AN ABSTRACT OF THE THESIS OF

Carlos Enrique Rojas-Calvo for the degree of Master of Science in Crop Science presented on May 4, 1990.

Title: Effect of Seed Burial and Vernalization on Germination and Growth of Bromus carinatus and its Control With Several Herbicides

Abstract approved: Redacted for Privacy

Myron Shenk

California brome (Bromus carinatus Hook & Arn), is considered an important weed infesting wheat and grass seed fields in the Willamette Valley of Oregon. Field and greenhouse experiments were conducted to study some biological aspects to develop more efficient management strategies.

A field experiment was conducted to determine the effect of depth (0 to 30 cm) and duration (1 to 11 months) of burial on germination, viability, and soil longevity of seed. Seed depletion was directly related to depth and duration of seed burial. Surface-sown seed germinated gradually, reaching 81% after 7 months. Buried seed germinated rapidly. Less than 3% of the initial population remained ungerminated after 1 month at all depths. Seed loss at depths of 10 to 30 cm was primarily due to in situ

germination, with little effect from induced or enforced dormancy. Persistence of surface-sown seed was due to both enforced and induced dormancy, with enforced dormancy being the more important mechanism of seed persistence. Highest degree of enforced dormancy (34%) was at 1 month, decreasing after 3 months. Properly timed tillage can be important for effective control since tillage increases germination, reducing soil persistence.

Greenhouse experiments were conducted to determine if imbibed seed vernalization promoted plant flowering. In the first experiment, cold treatment (5 C) of 10, 15, and 20 days reduced the vegetative phase. Flowering was absent in plants from seed receiving 5 days of cold and in unvernalized plants after 96 days, when this experiment was terminated. Plants from seeds vernalized for 20 days flowered within 36 days after transfer from cold treatment to the greenhouse. Number of culms per plant and shoot dry weight were highest on unvernalized plants and plants vernalized as imbibed seed for 5 days. Lengthening the vernalization period from 10 to 20 days decreased the total seed dry weight from 18.78 to 15.02 g. The ratio of total seed dry weight to total shoot dry matter was highest for plants vernalized as imbibed seed for 20 days. In the second experiment, only plants from seed vernalized for 20 days flowered within 109 days after transfer to the greenhouse, whereas plants from seed vernalized for 0, 5, 10, and 15 days did not flower. There was not a statistical difference for number of culms per plant. Plant height was consistent in all treatments, with the exception of plants vernalized for 20 days, which were taller than plants of the other treatments. Highest total shoot dry weight was observed on plants from seed vernalized for 15 or 20 days.

The effect of differential soil placement of cinmethylin (exo-1-methyl-4-(methylethyl)-2-[(2-methylphenyl)methoxy]-7oxabicyclo[2.2.1] heptane), diclofop ((±)-2-[4-(2,4-dichlorophenoxy)phenoxy]-propanoic acid), triallate (S-(2,3,3-trichloro-2-propenyl) bis(1-methylethyl)carbamothioate), and trifluralin (2,6-dinitro-N,N-dipronyl-4(trifluoromethyl) benzenamine) on California brome control was measured in the greenhouse, at a rate of 0.93, 1.8, 1.34, and 1.07 ppm, respectively. Cinmethylin had the greatest affect on plant height and plant weight, reducing both significantly. California brome plant height and dry weight were not affected by herbicide placement. Seedlings treated with diclofop with shoot plus root exposure differed in plant height from those treated only in the shoot or root zone. Seedlings with shoot exposure to triallate did not differ in height or dry weight from plants treated in the root or shoot plus root zone. Root exposure to trifluralin reduced height and dry weight less than did shoot or shoot plus root exposure.

Effect of Seed Burial and Vernalization on Germination and Growth of *Bromus carinatus* and its Control With Several Herbicides

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IN DEDICATION TO:

Patricia, my wife, for all her love,
moral support, patience, and help.
My parents Hernán and Eulalia, who love
and believe in their children and in education.

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EFFECT OF SEED BURIAL AND VERNALIZATION ON GERMINATION AND GROWTH OF *BROMUS CARINATUS* AND ITS CONTROL WITH SEVERAL HERBICIDES

INTRODUCTION

The genus *Bromus* comprises about 60 species, adapted to cool climates or to regions in which cool seasons prevail during parts of the growing season (Hughes, 1962). Like cereal crops, vegetative growth is produced during the early part of the season and seed is formed in the long days of the early summer. One of the most common, widespread, and variable groups of grass species in Western U.S. is the subgenus *Ceratochloa* of the genus *Bromus*. Perhaps the best known species native to the U.S. are California brome (*Bromus carinatus* Hook & Arn) and Mountain brome (*Bromus marginatus* Ness) (Stebbing and Tobgy, 1944).

California brome, an annual or perennial grass, is native to the Rocky Mountain and Pacific Coast regions of Western U.S. (Hughes. 1962). This species has been reported as a native grass common in roadsides, open woods, and waste places (Le Roy, 1923). California brome has been described as an erect plant, with culms 2 to 4 feet tall. Leaf blades are flat and sheaths are scabrous or covered with soft hairs. The inflorescence is open and 10 to 12 inches long. Spikelets contain 5 to 10 flowers, each of which is 1 to 1½ inches long with awns 1 to 1½ inches long (Crampton, 1960) (Davis, 1952).

California brome has been considered as a valuable forage species. Sampson (1924) and Wheeler (1950) reported California brome as one species of special importance of the numerous valuable forage species in the U.S. Crampton (1968), also mentioned that California brome is often abundant and forms dense stands locally where it becomes a valuable forage grass.

California brome is often confused with mountain brome. Hitchcock (1950), considered mountain brome a form of California brome. Stubbendieck (1986) also mentioned _Bromus marginatus_ as a selective synonym of _Bromus carinatus_. Crampton (1968) suggested that mountain brome is similar to and probably not specifically distinct from _Bromus carinatus_, differing mainly in the strict panicle with short, erect, or ascending branches and usually narrower blades, the sheaths often but not always densely hairy.

In recent years, California brome has become a serious weed problem in many grass seed and cereal crops in the Willamatte Valley of western Oregon (Mueller-Warrant, 1987).

Research presented in Chapter 1 was undertaken to evaluate the effect of depth and duration of seed burial on California brome persistence in soil.

Research in Chapter 2 determined the vernalization requirements for flowering of California brome.

Research in Chapter 3 investigated the effect of cinmethylin, diclofop, trifluralin, and triallate placement on the control of California brome.

Chapter 1. Effect of Depth and Duration of Seed Burial on California brome (Bromus carinatus Hook. and Arn.) Germination.

ABSTRACT

A field experiment was conducted to study the effect of seed depth (0 to 30 cm) and duration (1 to 11 months) of burial on the germination, viability, and deterioration of California brome (Bromus carinatus Hook & Arn). Seed depletion of California brome was directly related to burial depth and duration of seed burial. Surface-sown California brome germinated gradually, attaining its highest germination (80.75%) after 7 months. Buried California brome seed germinated readily, with less than 3% of the initial population ungerminated after 1 month at all depths. Seed depletion was related to seed burial depth. Seed depletion at depths of 10 to 30 cm was mainly due to in situ germination, with very limited influence from induced or enforced dormancy. Surface-sown seed persistence was due to both enforced and induced dormancy, with enforced dormancy being the more important mechanism of persistence. The highest degree (34%) of dormancy was found at 1 month, decreasing significantly after 3 months. Under suitable environmental conditions, tillage can be an important management practice for control of California brome since tillage increases germination, thus reducing seed persistence in the soil.

INTRODUCTION

California brome, which has been described as both an annual and a perennial species of bromegrass, has become a serious weed problem in many crops such as orchardgrass, tall fescue, bentgrass, and wheat in the Willamatte Valley[1] (13). Hughes et al (10), and Stebbing (15) classified California brome as a perennial brome native to the Rocky Mountain and Pacific Coast regions of the western United States. Crampton (3) reported that California brome usually forms dense stands locally where it becomes established. It is characteristic of open oak woodstands and pine forests, dry open woods of foothills, and lower mountain elevations throughout California, Arizona, New Mexico, Idaho, and British Columbia (3, 6, 9).

Control programs in orchardgrass, tall fescue, and winter wheat have been aimed principally at finding a herbicide to selectively control California brome. Attempts have not been successful, however, in part because these species have quiet similar susceptibility to many herbicides. Consequently, alternative control strategies are needed. A better understanding of the biology of California brome could be important in developing more effective control strategies.

[1]M. E. Mellbye, County Extension Agent, Oregon State University, Corvallis, Oregon. Personal communication.

Other brome grass species are reported as important weeds of rangeland and crops in many agricultural regions around the world. Budd (1), Gleichsner (5), Harradine (8) and Morrow and Stahlman (12) reported that under favorable climatic conditions, seed of many of these brome grasses possess low innate dormancy, and germinate quickly in the fall season (17). As brome species become more of a problem in cereal crops, it is important to study seed germination characteristics to better understand field behavior (11).

The objective of this experiment was to determine germination and soil longevity characteristics of California brome and to examine how these characteristics could be utilized to develop more efficient management strategies.

MATERIALS AND METHODS

Mature California brome seed were hand-harvested from a field at the Oregon State University Schmidt Farm, near Corvallis, Oregon, in July 1988. The seed was mechanically cleaned, deawned, and stored at room temperature until use. The seed population was 100% viable with no dormancy when evaluated in August 1988.

Before burial, each group of 100 seeds was placed in 7.5- by 7.5- cm, 113-mesh polypropylene cloth[2] packets that were permeable to water. Packets were buried in a Woodburn silt loam (fine-silty, mixed, mesic Aquultic Argixeroll) at the Oregon State University Hyslop Research Farm near Corvallis, Oregon, on October 10, 1988.

The experimental design was a split-plot replicated in four randomized blocks. Main plots were burial times of 1, 3, 5, 7, 9, and 11 months, and subplots were burial depths of 0, 10, 20, and 30 cm. Each subplot was 0.3 by 0.3 m. Surface sown packets were secured to stakes with a wire to avoid wind disturbance. The experimental area was kept weed-free by hand-pulling and by spraying paraquat (1,1'-dimethyl-4,4'-bypiridinium ion). Surface-sown packets were protected at spraying time by an inverted plastic bowl to prevent paraquat exposure. Total precipitation from October 1,

[2]Tetko Inc., Monterey Park, CA.

