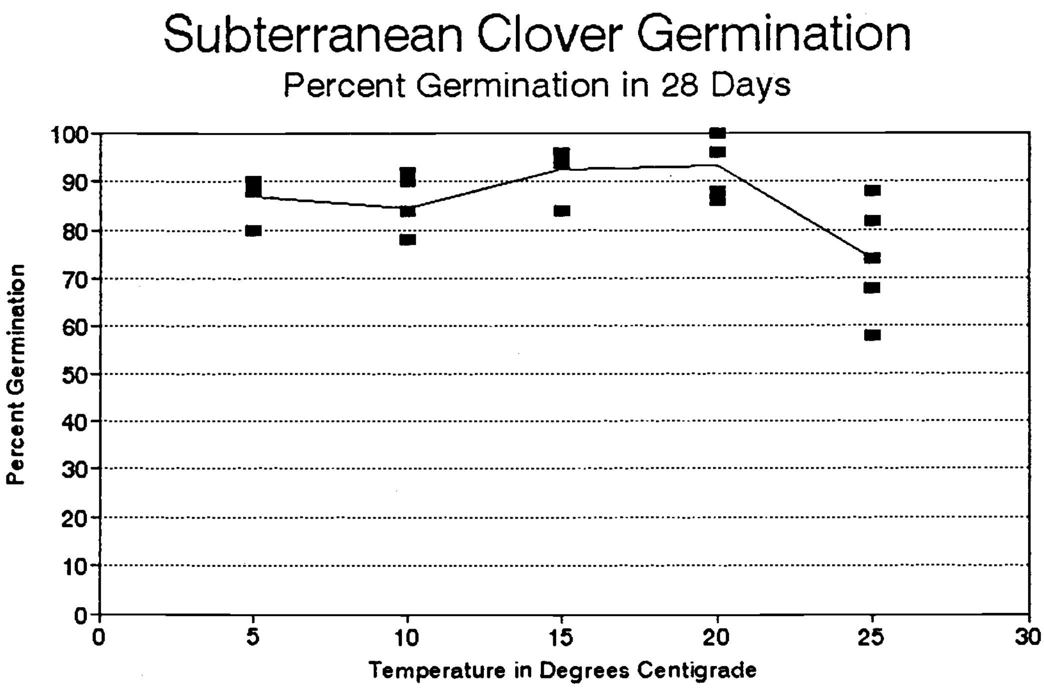
Appendix Figure 5. Percent Germination of Soft Chess. Percent germination of soft chess (*Bromus mollis* L.) at five temperatures.



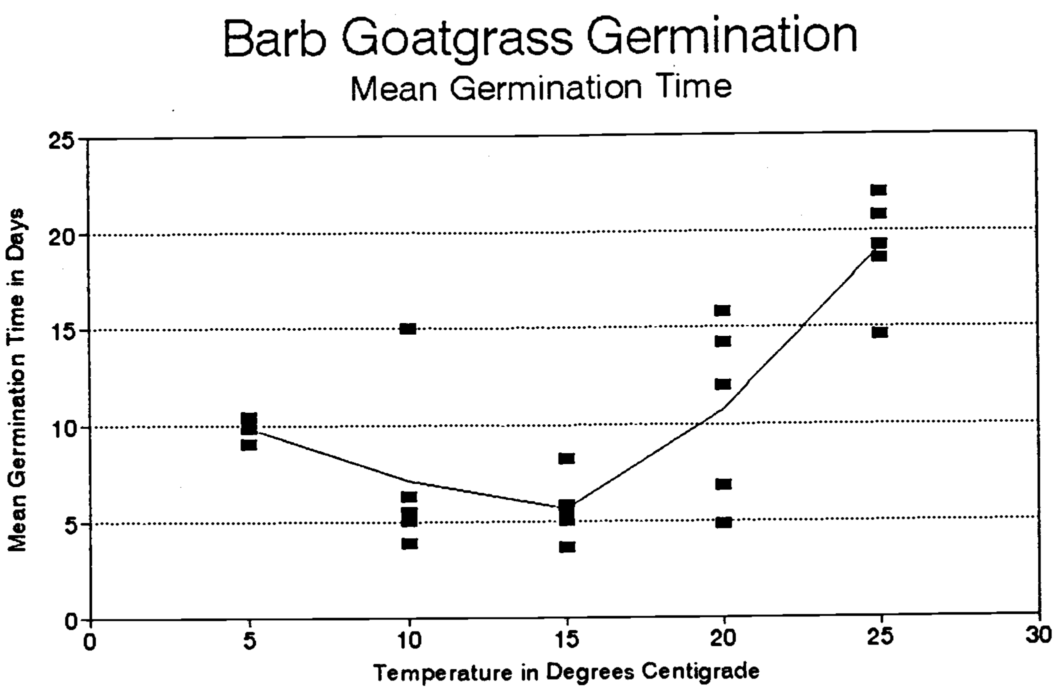
Appendix Figure 6. Percent Germination of Medusahead Rye. Percent germination of medusahead rye (*Taeniatherium caput-medusae* L.) at five temperatures.



