AN ABSTRACT OF THE THESIS OF

Gregory S. Vollmer for the degree of Master of Science in Crop Science presented on September 16, 1986. Title: The Effect of Residue Removal and Burning on the Growth of *Festuca longifolia* Thuill. and *Festuca rubra* L. subsp. *commutata* Gaud. Established for Seed Production

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Harold Youngberg

Hard Fescue (*Festuca longifolia* Thuill.) has potential for increased turf use but does not respond well to normal seed production management practices in Oregon. Field burning (the normal residue management practice) results in reduced seed yields in commercial hard fescue seed production fields but stimulates seed production in Chewings fescue (*Festuca rubra* L. subsp. *commutata* Gaud.) and other species. The purpose of this study was to describe differences in tillering patterns in hard fescue and Chewings fescue in response to various post harvest residue management treatments.

Burn and crewcut (clip and vacuum) post harvest residue management treatments were applied on two different dates. Information on number and type of tiller units and tillers produced, dry weights, leaf number and length, tiller fertility and components of yield was collected through one seed production season.

Differences in hard and Chewings fescue were indicated by cultivar x management interactions in many of the components measured. Chewings fescue has the ability to recover from all but the most

severe (late burn) management by November while tiller numbers were reduced in all but the least severe (early crewcut) management in hard fescue on that date.

Differences were also observed in the type of tiller produced. Hard fescue produced a higher percentage of aerial tillers than did the Chewings fescue. These aerial tillers did not survive beyond February and made no apparent contribution to yield. No differences were observed in the number of early season basal tillers. A high vegetative tiller population was maintained in hard fescue until harvest while in Chewings fescue dry matter production was concentrated in fertile tillers.

The superior seed yield of the Chewings fescue cultivar was due to a 30% greater number of fertile tillers per unit area and a 25% greater mean seed weight. Differences in seed yield between species cannot be simply attributed to the availability of early season basal tillers for floral induction but are due to the effects of inter-tiller competition, dry matter partitioning and the genetic propensity to favor seed production over the maintenance of vegetative tillers.

In this study, normal (early) burning did not reduce the seed yield of the hard fescue cultivars. This was attributed to the pre-treatment flail chop and partial removal of harvest litter. This suggests that a modified burn management system may increase or maintain hard fescue seed yield.

The Effect of Residue Removal and Burning on the Growth of *Festuca longifolia* Thuill. and *Festuca rubra* L. subsp. *commutata* Gaud. Established for Seed Production

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THE EFFECT OF RESIDUE REMOVAL AND BURNING ON THE GROWTH OF FESTUCA LONGIFOLIA THUILL. AND FESTUCA RUBRA L. SUBSP. COMMUTATA GAUD. ESTABLISHED FOR SEED PRODUCTION

INTRODUCTION

The production of grass and legume seeds in Oregon resulted in sales of $121,100,000, about seven percent of Oregon farm sales in 1985 (Miles, 1986). Of the 366,010 acres in seed production, approximately 27,000 acres are devoted to the production of Chewings, red and hard fescues. Seed from these species is used for turf and to a lesser extent for erosion control and forage. Much of this seed production (about 24,000 acres) is certified by the Oregon Seed Certification Service for domestic consumption and, through the OECD scheme, for export. Hard fescue is produced and certified on approximately 750 acres in Oregon (McLaughlin and Jones, 1986).

Chewings and red fescues have been used for turf in cool, humid climates for many years. These species are superior to most cool season turf grasses in their shade adaptation. They are frequently used in mixtures with Kentucky bluegrass for lawns and general purpose turfs. Many improved cultivars have been developed.

Typical production practices for Chewings and red fescue include open field burning as a post harvest management treatment. This treatment removes straw and standing stubble, controls weeds and certain diseases and reduces damage by insects and rodents. Previous studies have shown that field burning enhances fall tiller development and results in an increase of fertile tiller numbers in June. Unburned stands of fescue decline in seed yield after one or two years. Field burning stimulates the seed yield in second and subsequent years so high yields are maintained through the life of the stand. Field burning also controls volunteer seedlings through the destruction of seed left in the field following harvest. Fields with excessive volunteers will fail to meet certification standards and have a reduced crop value.

While an improved hard fescue cultivar with better adaptation to range use (Durar) has existed since 1949, the breeding and release of hard fescues for turf has occurred since 1970. The new hard fescue turf cultivars have several advantages over Chewings and red fescues. Better resistance to turf diseases, more drought resistance and better persistence in turf are considered important advantages. The hard fescues have a reduced rate of vertical growth which, when combined with their other attributes gives them the ability to perform well under low maintenance turf conditions. Unfortunately, hard fescues do not respond well to field burning. Seed yields are reduced in subsequent years following field burning. Plant destruction coupled with lower tiller production from surviving plants may account for this adverse reaction. Because of these problems in seed production, the potential for hard fescue has not been fully realized.

In an effort to understand the difference in Chewings fescue and hard fescue reactions to field burning, an experiment was designed to compare hard fescue and Chewings fescue tillering patterns through the course of a growing season as influenced by post harvest management treatments.

LITERATURE REVIEW

Various management practices are applied to seed production fields to improve seed yields. The effect of these practices cannot be fully understood without examining changes in tillering patterns. Ryle (1966) suggests that to study seed yield, the history of individual tillers and the development of these tillers within the seasonal environment must be explored.

This literature review will present the effects of various management practices on tiller development, environment and seed yield. Specific topics include the origin of tillers, seasonal patterns of tiller development, aerial tillering, and the effect of burning and clipping on the microclimate and subsequent tiller development.