1988, to September 15, 1989 was 1156 mm (Figure 1.1). Mean monthly soil temperatures at 10 cm depth ranged from 4.8 to 20.7 C from October 1988 to September 1989 (Figure 1.2).

Seed packets were collected after the intended burial durations and analyzed after air-drying for 48 hours. A modified Schafer and Chilcote model (14) was followed for partitioning of recovered seed (Figure 1.3). The model is: $S = P_{ex} + P_{end} + D_g + D_n$; where S is the total number of California brome seed initially buried, P is the population's persistent portion, and D is the non-persistent portion. California brome persistent population was separated into two parts, seed under enforced dormancy (P_{ex}), and seed under induced or innate dormancy (P_{end}). The non-persistent population was also separated into two parts, seed germinating <u>in situ</u> (D_g), and seed losing viability before germination (D_n). Partitioning of missing seed (difference between number buried at the beginning and number recovered) between <u>in situ</u> germination (D_g) and rotted nonviable (D_n), represented a problem because both germinated and dead seed are subject to degradation by soil microorganisms. Separation between D_g and D_n was done by counting emerged radicles and checking for nonviable seed using 0.1% (w/v) tetrazolium chloride (7).

Germination was determined for seed recovered at the final time period. Seeds were placed in 100-by 100-by 15-mm petri dishes using blotter paper moistened with deionized water. Petri dishes were wrapped with aluminum foil and placed in a growing chamber at 20 C. Germination counts were made after 7 days of incubation. Seeds that germinated in this test were considered as seeds undergoing enforced dormancy (P_{ex}) at recovery time. A tetrazolium test was conducted on seeds that failed to germinate to differentiate between nonviable (D_n) and induced or innate dormancy (P_{end}).

Germination studies were made before starting the burial study with the aim of determining optimum incubation temperature. Seed were placed in petri dishes wrapped with aluminum foil and placed in a growing chamber at five constant temperatures (5, 10, 15, 20, and 25 C) for an 18-day period. Germinated seed were counted every 3 days in fluorescent light at room temperature. Complete germination was attained in 12 days at 15, 20, and 25 C (data not shown).

RESULTS AND DISCUSSION

Prior to initiating this experiment, California brome seed was in a non-dormant stage, with 98% of germination. Most California brome seed should germinate if the environmental conditions are favorable.

Depletion of California brome seed was directly related to depth and duration of burial (Figure 1.4). California brome seed on the soil surface germinated gradually, reaching its highest germination (81%) after seven months. In contrast, buried seed germinated rapidly. One month after burial, only 1-3% of the initial population of buried seed remained ungerminated. One possible reason for the low germination of California brome when it was placed on the soil surface may be photoinhibition of seed germination. However, this is probably not the case since in the growth chamber the seed germinated with or without exposure to light. Another possible reason for the low germination, that seems more probably, is insufficient contact between the seed and soil moisture. The low germination of seed placed in polypropylene bags at the soil surface may have been a function of the use of these bags, combined with very limited moisture in the first two months of this study (Figure 1.1)

In situ germination (D_g) was the most important way by which buried (10, 20, 30 cm) seed were lost from the original population. After 1 month, in situ germination occurred at all burial depths except surface (Figure 1.5). Soil moisture and temperature were generally suitable for germination of California brome seed (Figures 1.1 and 1.2). Nonviability loss of ungerminated seed, mainly rotted nonviable seed (D_n), was less than 2% of the seed population after 7 months (Figure 1.8).

On the other hand, nonviability loss (D_n) and in situ germination for seed on the soil surface were very low up to 7 months and 5 months, respectively (Figures 1.5 and 1.8). After 7 months, nonviability loss (rotted seed) of California brome seed increased substantially, which coincides with the loss of induced dormancy in the initial population. Inadequate seed-soil moisture contact is probably the cause of a relatively low seed germination at the soil surface.

Seed persistence of California brome on the soil surface results principally from enforced (P_{ex}) and induced (P_{end}) dormancy. Enforced dormancy was more prevalent than induced dormancy during the first 5 months. The highest percentage of enforced dormancy (34%) was found at 1 month, decreasing significantly by 3 months (Figure 1.6).

The almost complete absence of induced dormancy of California brome in this experiment is similar to that found with ripgut brome (Bromus rigidus) (5), downy brome (Bromus tectorum) (16), and poverty brome (Bromus sterilis) (4).

For buried seed, enforced and induced dormancy could be considered as an insignificant seed persistence mechanism. In fact, there was nearly a complete lack of seed persistence at any seed burial depth (Figures 1.6 and 1.7).

Elucidation of these germination characteristics is important in understanding the biology and behavior of California brome. Also, knowledge of these characteristics is important when developing other control alternatives.

Because California brome is considered a relatively short-lived plant, with a short period of dormancy when the seed is on the soil surface and almost no dormancy when buried under favorable environmental conditions, properly timed tillage should reduce the soil seed bank in a period of a few years. Additional information on interactions between soil moisture conditions and tillage, and their effects on germination of California brome should be helpful in identifying the most efficient management strategies.

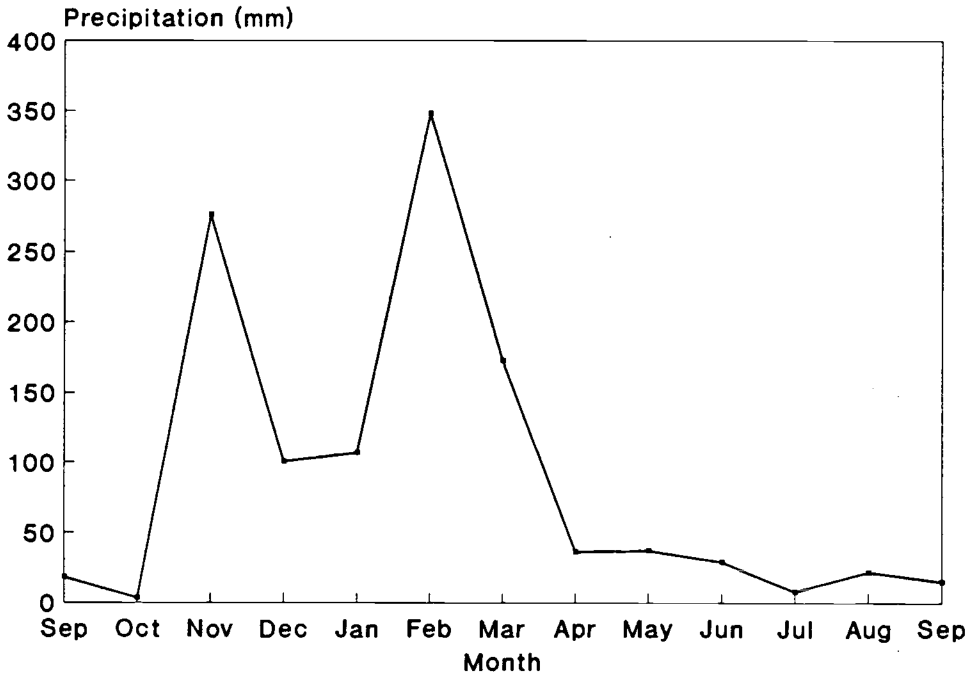

Figure 1.1. Monthly precipitation from September, 1988 to September, 1989, recorded at Hyslop Research Farm near Corvallis, Oregon.

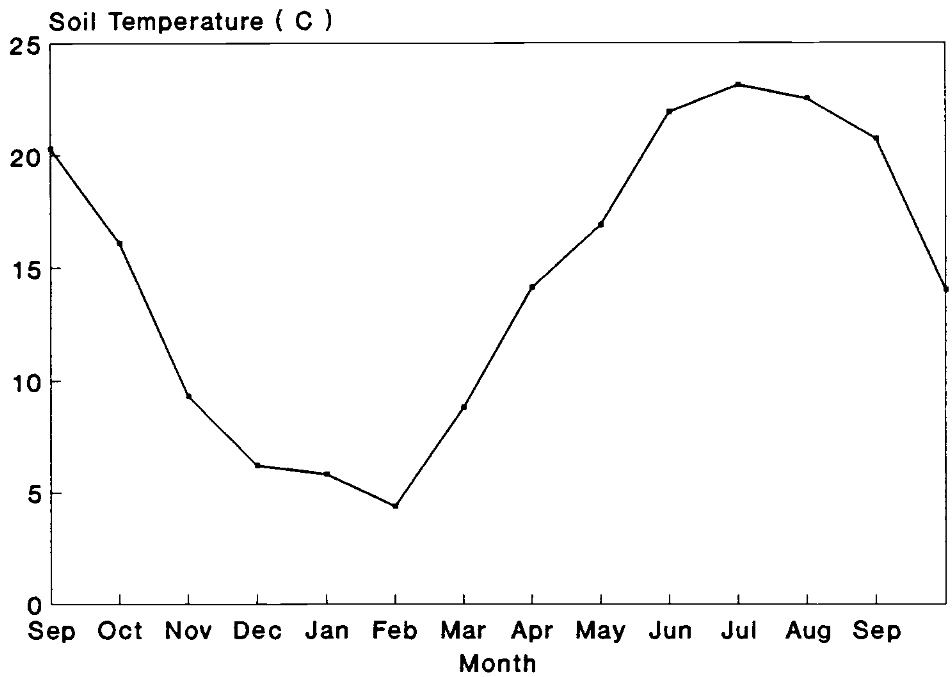

Figure 1.2. Mean monthly soil temperature at a depth of 10 cm from September, 1988 to September, 1989, recorded at Hyslop Research Farm near Corvallis, Oregon.