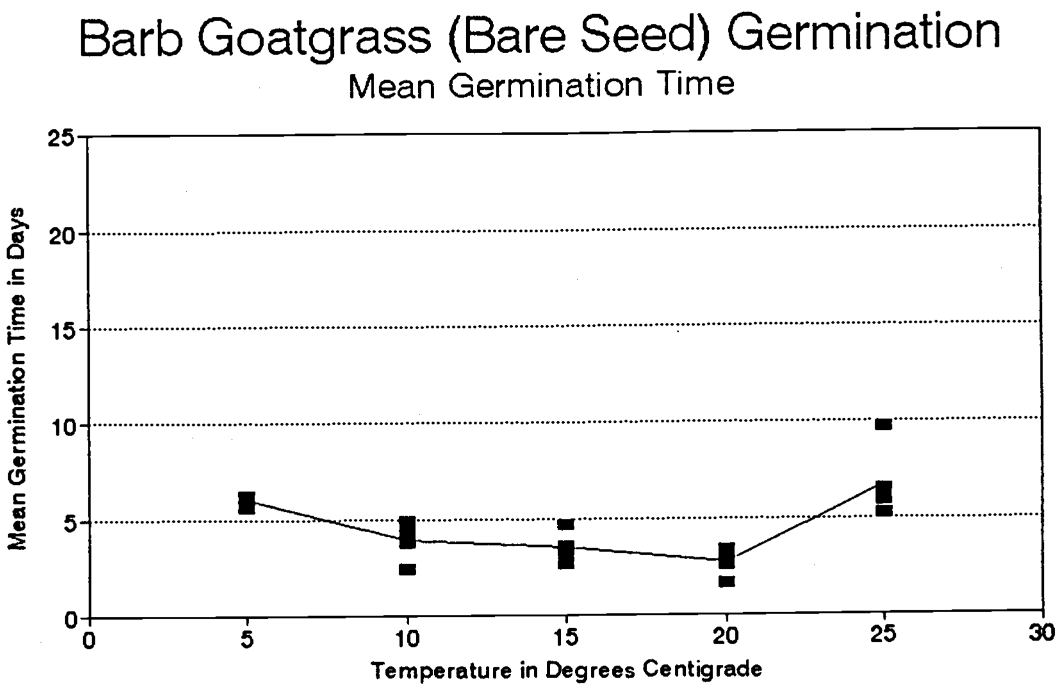
Appendix Figure 7. Percent Germination of Slender Wild Oats. Percent germination of slender wild oats (*Avena barbata* Link.) at five temperatures.