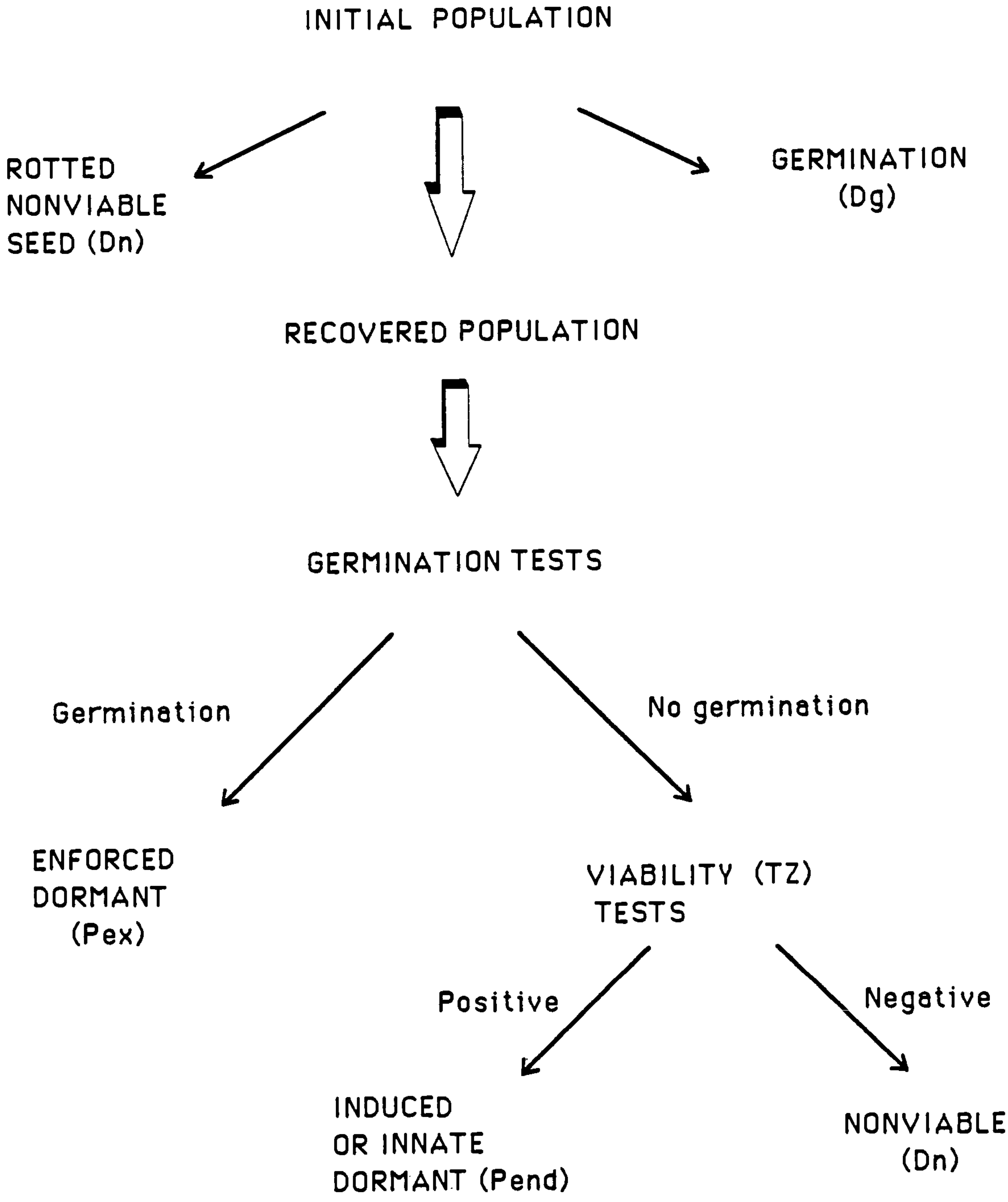

Figure 1.3. Model used to partition California brome seed recovered from soil into components of persistence (P_{ex} + P_{end}) and depletion (D_g + D_n) (14).

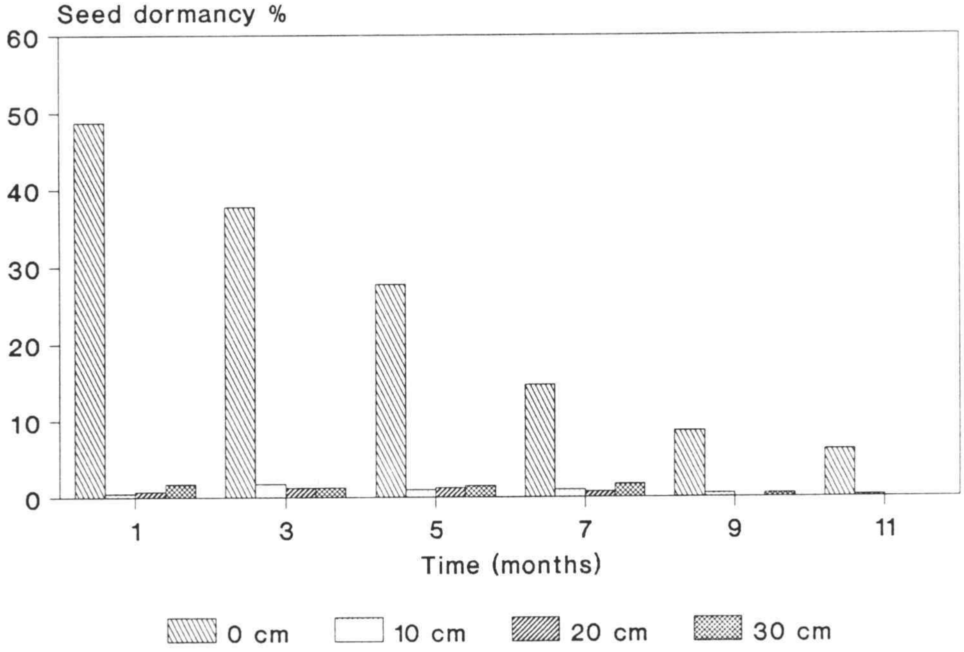

Figure 1.4. Effect of depth and duration of burial on persistence (P_{ex} + P_{end}) of California brome seed.

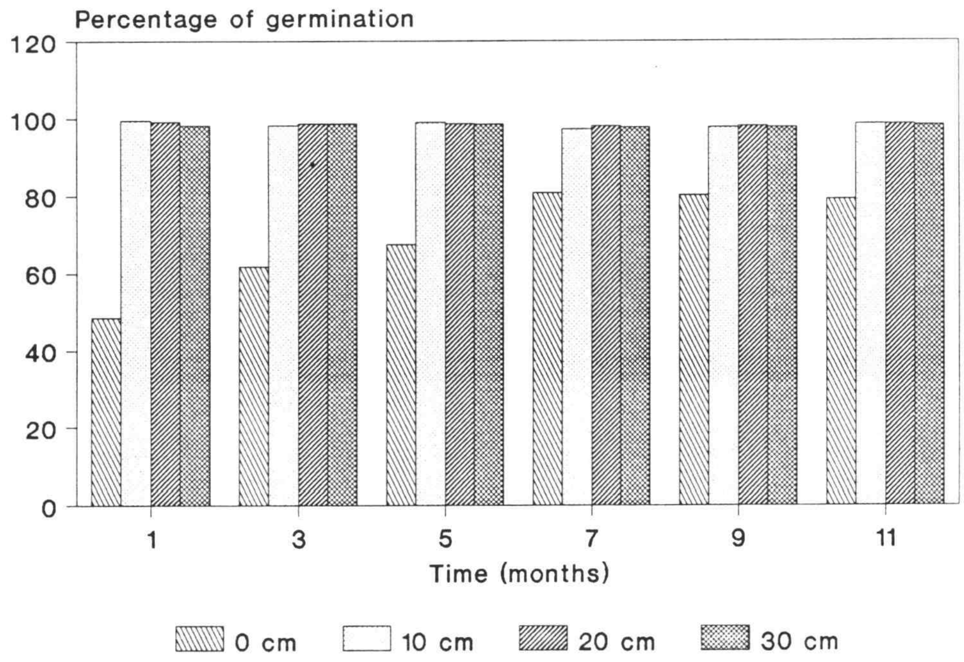

Figure 1.5. Effect of depth and duration of burial on *in situ* germination (D_g) of California brome seed. LSD (0.05)= 4.7 for comparing depths within a time, LSD (0.05)= 5.7 for comparing times within a depth.

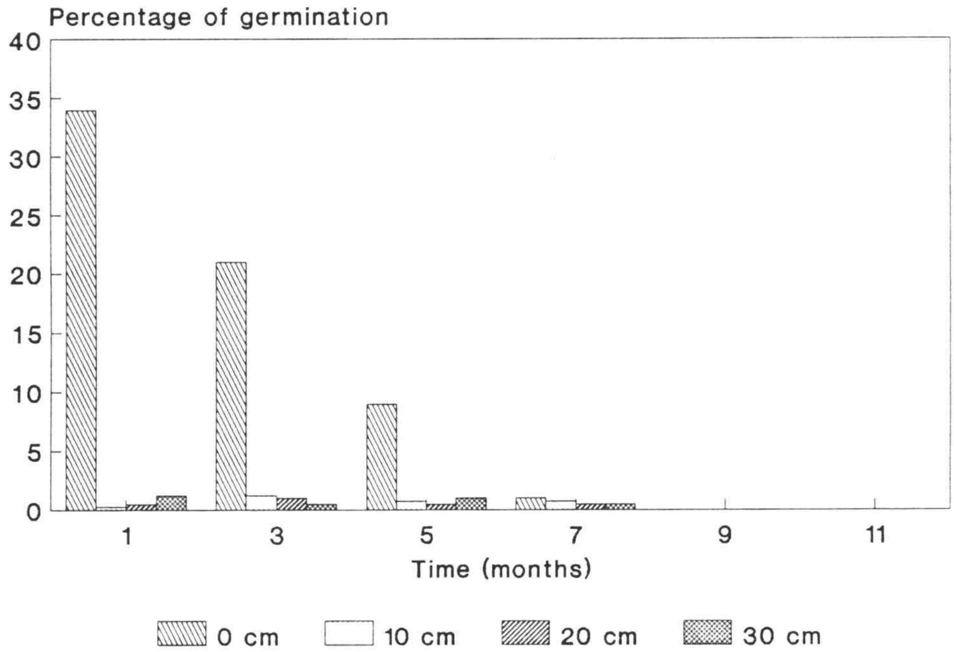

Figure 1.6. Effect of depth and duration of burial on enforced dormancy (P_{ex}) of California brome seed. LSD (0.05)= 3.3 for comparing depths within a time, LSD (0.05)= 4.0 for comparing times within a depth.

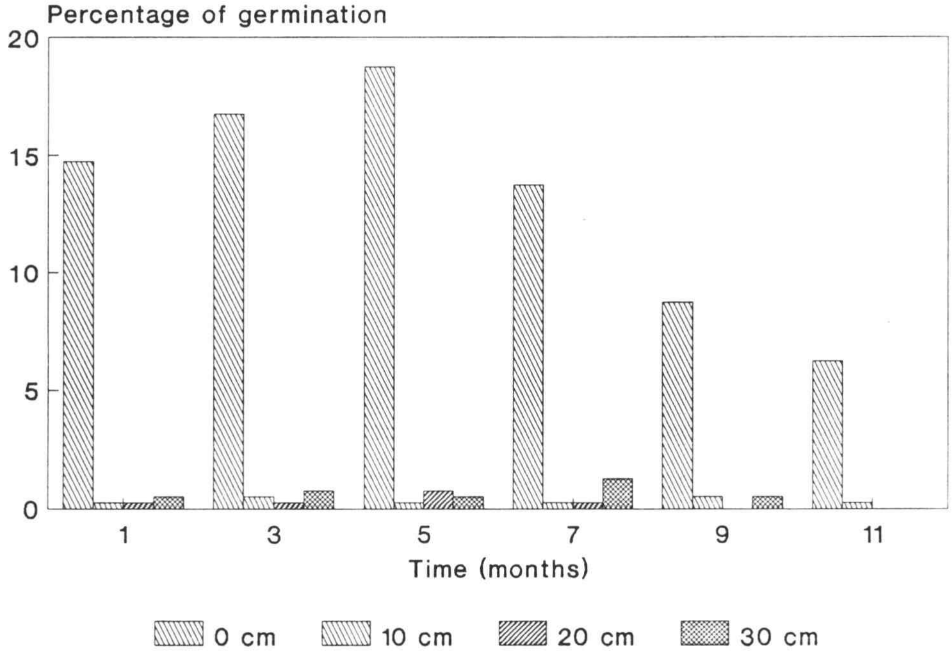

Figure 1.7. Effect of depth and duration of burial on induced dormancy (P_{end}) of California brome seed. LSD (0.05)= 3.1 for comparing depths within a time, LSD (0.05)= 3.8 for comparing times within a depth.

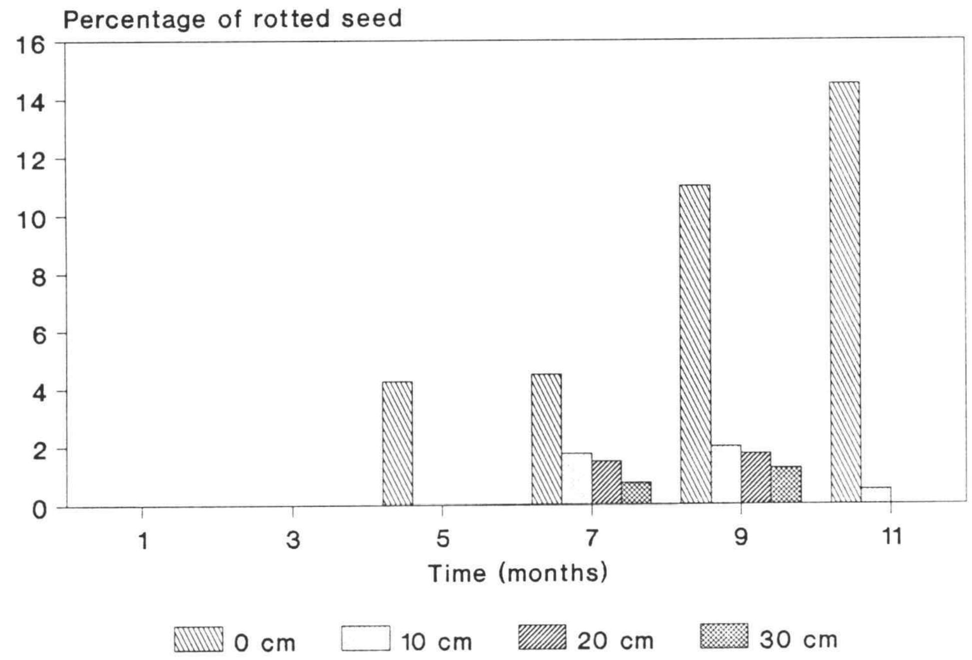

Figure 1.8. Effect of depth and duration of burial on rotted nonviable (D_n) California brome seed. LSD (0.05)= 1.8 for comparing depths within a time, LSD (0.05)= 2.2 for comparing times within a depth.

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Chapter 2. Effect of Vernalization on California brome (*Bromus carinatus* Hook & Arn) Flowering.

ABSTRACT

A greenhouse experiment was conducted to study the effect of vernalization of imbibed California brome seed on flowering. Vernalization of imbibed seed promoted flowering. In the first experiment, chilling treatment (5 C) of 10, 15, and 20 days reduced the vegetative phase. Flowering was absent in the 0- and 5-day vernalization treatments after 96 days when the experiment was terminated. Plants vernalized for 20 days as imbibed seed flowered within 36 days after transfer to favorable conditions. Culms per plant and shoot dry weight were greater for the treatments of unvernalized and 5-day vernalization as imbibed seed, than for other treatments. Increasing vernalization from 10 days to 20 days decreased seed production from a weight of 18.78 g to 15.02 g. The ratio of total seed dry weight to total shoot dry matter was highest for plants vernalized as imbibed seed for 20 days. In the second experiment, only plants vernalized as imbibed seed for 20 days flowered within 109 days after transfer to the greenhouse, whereas plants vernalized as imbibed seed for 0, 5, 10, and 15 days did not flower. No statistical difference on the number of culms per plant was found. Plant height was not different among treatments, except plants vernalized as imbibed seed for 20 days, which were

taller than plants of the other treatments. Highest total shoot dry weight was found on plants vernalized as imbibed seed for 15 and 20 days.

INTRODUCTION

California brome (Bromus carinatus Hook & Arn), is an annual or perennial grass native to the Rocky Mountains and Pacific coast regions of western United States (11, 15). In the last decade, its infestation in grass seed and wheat fields in the Willamette Valley has increased principally because of the lack of a herbicide for its selective control. Control programs in several grass seed crops and winter wheat have focused on finding herbicides which selectively control California brome. Success has been very limited to date[1]. Vernalization, or chilling, is a precondition for flowering, although floral primordia generally do not form during cold treatment (3).

Vernalization hastens the flowering of plants when conditions become inductive for floral initiation (4), by conferring responsiveness to stimuli that initiate flowering (9), and can only be measured as an after-effect following the end of a cold treatment (5). Seed imbibition is a prerequisite for responsiveness to cold treatment (quantitative vernalization) (4). Some species cannot be vernalized as imbibed seed and must first produce a certain amount of vegetative growth as seedlings (qualitative vernalization). For example, reed canarygrass (Phalaris

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arundinacea L.) must undergo a juvenile vegetative phase before it can be vernalized (5).

Previous studies on the reproductive biology of other brome species, such as downy brome (_Bromus_ _tectorum_ L.) (14) and ripgut brome (_Bromus_ _rigidus_ Roth) (8), indicate that cold exposure of the seed (seed vernalization) or seedling plant (seedling vernalization) is required for flowering (14). Hulbert (12) found that winter plantings of downy brome in Idaho normally flowered in June. But plants from March, April, and May seedings failed to produce panicles in summer. Finnerty and Klingman (6) reported that an inductive period of seed vernalization, or short days followed by long days, was required for panicle production of downy brome. Flowering was inhibited when plants were exposed to continuous short or long days. Downy brome plants also failed to produce panicles when they were exposed to short days following vernalization (6). Ripgut brome, a winter annual weed in winter wheat, has a quantitative requirement for vernalization in order to flower. Gleichsner (8) reported that ripgut brome plants flowered within 17 days following vernalization of caryopses at 5 ± 2 C for 8 weeks. Unvernalized plants flowered within 53 days after planting in the greenhouse. Other species of the genus _Bromus_ respond differently to temperature and photoperiod. For example, soft brome (_Bromus_ _mollis_ L.) flowered when it was exposed to continuous long days and low temperature but it did not flower under continuous long days and high temperature (7). Richardson (14), reported that vernalizing imbibed downy brome seed at 3 C for 0 to 30 days did not induce earlier flowering.

The objective of this study was to determine the effect of vernalization on flowering of California brome under greenhouse conditions.

MATERIALS AND METHODS

Mature California brome seed was hand-harvested at the Oregon State University Schmidt Farm, near Corvallis, Oregon, in July 1988. The seed was mechanically cleaned, deawned, and stored at room temperature until it was utilized. The seed population was 100% viable with no dormancy when it was tested in August and December 1988. California brome seed were placed in 100-by 100-by 15-mm petri dishes using blotter paper moistened with deionized water. Petri dishes were wrapped with aluminum foil to exclude light and deionized water was supplied periodically to keep the seed moist. The petri dishes were placed in a refrigerator at 5 ±2 C for 0, 5, 10, 15, and 20 days. Vernalization treatments were staggered in order to terminate all treatments at the same time.

At the end of vernalization, seed from the 5, 10, 15, and 20 day treatments germinated. To avoid devernalization, seed from the 0-day-vernalization treatment and seedlings from the other treatments were placed in a dark growing chamber at 15 C for a period of 5 days. During this period of time the unvernalized seed also germinated. Three uniform seedlings from each treatment were transplanted into each pot (15.2 cm diameter by 17.8 cm, containing 3.0 L soil). The potting mixture included soil, peat, sand, and pumice (1:1:1:2, v/v/v/v; pH 6.5). Two weeks after transplanting the plants were thinned to one plant per pot. Plants were fertilized with a slow release granular fertilizer (18:6:12, N:P:K) and were subirrigated.

The dates of transplanting, seedling emergence, and the first emergence of the awns were recorded. The time of awn emergence was chosen as a relative measure of the rate of flowering and was recorded on alternate days. Floral initiation, development, and awn emergence were assumed to be influenced similarly by the process of vernalization (2).

Plant height (measured from the soil surface to the uppermost leaf tip), number of culms, total seed dry weight, and total shoot dry weight were recorded. As seed matured, it was harvested and oven dried at 70 C for 48 hours.

This experiment was conducted twice. The first experiment was conducted from July to October, 1989, and the second experiment from November, 1989 to March, 1990. Daylight was supplemented with fluorescent light to provide a minimum 16 hour photoperiod throughout the year. Light intensity was between 95 and 165 μmol m^{-2} s^{-1} at the soil surface, at 25/16 C, and 24/14 C day/night in the first and second experiment, respectively. A randomized complete block design with 10 replications per treatment was used. Analyses of variance were computed, and differences between means were compared using Fisher's protected Least Significant Difference Test (LSD) at the 0.05 level of significance.