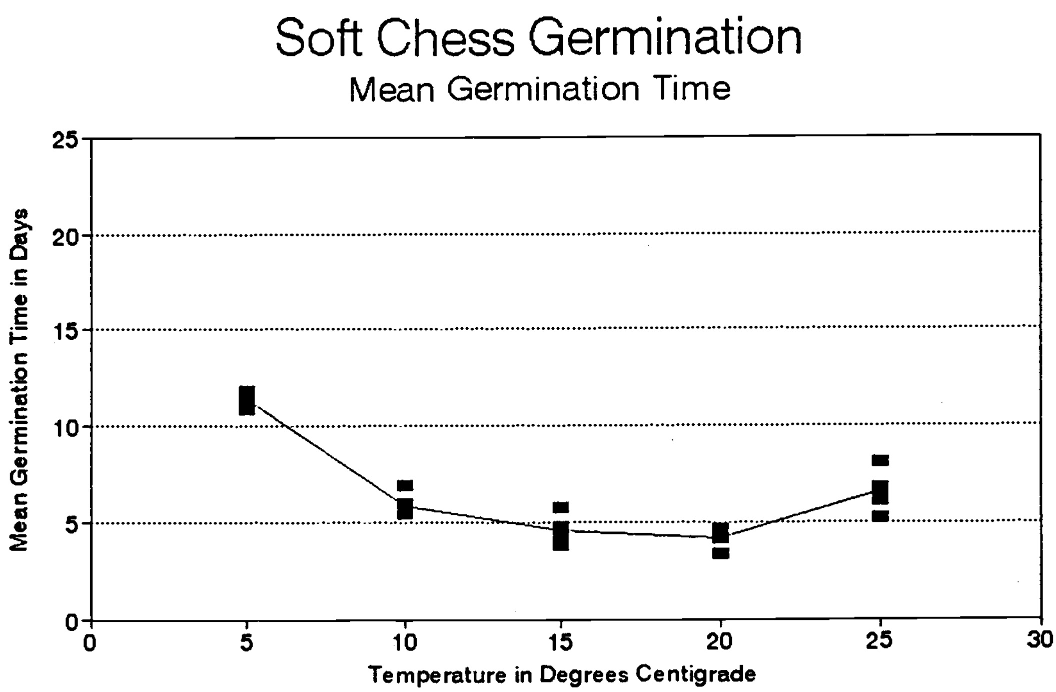
Appendix Figure 8. Percent Germination of Subterranean Clover. Percent germination of subterranean clover (*Trifolium subterraneum* L.) at five temperatures.



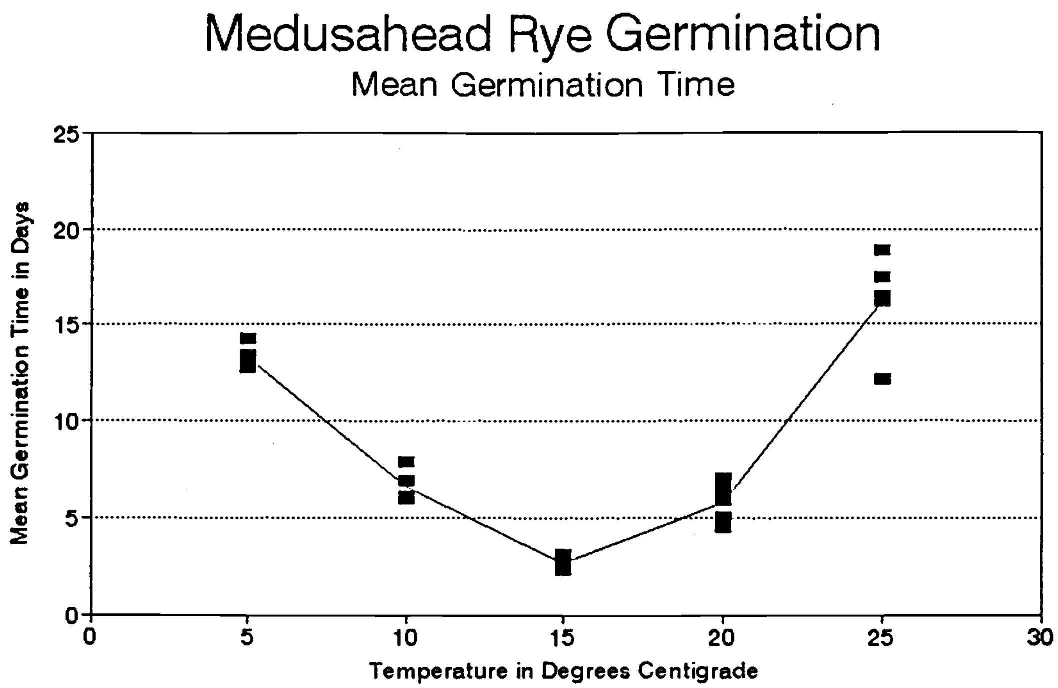
Appendix Figure 9. Average Germination Time of Intact Barb Goatgrass. Average germination time in days of barb goatgrass (*Aegilops triuncialis* L.) seed in the spikelet at five temperatures.



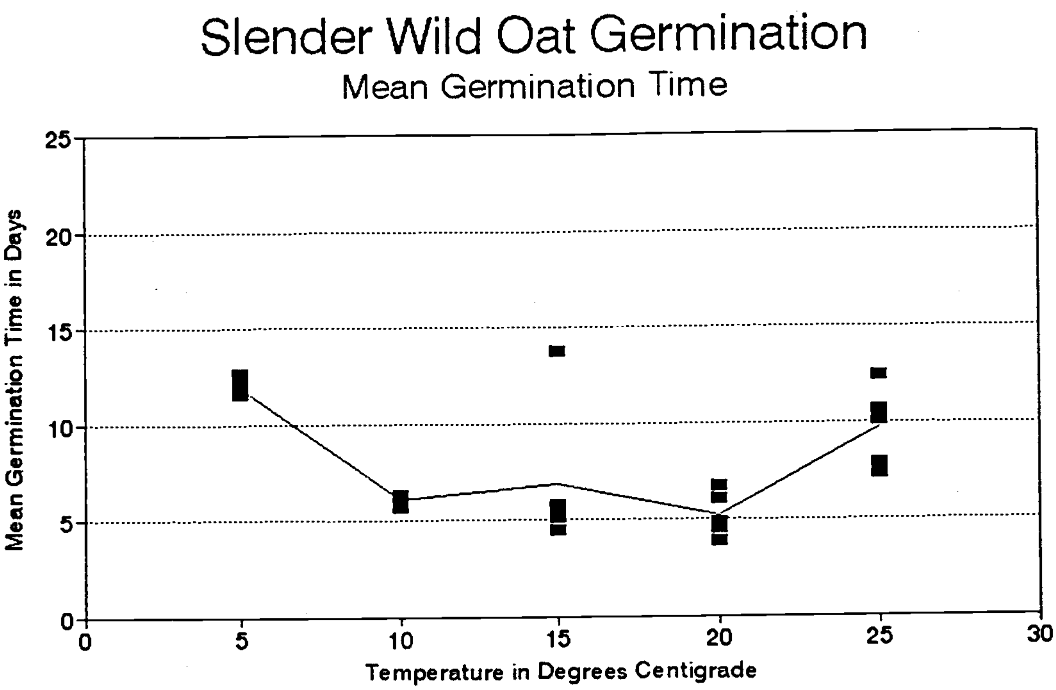
Appendix Figure 10. Average Germination Time of Bare Barb Goatgrass. Average germination time in days of bare barb goatgrass (*Aegilops triuncialis* L.) seed at five temperatures.