RESULTS AND DISCUSSION

Analysis of variance performed on the combined data from the two experiments indicated that there was a significant difference between experiments, so the data were analyzed separately.

In the first experiment, vernalization or chilling treatment of imbibed seed hastened floral initiation and completion of the life cycle of California brome under greenhouse conditions. As the duration of low temperature treatment increased from 10 to 20 days, there was a decrease in the vegetative phase of California brome seedlings (Figure 2.1). Imbibed seed that had been vernalized for 20 days flowered within 36 days after transfer to the greenhouse. Plants vernalized for 5 days and unvernalized plants remained vegetative and failed to flower in the 96-day duration of this experiment. This information demonstrates that California brome, like other bromes species such as ripgut brome (*Bromus rigidus* Roth) (8), and downy brome (*Bromus tectorum* L.) (14), has a quantitative vernalization requirement.

As the length of vernalization increased, the number of culms per plant decreased from 32 for unvernalized plants to 20 in plants vernalized as imbibed seed for 20 days (Figure 2.2). Similar results were obtained by Gleichsner (8) with ripgut brome.

Plant height was similar in all treatments. Unvernalized plants and plants vernalized for 5 days tended to be slightly taller than in other treatments (Figure 2.3).

Highest total shoot dry weight was obtained on unvernalized plants (Figure 2.4). Total seed dry weight tended to decrease as the vernalization period increased (Figures 2.5). In general, as the period of cold treatment increased, total shoot dry weight and total seed dry weight decreased. The ratio of total seed dry weight to total shoot dry weight was greater for the 20-day cold treatment (data not shown).

In the second experiment, conducted during the winter, only plants vernalized as imbibed seed for 20 days flowered within 109 days after transfer to the greenhouse. Plants in the remaining treatments failed to flower (data not shown). There was no difference for the number of culms per plant among treatments (Figure 2.2). In general, plant height was uniform in all treatments, with the exception of plants vernalized as imbibed seed for 20 days, which were taller than plants of the other treatments (Figure 2.3). Highest total shoot dry weight was observed on plants vernalized as imbibed seed for 15 and 20 days (Figure 2.4).

Since the two experiments were conducted at different times of the year, differences between experiments may be due to differences in solar radiation, temperature, and the duration of each experiment. Solar radiation and temperature were higher in the first experiment than in the second experiment.

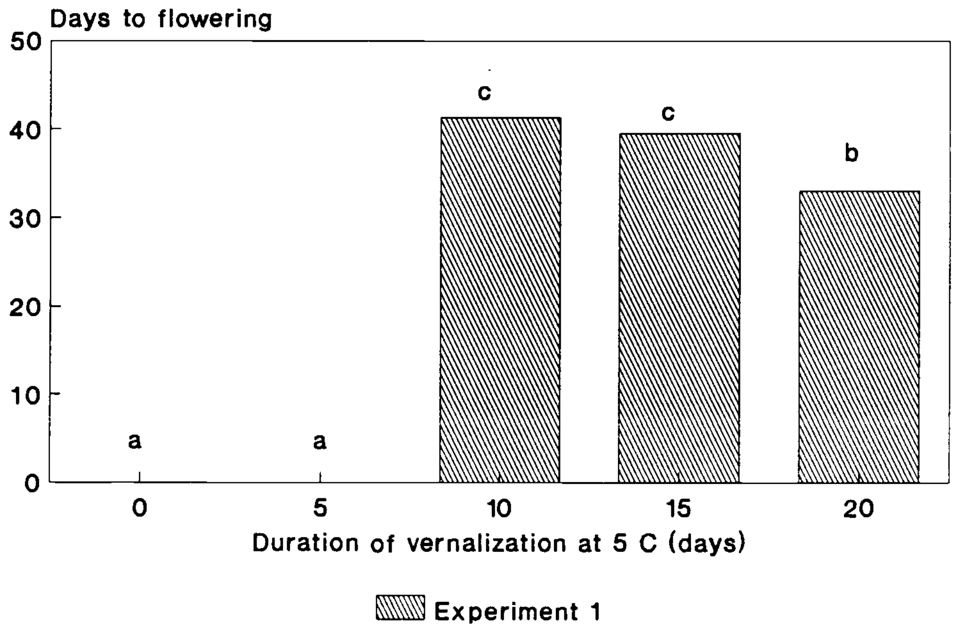

Figure 2.1. Effect of vernalization duration at 5 C on days to flowering of California brome after transfer to the greenhouse. Treatments with the same letter are not different according to Fisher's Protected LSD (P= 0.05).

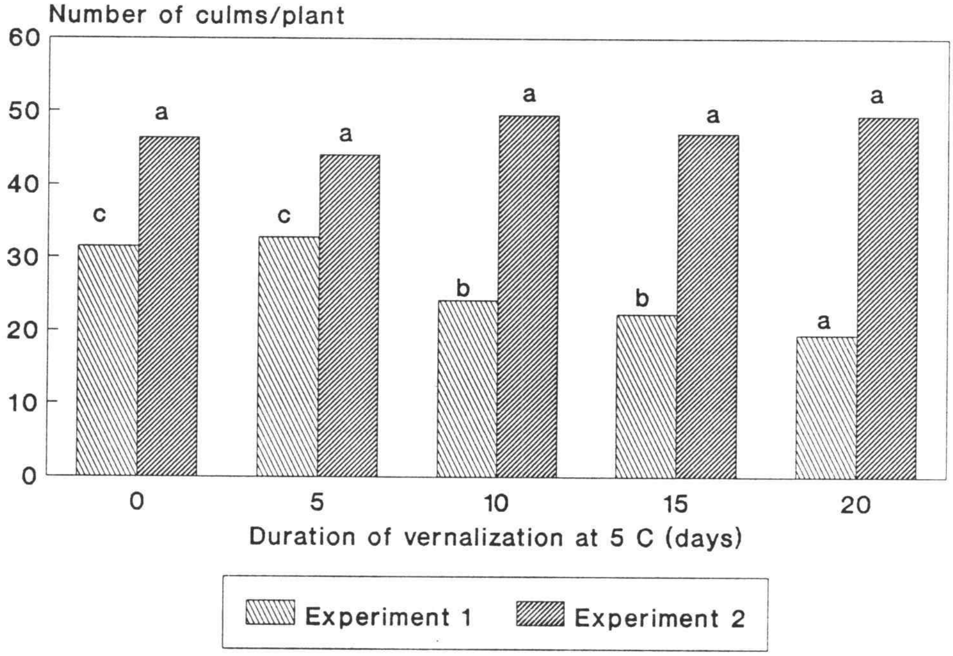

Figure 2.2. Effect of vernalization duration at 5 C on number of culms per plant of California brome after transfer to the greenhouse. Treatments with the same letter within a given experiment are not different according to Fisher's Protected LSD (P= 0.05).

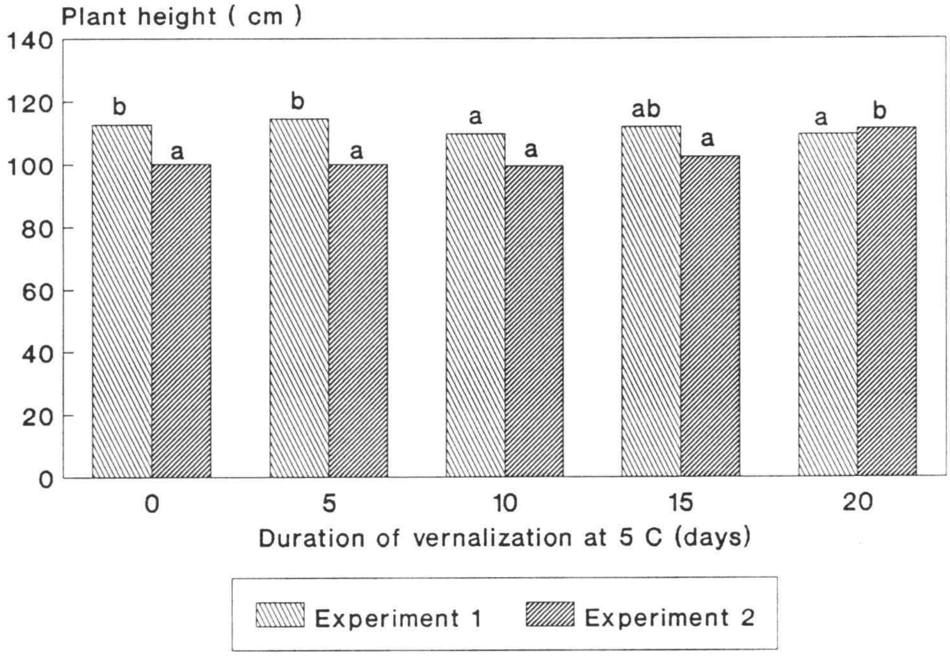

Figure 2.3. Effect of vernalization duration at 5 C on California brome plant height after transfer to the greenhouse. Treatments with the same letter within a given experiment are not different according to Fisher's Protected LSD (P= 0.05).

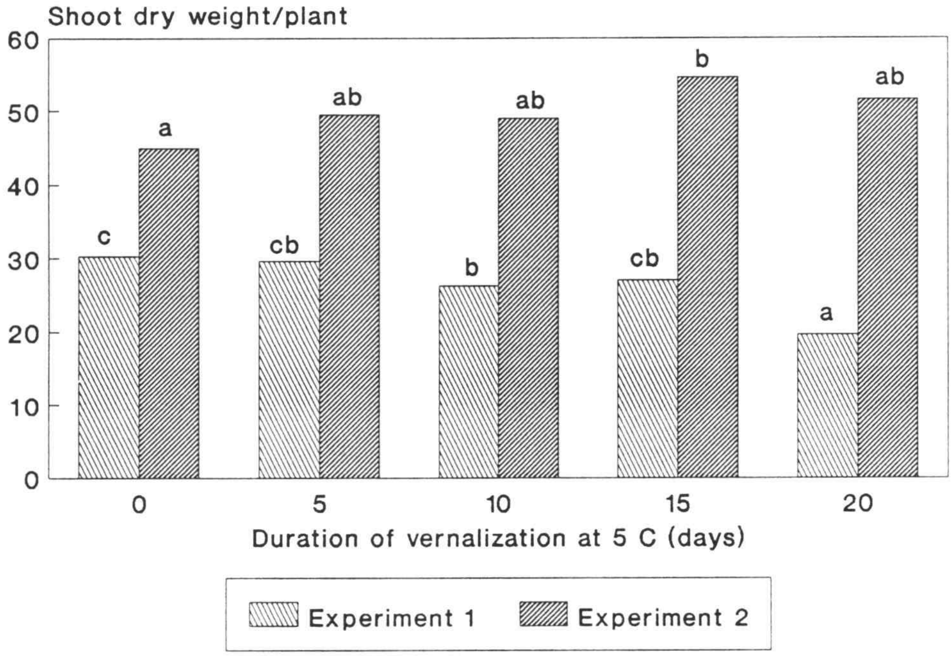

Figure 2.4. Effect of vernalization duration at 5 C on total shoot dry weight of California brome after transfer to the greenhouse. Treatments with the same letter within a given experiment are not different according to Fisher's Protected LSD (P= 0.05).

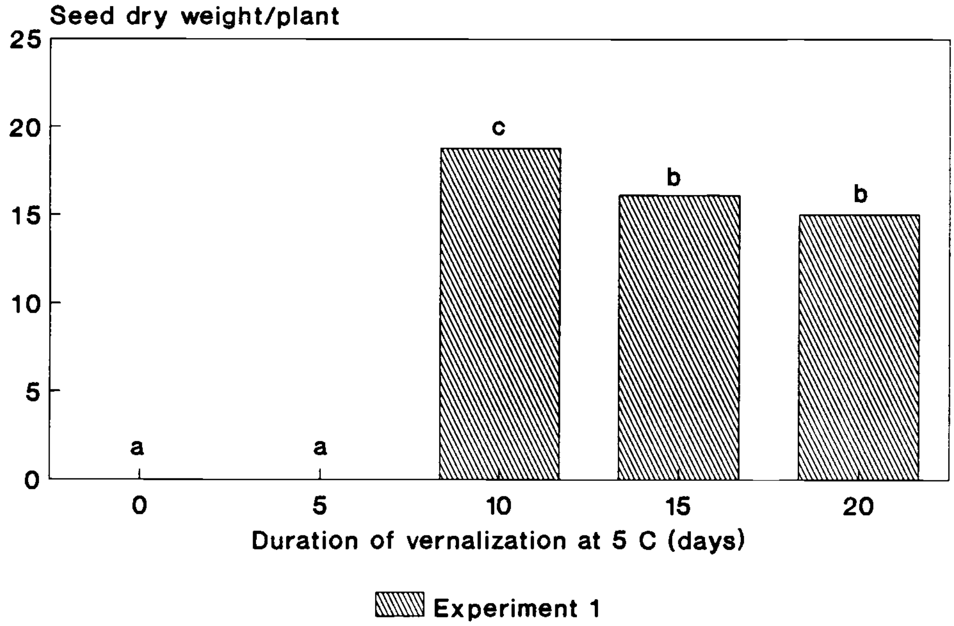

Figure 2.5. Effect of vernalization duration at 5 C on total seed dry weight per plant of California brome after transfer to the greenhouse. Treatments with the same letter are not different according to Fisher's Protected LSD (P= 0.05).

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Chapter 3. Effect of Soil Placement of cinmethylin, diclofop, triallate, and trifluralin on California brome (<u>Bromus</u> <u>carinatus</u> Hook & Arn).

ABSTRACT

A greenhouse experiment was conducted to measure the effect of differential soil placement of cinmethylin (exo-1-methyl-4-(methylethyl)-2-[(2-methylphenyl)methoxy]-7oxabicyclo[2.2.1] heptane), diclofop ((±)-2-[4-(2,4-dichlorophenoxy)phenoxy]-propanoic acid), triallate (S-(2,3,3-trichloro-2-propenyl) bis(1-methylethyl) carbamothioate), and trifluralin (2,6-dinitro-N,N-dipronyl-4-(trifluoromethyl)benzenamine) on California brome (<u>Bromus carinatus</u> Hook & Arn) control. Herbicide doses were 0.93, 1.8, 1.34, and 1.07 ppm, respectively. Cinmethylin had the greatest affect on plant height and plant weight, reducing both significantly. California brome plant height and dry weight did not differ among placements of cinmethylin. Seedlings treated with diclofop with shoot plus root exposure differed in plant height from those treated only in the shoot or root zone. Seedlings exposure to triallate did not differ in height or dry weight among exposure zones. Root exposure to trifluralin reduced height and dry weight less than shoot or shoot plus root exposure.

INTRODUCTION

The lack of a consistently effective control for various *Bromus* species has become a serious production problem for many winter wheat farmers (10). Mueller-Warrant (9) and Brewster[1] reported that California brome infestations have been increasing in tall fescue, orchardgrass, and wheat in Western Oregon fields, apparently tolerating diuron and atrazine herbicides at rates normally used. Because of the limitations associated with the herbicides currently used on these crops, more versatile herbicides are needed for selective control of *Bromus carinatus* in winter and spring wheat.

Diclofop, triallate, and trifluralin are herbicides generally applied as a preemergence or preplant soil incorporated treatment for control of weeds in winter and spring wheat in Oregon. Cinmethylin has been investigated for similar use.

Cinmethylin controls annual grasses and certain broadleaved weeds in soybeans, cotton, vine and ornamental crops (14). Uptake of this herbicide occurs through the shoots and roots of germinating or emerging plants (14). Although, cinmethylin is not registered for use in wheat, it

[1]B. D. Brewster, Crop Science Department, Oregon State University, Corvallis, Oregon. Personal communication.

reduced the population of California brome seedling as much as 98% when applied as a preemergence treatment[2] (9).

Diclofop is a selective herbicide registered for the control of annual grassy weeds in crops such as barley, wheat, and soybeans. When applied to the soil, it effectively controls several brome species including downy brome (Bromus tectorum) and ripgut brome (Bromus rigidus) (11, 12, 14), but does not adequately control California brome (9, 11). When soil applied, diclofop is absorbed by emerging barnyardgrass (Echinochloa crusgalli) seedlings via the coleoptile, the first internode of the shoot, or the roots (15). However, root uptake by barnyardgrass and yellow foxtail (Setaria lutescens) was as much as twice the shoot uptake (3).

Triallate is a soil incorporated herbicide used to control weeds in various cereal and oil seed crops. Its uptake by wild oats is mainly by the coleoptile (14). Triallate has a relatively high vapor pressure (25.73 kPa at 25 C), and volatilizes from moist soils at field temperatures during application and incorporation. Tolerance of wheat and other cereals to this herbicide is based on seeding these crops below the treated zone (2). Gillespie (4) reported that triallate applied as a preemergence treatment in combination with chlorsulfuron may

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injure wheat more than either herbicide applied alone.

Trifluralin, which should also be soil incorporated, controls downy brome, cheat (bromus secalinus L.), and many other grasses and some broadleaf weeds. It is used in more than 20 dicotyledonous and several monocotyledonous crops such as barley, winter wheat, and spring wheat. Trifluralin is registered for use in wheat and barley in Canada as a preemergence, shallowly incorporated (5-cm), herbicide for control of green foxtail (Setaria viridis L. Beauv.). It is also used to control wild oat (Avena fatua L.), green foxtail, and several broadleaf weeds in Argentine rape (Brassica napus L.) (8). Trifluralin is mainly absorbed by the coleoptile in monocotyledons (14). Trifluralin is a more effective grass herbicide when placed in the shoot zone rather than the root zone of emerging seedlings (1, 7). Talbert et al (13) reported that trifluralin generally provided better weed control when uniformly incorporated to a depth of 2.5 cm or 5.0 cm rather than 10 cm. The deeper incorporation probably reduces the herbicide concentration to which emerging shoots were exposed.

The objective of this experiment was to determine the effect of cinmethylin, diclofop, trifluralin, and triallate placement (shoot, root, and shoot plus root regions) on the control of California brome.

MATERIALS AND METHODS

Woodburn silt loam (fine-silty, mixed, mesic Aquultic Argixeroll) soil was used in this experiment. Diclofop methyl, triallate, trifluralin, and cinmethylin at 1.8, 1.34, 1.07, and 0.93 ppm, respectively, were incorporated into 2 Kg air dry soil in a mixer with enough water to bring soil moisture to 10%. Treated soil was placed: a) above the seeds only, b) below the seeds only, or c) above and below the seeds. A thin layer of charcoal was placed on the soil below the seeds to prevent movement of the herbicide beyond the desired location. Two untreated checks were also included. Five seeds were placed at 3.75 cm deep, in 5.0 by 7.5-cm pots. Sunlight was supplemented with fluorescent tubes to maintain light intensity between 95 and 160 μmol m^{-2} s^{-1} at the soil surface, with temperatures of 22/16 C day/night. Soil moisture was maintained at field capacity by subirrigation.

The experimental design was a split-plot replicated in four randomized blocks. Main plots were herbicides and subplots were herbicide placement. Plant height and foliage dry weight were measured 3 weeks after planting. Analyses of variance (ANOVA) were computed, and differences between means were compared using Fisher's Protected Least Significant Difference Test (F-LSD) at the 0.05 level of significance.

RESULTS AND DISCUSSION

In general, cinmethylin controlled California brome more effectively than the other herbicides used in this greenhouse experiment, as measured by plant height (Figure 3.1) and plant weight (Figure 3.2). Cinmethylin has been reported as an excellent herbicide for control of California brome (9). It is absorbed through both the shoot and roots (14). There were no differences in California brome plant height and dry weight among placements. Although the response of California brome to cinmethylin was greater than to the other herbicides used in this experiment, its use in wheat is doubtful since wheat is not completely tolerant of this herbicide (5).

California brome seedlings exposed to trifluralin in the root zone were less damaged and differed in height and dry weight from those treated in the shoot zone or both shoot plus root zone (Figure 3.1 and 3.2). This agrees with other reports that trifluralin uptake occurs mainly in the shoot region (14).

Triallate has been shown to be absorbed primarily by shoots (11). However, in this experiment, plants treated in the shoot zone did not differ in height or dry weight from plants treated in the root or shoot plus root zone (Figures 3.1 and 3.2).