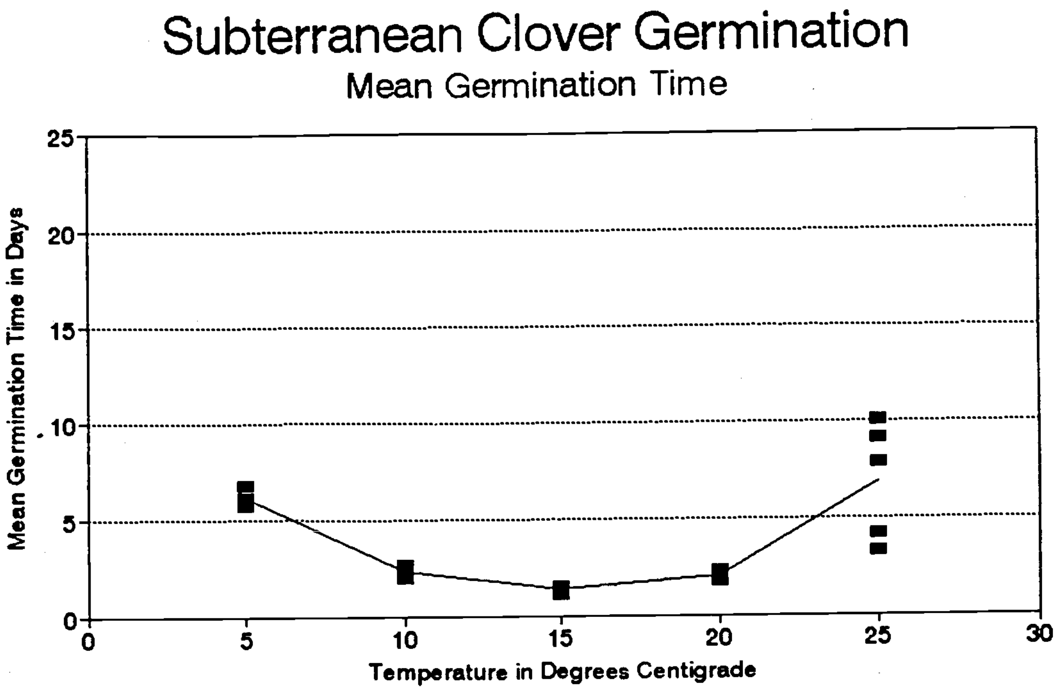
Appendix Figure 11. Average Germination Time of Soft Chess. Average germination time in days of soft chess (*Bromus mollis* L.) seed at five temperatures.



Appendix Figure 12. Average Germination Time of Medusahead Rye. Average germination time in days of medusahead rye (*Taeniatherium caput-medusae* (L.) Nevski) seed at five temperatures.



Appendix Figure 13. Average Germination Time of Slender Wild Oats. Average germination time in days of slender wild oats (*Avena barbata* Link.) seed at five temperatures.



Appendix Figure 14. Average Germination Time of Subterranean Clover. Average germination time in days of subterranean clover (*Trifolium subterraneum* L.) seed at five temperatures.

Appendix Table 1. Seed Dimensions. Dimensions of 50 randomly selected barb goatgrass seeds collected at the Hopland Field Station.

Goatgrass Seed Dimensions			
Parameter	Weight grams	Length mm	Width mm
Mean	0.0121	7.65	2.05
Standard Deviation	0.0042	0.75	0.20
Maximum	0.0192	9.23	2.53
Minimum	0.0040	5.87	1.64
Maximum/minimum	4.80	1.57	1.54

Appendix Table 2. Climatic table of monthly precipitation, maximum, and minimum temperatures from the Hopland Field Station weather station at Headquarters (elevation 800 ft.).