Although diclofop is principally absorbed in the root zone (3), some absorption occurs via the coleoptile (15). In this experiment only plant height for the shoot plus root placement differed from those treated in the shoot or root zone (Figure 3.1).

Crop rotation can be a feasible alternative to reduce the density and prevent the increase of California brome in wheat. For example, successful control could be achieved with a rotation with red clover. This rotation allows the use of cinmethylin to control California brome, which is not selective in wheat.

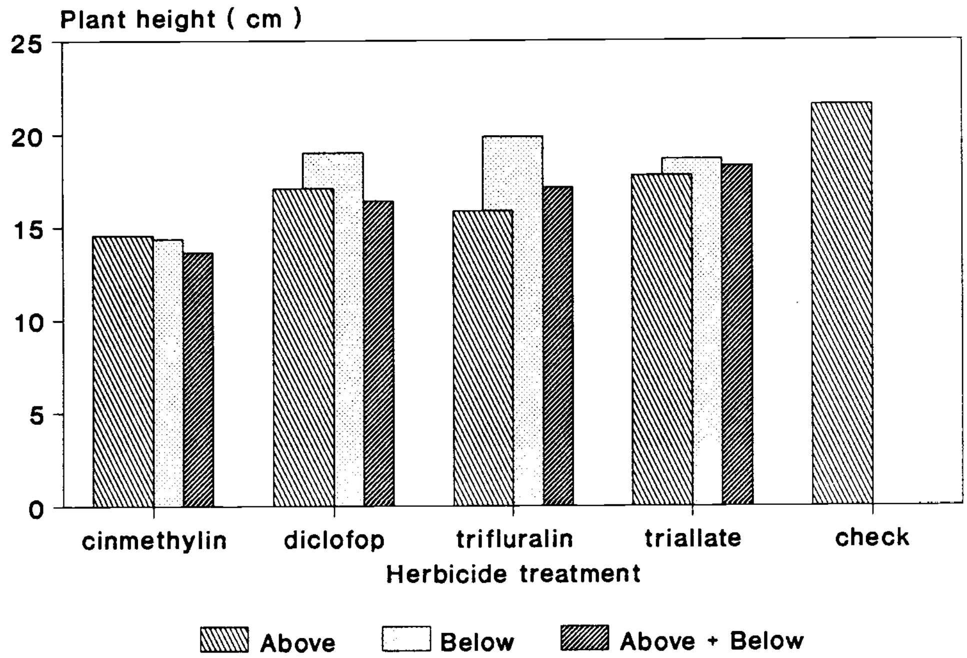

Figure 3.1. Effect of herbicide and herbicide placement on California brome plant height. LSD (0.05)= 1.73 for comparing herbicides within placements, LSD (0.05)= 2.30 for comparing placements within herbicides.

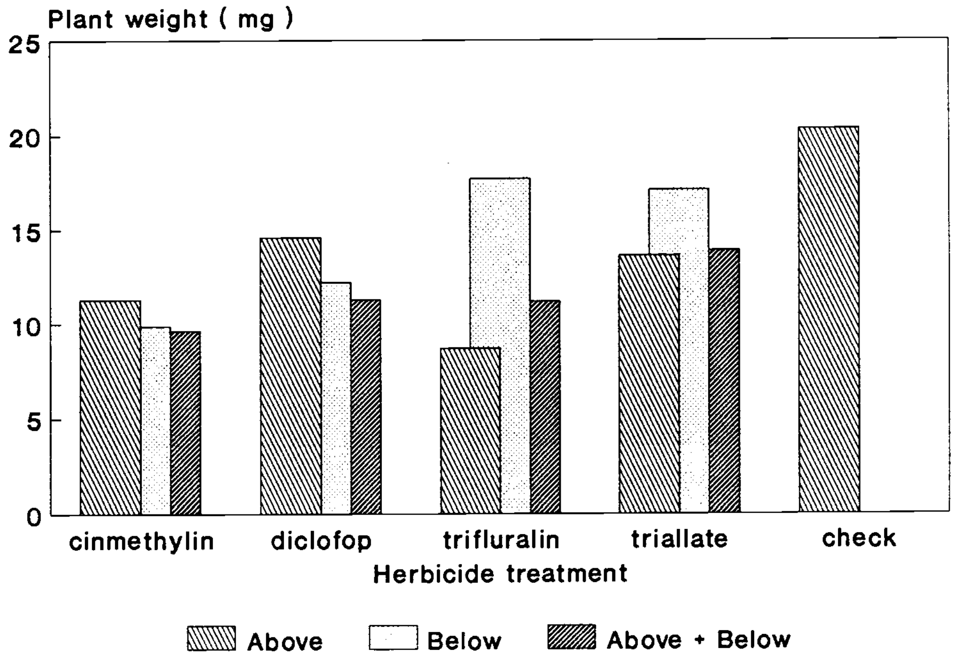

Figure 3.2. Effect of herbicide and herbicide placement on California brome plant weight. LSD (0.05)= 4.2 for comparing herbicides within placements, LSD (0.05)= 5.5 for comparing placements within herbicides.

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APPENDIX

Appendix Table 1. Effect of depth and duration of burial on persistence (enforced and induced dormancy) of California brome seed[a].

Burial duration (months[b])	Persistence of California brome seed at various depths (cm)			
	0	10	20	30
	---------(% of initially buried seed)----------			
1	51	-	-	2
3	38	2	1	1
5	32	1	1	1
7	19	3	2	2
9	20	2	2	2
11	21	1	2	2

[a]Values presented are means of four replications of 100 seeds each.
[b]Months following October 10, 1988.

Appendix Table 2. Effect of depth and duration of burial on *in situ* germination (D_g) of California brome seed[a].

Burial duration (months[b])	*In situ* germination of California brome seed at various depths (cm)			
	0	10	20	30
	------------(% of initially buried seed)--------			
1	49	100	99	98
3	62	98	99	99
5	68	98	99	98
7	81	97	98	98
9	80	98	98	98
11	79	99	98	98

[a]Values presented are means of four replications of 100 seeds each.
[b]Months following October 10, 1988.

Appendix Table 3. Effect of depth and duration of burial on enforced dormancy (P_{ex}) of California brome seed[a].

Burial duration (months[b])	Persistence of California brome seed at various depths (cm)			
	0	10	20	30
	------------(% of initially buried seed)--------			
1	35	0	0	0
3	21	0	0	0
5	9	1	0	1
7	0	1	0	0
9	0	0	0	0
11	0	0	0	0

[a]Values presented are means of four replications of 100 seeds each.
[b]Months following October 10, 1988.

Appendix Table 4. Effect of depth and duration of burial on induced dormancy (P_{end}) of California brome seed[a].

Burial duration (months[b])	Persistence of California brome seed at various depths (cm)			
	0	10	20	30
	------------(% of initially buried seed)--------			
1	16	0	0	0
3	17	0	0	0
5	19	1	0	0
7	14	0	0	0
9	9	0	0	1
11	6	0	0	1

[a]Values presented are means of four replications of 100 seeds each.
[b]Months following October 10, 1988.

Appendix Table 5. Effect of depth and duration of burial on nonviability loss (D_n) of California brome seed[a].

Burial duration (months[b])	Nonviability loss of California brome seed at various depths (cm)			
	0	10	20	30
	------------(% of initially buried seed)--------			
1	0	0	0	0
3	0	0	0	0
5	4	0	0	0
7	5	2	0	1
9	11	2	2	1
11	15	1	2	1

[a]Values presented are means of four replications of 100 seeds each.
[b]Months following October 10, 1988.

<u>Appendix Table 6</u>. Analysis of variance table for effect of depth and duration of burial on California brome seed germination.

Source of variation	df	SS	MS	F
Blocks	3	72.60	24.19	
Treatments (T)	5	634.30	126.80	9.25**
Error (a)	15	205.70	13.71	
Depths (D)	3	14620.00	874.00	296.80**
T*D	15	2549.00	169.90	10.35**
Error	54	886.80	16.42	
Total	95	18968.38		

**= significant at 1% level.

Appendix Table 7. Analysis of variance table for effect of depth and duration of burial on enforced dormancy of California brome seed.

Source of variation	df	SS	MS	F
Blocks	3	15.75	5.25	
Treatments (T)	5	1142.00	228.30	34.90**
Error (a)	15	98.13	6.54	
Depths (D)	3	1985.00	661.60	82.20**
T*D	15	2932.00	195.40	24.28**
Error	54	434.60	8.05	
Total	95	6607.48		

**= significant at 1% level.

Appendix Table 8. Analysis of variance for effect of depth and duration of burial on induced dormancy of California brome seed.

Source of variation	df	SS	MS	F
Blocks	3	21.36	7.12	
Treatments (T)	5	139.70	27.94	4.03*
Error (a)	15	103.90	6.93	
Depths (D)	3	3024.00	1008.00	143.10**
T*D	15	341.20	22.75	3.23**
Error	54	380.40	7.05	
Total	95	4010.56		

*= significant at 5% level.
**= significant at 1% level.

Appendix Table 9. Analysis of variance table for effect of depth and duration of burial on rotting of California brome seed.

Source of variation	df	SS	MS	F
Blocks	3	2.80	0.93	
Treatments (T)	3	87.92	29.31	12.63*
Error (a)	9	20.89	2.32	
Depths (D)	3	735.00	245.00	100.20**
T*D	9	240.60	26.74	10.93**
Error	36	88.06	2.45	
Total	63	1175.27		

*= significant at 5% level.
**= significant at 1% level.

Appendix Table 10. Effect of duration of vernalization at 5 C on days to flowering, culms per plant, plant height, and total shoot dry weight of California brome after transfer to the greenhouse.
Experiment 1.

Block	Duration of vernalization	Time to flowering	Culms/ plant	Shoot height	Seed weight
	(days)	(days)	(no.)	------(g)	-----
1	0	-	31	29.84	-
2	0	-	32	33.80	-
3	0	-	33	27.32	-
4	0	-	31	30.12	-
5	0	-	31	29.82	-
6	0	-	33	32.54	-
7	0	-	31	28.65	-
8	0	-	29	30.77	-
9	0	-	30	29.81	-
10	0	-	34	30.24	-
1	5	-	36	29.69	-
2	5	-	34	32.14	-
3	5	-	35	33.05	-
4	5	-	34	25.52	-
5	5	-	30	22.09	-
6	5	-	34	27.18	-
7	5	-	32	31.24	-
8	5	-	35	30.47	-
9	5	-	32	33.80	-
10	5	-	26	30.82	-
1	10	35	18	21.68	22.26
2	10	45	26	36.23	13.47
3	10	37	26	31.46	15.71
4	10	36	24	26.12	23.97
5	10	43	21	22.71	21.63
6	10	36	26	23.12	17.67
7	10	37	22	24.27	13.94
8	10	45	27	19.88	16.62
9	10	44	26	28.75	22.55
10	10	55	25	27.69	19.99
1	15	43	19	24.85	16.28
2	15	44	22	29.17	11.54
3	15	37	21	30.66	19.73
4	15	40	22	28.89	12.33

Appendix Table 10. (continued).

Block	Duration of vernalization	Time to flowering	Culms/ plant	Shoot weight	Seed weight
	(days)	(days)	(no.)	----- (g)	-----
5	15	42	23	34.36	20.43
6	15	41	23	26.91	20.67
7	15	40	24	22.73	12.83
8	15	33	21	19.57	13.46
9	15	38	24	25.62	13.57
10	15	37	24	27.25	20.34
1	20	33	19	16.53	18.25
2	20	32	19	15.24	11.94
3	20	32	21	28.77	16.54
4	20	36	21	22.46	19.60
5	20	33	19	25.06	16.52
6	20	32	16	11.94	8.01
7	20	34	20	17.12	14.45
8	20	34	22	22.58	9.39
9	20	32	22	18.83	17.42
10	20	32	16	16.44	18.05

Appendix Table 11. Analysis of variance table for effect of duration of vernalization at 5 C on days to flowering of California brome after transfer to the greenhouse. Experiment 1.

Source of variation	df	SS	MS	F
Blocks	9	55.92	6.21	
Treatments	4	17650.00	4412.00	381.2**
Error	36	416.70	11.57	
Total	49	18122.62		

** = significant at 1% level.

Appendix Table 12. Analysis of variance table for effect of duration of vernalization at 5 C on culms/plant of California brome after transfer to the greenhouse. Experiment 1.

Source of variation	df	SS	MS	F
Blocks	9	39.12	4.35	
Treatments	4	1360.00	340.10	60.46**
Error	36	202.50	5.62	
Total	49	1601.62		

** = significant at 1% level.

Appendix Table 13. Analysis of variance table for effect of duration of vernalization at 5 C on California brome plant height after transfer to the greenhouse. Experiment 1.

Source of variation	df	SS	MS	F
Blocks	9	173.1	19.24	
Treatments	4	181.1	45.28	4.17**
Error	36	391.3	10.87	
Total	49	745.5		

** = significant at 1% level.

Appendix Table 14. Analysis of variance table for effect of duration of vernalization at 5 C on total shoot dry weight of California brome after transfer to the greenhouse. Experiment 1.

Source of variance	df	SS	MS	F
Blocks	9	188.8	20.97	
Treatments	4	733.7	183.40	11.50**
Error	36	574.2	15.95	
Total	49	1496.7		

** = significant at 1% level.

Appendix Table 15. Analysis of variance table for effect of duration of vernalization at 5 C on total seed dry weight of California brome after transfer to the greenhouse. Experiment 1.

Source of variation	df	SS	MS	F
Blocks	9	122.5	13.62	
Treatments	4	3397.0	849.30	109.7**
Error	36	278.7	7.74	
Total	49	3798.2		

** = significant at 1% level.

<u>Appendix Table 16</u>. Effect of duration of vernalization at 5 C on culms per plant, plant height, and total shoot dry weight of California brome after transfer to the greenhouse. Experiment 2.

Block	Duration of vernalization	Culms/ plant	Plant height	Shoot weight
	(days)	(no.)	(cm)	(g)
1	0	28	100	30
2	0	42	103	42
3	0	45	104	40
4	0	48	102	41
5	0	49	97	55
6	0	47	95	43
7	0	54	104	45
8	0	53	98	53
9	0	48	102	53
10	0	50	97	47
1	5	53	101	53
2	5	48	98	53
3	5	43	102	45
4	5	40	103	42
5	5	48	95	42
6	5	39	98	44
7	5	41	99	62
8	5	36	101	60
9	5	46	104	52
10	5	47	99	42
1	10	64	101	57
2	10	48	108	42
3	10	56	99	53
4	10	58	102	40
5	10	41	102	38
6	10	47	87	50
7	10	47	95	59
8	10	48	101	62
9	10	40	106	48
10	10	50	93	41
1	15	41	102	57
2	15	45	116	74
3	15	46	97	44
4	15	50	101	60

Appendix Table 16. (continued).

Block	Duration of vernalization	Culms/ plant	Plant height	Shoot weight
	(days)	(no.)	(cm)	(g)
5	15	42	116	43
6	15	53	95	56
7	15	55	102	45
8	15	47	105	60
9	15	39	94	46
10	15	52	96	61
1	20	54	105	46
2	20	56	106	48
3	20	48	113	63
4	20	47	118	50
5	20	44	103	40
6	20	51	110	57
7	20	49	119	48
8	20	58	116	73
9	20	44	118	47
10	20	43	104	44

Appendix Table 17. Analysis of variance table for effect of duration of vernalization at 5 C on culms/plant of California brome after transfer to the greenhouse. Experiment 2.

Source of variation	df	SS	MS	F
Blocks	9	149.30	16.59	
Treatments	4	203.90	50.97	1.13ns
Error	36	1623.00	45.08	
Total	49	1976.20		

ns = not significant at 5% level.

Appendix Table 18. Analysis of variance table for effect of duration of vernalization at 5 C on California brome plant height after transfer to the greenhouse. Experiment 2.

Source of variation	df	SS	MS	F
Blocks	9	418.70	46.52	
Treatments	4	967.50	241.90	8.43**
Error	36	1033.00	28.70	
Total	49	2419.20		

** = significant at 1% level.

Appendix Table 19. Analysis of variance table for effect of duration vernalization at 5 C on total shoot dry weight of California brome after transfer to the greenhouse. Experiment 2.

Source of variance	df	SS	MS	F
Blocks	9	1030.00	114.50	
Treatments	4	509.50	127.40	1.87ns
Error	36	2450.00	68.05	
Total	49	3989.50		

ns = not significant at 5% level.

Appendix Table 20. Mean monthly solar radiation recorded at Hyslop Research Farm near Corvallis, Oregon.

First Experiment		Second Experiment	
Month	Solar Radiation	Month	Solar Radiation
	($cal \cdot cm^{-2} \cdot min^{-1}$)		($cal \cdot cm^{-2} \cdot min^{-1}$)
July	469	November	113
August	458	December	68
September	406	January	80
October	220	February	159
		March	283

Appendix Table 21. Mean daily maximum and minimum monthly air temperature under greenhouse conditions, recorded at Oregon State University, Corvallis, Oregon.

First Experiment			Second Experiment		
Month	Temperature (C)		Month	Temperature (C)	
	max	min		max	min
July	23.5	16.2	November	21.9	14.0
August	25.5	16.1	December	19.3	14.4
September	24.0	15.5	January	21.8	15.9
October	21.0	15.2	February	24.0	15.6
			March	21.4	14.4

Appendix Table 22. Height (cm) of California brome seedlings exposed to various herbicides at different soil placements.

HERBICIDE AND EXPOSURE REGION	REPLICATION I	II	III	IV
	(cm)			
cinmethylin				
Shoot	14.67	13.28	14.60	15.65
Root	11.15	13.40	16.55	16.27
Shoot + Root	14.75	14.65	11.53	13.65
diclofop				
Shoot	16.93	17.40	16.92	17.05
Root	19.30	18.18	20.15	18.34
Shoot + Root	16.30	16.60	16.25	16.50
trifluralin				
Shoot	14.70	14.55	16.50	17.65
Root	19.40	18.75	20.85	20.45
Shoot + Root	18.25	17.80	16.57	15.79
triallate				
Shoot	16.68	21.09	15.18	18.10
Root	17.80	17.90	17.99	20.87
Shoot + Root	17.40	17.65	19.47	18.60
Check	21.75	22.15	21.16	21.24

<u>Appendix Table 23</u>. Weight (mg) of California brome seedlings exposed to various herbicides at different soil placements.

HERBICIDE AND EXPOSURE REGION	REPLICATION			
	I	II	III	IV
	---------------- (mg) ----------------			
cinmethylin				
Shoot	11.11	13.44	9.53	11.03
Root	7.53	9.15	11.08	11.77
Shoot + Root	13.02	9.23	8.17	8.24
diclofop				
Shoot	13.66	16.31	14.90	13.47
Root	12.33	11.65	12.69	12.69
Shoot + Root	10.26	11.92	12.00	10.96
trifluralin				
Shoot	10.08	8.35	8.37	8.05
Root	16.07	22.22	16.80	15.75
Shoot + Root	11.13	12.92	9.67	11.21
triallate				
Shoot	12.40	17.92	10.95	13.29
Root	18.45	17.84	15.45	17.83
Shoot + Root	13.35	13.37	15.82	13.19
Check	22.23	19.7	17.11	22.37

<u>Appendix Table 24</u>. Analysis of variance table for effect of herbicides, and herbicide placement on California brome plant height.

Source of variation	df	SS	MS	F
Blocks	3	8.05	2.68	-
Exp. (E)	1	25.32	25.32	1.61
Error (a)	3	47.13	15.71	-
Herbicide (H)	4	706.50	176.60	38.89**
Place (P)	2	42.67	21.33	4.70*
H*P	8	62.89	7.86	1.73
P*E	2	5.65	2.82	0.62
E*H	4	11.33	2.83	0.62
E*H*P	8	55.15	6.89	1.52
Error	84	381.40	4.54	

* = significant at 5% level.
** = significant at 1% level.

Appendix Table 25. Analysis of variance table for effect of herbicides, and herbicide placement on California brome plant weight.

Source of variation	df	SS	MS	F
Blocks	3	.048	.016	-
Exp(E)	1	.071	.0712	1.39
Error (a)	3	.154	.0512	-
Herbicide (H)	4	1.620	.404	37.76**
Place (P)	2	.117	.0583	5.44*
H*P	8	.372	.0465	4.34*
P*E	2	.0523	.0261	2.44
E*H	4	.0265	.0066	0.62
E*H*P	8	.141	.0176	1.64
Error	84	.901	.0107	

* = significant at 5% level
** = significant at 1% level