	Precipitation (in)			Mean Maximum Temperature (F)			Mean Minimum Temperature (F)		
	1991	1992	1993	1991	1992	1993	1991	1992	1993
Jan	0.65	3.37	13.04	57.3	54.8	51.7	31.4	32.6	35.2
Feb	3.04	9.06	7.75	66.9	62.0	56.7	39.1	41.4	36.8
Mar	15.63	4.78	2.89	56.6	65.3	66.8	37.5	42.2	44.1
Apr	0.75	1.05	2.52	66.6	73.3	66.2	39.9	43.7	41.3
May	0.44	0.23	3.70	72.5	85.1	72.2	44.0	49.1	47.4
Jun	0.54	1.07	0.70	82.5	85.5	82.1	47.5	53.0	50.0
Jul	0.13	0.00	0.00	93.2	89.9	89.0	54.7	53.9	52.2
Aug	0.02	0.00	0.00	88.8	95.6	91.4	51.9	53.2	52.2
Sep	0.01	0.01	0.00	93.8	89.1	90.2	51.3	49.7	48.1
Oct	1.82	3.70	0.79	85.5	80.1	79.1	47.4	47.2	46.6
Nov	1.88	1.23	2.27	64.3	62.9	64.1	38.5	38.7	34.6
Dec	3.17	12.38	4.82	55.1	51.7	52.8	32.5	34.1	33.5
Total	28.02	36.88	38.48						

Appendix Table 3. Climatic table of monthly precipitation, maximum, and minimum temperatures from the Hopland Field Station weather station at Coon Lake (elevation 1700 ft.).

	Precipitation (in)			Mean Maximum Temperature (F)			Mean Minimum Temperature (F)		
	1991	1992	1993	1991	1992	1993	1991	1992	1993
Jan	0.69	3.84	11.27	58.3	57.9	54.5	41.4	42.2	40.7
Feb	3.16	8.55	7.63	64.0	60.2	53.5	46.2	46.2	40.2
Mar	15.69	4.76	3.72	52.5	62.3	62.5	38.4	45.5	46.1
Apr	1.07	1.29	2.04	62.8	69.7	62.6	41.7	48.6	43.9
May	0.65	0.47	4.07	69.3	83.5	67.4	45.4	55.2	48.4
Jun	0.79	1.15	0.69	79.7	82.0	79.0	50.3	56.1	53.9
Jul	0.00	0.00	0.00	87.7	88.6	85.6	59.3	59.6	57.8
Aug	0.02	0.00	0.00	84.6	93.1	87.0	56.3	63.7	59.3
Sep	0.00	0.03	0.00	91.5	86.5	87.2	64.1	59.1	59.2
Oct	2.02	4.03	0.25	83.3	73.6	77.0	60.0	53.7	56.1
Nov	2.09	1.15	0.52	66.6	64.2	64.9	48.6	46.2	45.5
Dec	3.28	14.76	0.48	58.9	54.4	56.3	44.2	39.8	41.8
Total	29.46	40.03	30.67						

Appendix Table 4. Species List. Species observed growing on the study plots.

GRASSES AND GRASSLIKE	
Aegilops triuncialis	Barb Goatgrass
Avena fatua	Slender Wild Oat
Briza maxima	Rattlesnake Grass
Bromus mollis	Soft Chess
Carex spp.	Carex
Cynosurus echinatus	Dogtail
Deschampsia spp.	Hairgrass
Hordeum spp.	Foxtail Barley
Taeniatherum caput-medusae	Medusahead Rye
OTHER PLANTS	
Centaureum erythrea	Common Centaury
Eremocarpus setigerus	Turkey Mullein
Erodium cicutarium	Filaree
Filago gallica	Herba Impia
Galium divericatum	Lamark's Bedstraw
Gastridium ventricosum	Gastridium
Navaretia spp.	Navaretia
Medicago spp.	Burclover
Pteridium spp.	Fern
Quercus spp.	Oak
Rumex crispus	Curly Dock
Stellaria media	Chickweed
Tragopogon dubius	Salsify
Trifolium hirtum	Rose Clover
Trifolium subterraneum	Subterranean Clover
Vicia americana	Vetch