I. Tiller Development

1. Origin of Tillers

Tillering in grasses has been widely studied and reviewed (Sharman, 1947; Booysen, et al., 1963; Langer, 1963; Barnard, 1964; Jewiss, 1966, 1972). A single shoot, consisting of a short stem with leaves placed in opposite ranks at nodes emerges after germination. The stem apex consists of the apical dome and alternating leaf primordia. Buds are formed in the axils of these leaves which give rise to axillary tillers. Buds are formed in the axils of the leaves in axillary tillers which can give rise to additional tillers. Tillers can be ranked in order of appearance as primary, secondary or tertiary. Tillering is dependent upon species and upon environmental factors. A certain number of leaves must be produced on the shoots of certain species before a tiller can be produced (Langer, 1963). All tillers originate in cell divisions of the axillary bud and repeat the structure of the main stem while the grass plant remains in the vegetative condition (Barnard, 1964).

Successive leaf primordia are stacked above each other during early vegetative development. Internodes are formed from cell divisions in the axis between leaf primordia. As the internodes grow, the region of cell division (intercalary meristem) becomes restricted to the base of the internode. Growth habits of different grasses vary due to the activity of the intercalary meristem (Barnard, 1964).

Three common forms forms of vegetative growth habit are suggested by Jewiss (1966): 1) The tufted habit is formed when the stem internodes do not elongate during vegetative growth resulting in a dense population of tillers with the stem apex close to the ground; 2) an elevated stem apex results when stem internode elongation occurs in tall species such as <u>Panicum virgatum</u> while still in the vegetative stage; 3) stem internode elongation causes the formation of prostrate tillers as stolons, or if negatively geotropic, rhizomes.

Intravaginal tillers (those that grow grow upward within the subtending leaf sheath) are represented by the first two above mentioned growth forms. Extravaginal tillers (those that grow through the subtending leaf sheath) are represented by stolons and rhizomes (Langer, 1963).

The stem apex may be elevated without internode elongation if new leaf primordia are produced faster than leaves are developed from the primordia (Sharman, 1947; Booysen, et al., 1963).

2. Seasonal patterns of tiller development

In studying *Phleum pratense*, Langer (1956) observed that tillers may assume an annual habit (arising and flowering in the same year), a biennial habit (arising one year and flowering the next) or they may arise and die without flowering. Langer found that rarely does tiller life span exceed one year and tiller lifespan depends upon the date of origin. Of the vegetative tillers formed in June, 25% survived until February. About 50% of the tillers formed in July and August survived until February but only about 30% survived until June. He concluded that tillers arising in the late summer and fall make the highest contribution to the plant the following spring.

Lamp (1952) noted two periods of active tiller emergence in *Bromus inermis*: mid-March to early May (breaking of winter dormancy through floral initiation) and Mid-June through late July (after anthesis through harvest). Langer (1958) working with meadow fescue (*Festuca elatior*) found a decrease in tillering coinciding with ear emergence and continuing through mid-summer. Tiller production increased from mid-summer through early winter until the original tiller population was reestablished.

Hill et al. (1975) studying tiller development in ryegrass (*Lolium* sp.), timothy (*Phleum pratense*), and prairie grass (*Bromus unioloides*) following autumn seeding found that tillers produced in the first four months of the first year and in the post-harvest through autumn of the second year made the greatest contributions to seedhead number and yield in the respective springs. Langer, et al. (1964) reported a reduction of plant numbers and an increase in tillers per unit area following a fall seeding. The greatest decline in plant number was between March and June in the year following sowing. He reported an increase in tillers per plant (and per unit area) during early winter followed by a decline in the per plant tillering rate.

A decrease in the number of tillers during stem elongation has been reported by several researchers (Lamp, 1952; Langer, 1956, 1958; Ong, 1978; Kim, 73; Meijer, 1984). This is due to a low tillering rate (Langer, 1958), a high rate of tiller mortality (Ong, 1978; Meijer, 1984) or a combination of both. Jewiss, (1972) demonstrated that tillering is restricted during reproductive development and suggested that substances derived from the meristematic centers in the elongating stem or terminal meristem indirectly control metabolic activity of the lateral buds. Meijer (1984) observed that the highest rate of tiller mortality occurred during stem elongation in Festuca rubra. Ong, et al. (1978) determined through radiocarbon studies that the tillers which died during stem elongation were generally small vegetative tillers which did not have well developed root systems and were heavily shaded by elongating stems. They concluded that a major cause of tiller death during this period is due to the failure of favorably placed tillers to support the nutrient status of heavily shaded tillers.

3. The relationship between time of origin, tiller position and tiller fertility

Tiller fertility was found to be higher among early formed tillers and declined with later dates of origin Langer (1956). He found that main stem tillers were more likely to become fertile than secondary tillers and that tiller fertility of main stem axillary tillers was higher than that of secondary axillary tillers. Langer concluded that the probability of a tiller producing an inflorescence depended upon the date of origin, the position of the tiller on the parent axis and the position and age of the parent tiller. Langer and Lambert (1959) and Wilson (1959) noted that there were differences among species as to the time of tiller origin for fertile tiller production. Langer and Lambert (1959) found that orchardgrass tillers present in November produced the majority of inflorescences while in meadow fescue, tillers present in December produced the majority of inflorescences. Wilson noted that the tillers with the highest ear production were formed during winter and early spring in perennial and annual ryegrass and timothy. In orchardgrass (Dactylis glomerata), tillers formed during early winter were more important. Meijer (1984) found that in the Netherlands, high fertility could be expected in red fescue (Festuca rubra) from tillers emerging by mid-November. Earlier (summer) and later (spring) tillers produced fewer seed heads.

In a study of meadow fescue, Lambert and Jewiss (1970) concluded that ontogenetic age was more important than chronological age in determining which tillers became fertile. The major contribution of inflorescences was made by primary tillers in the first year (following sowing), by secondary and tertiary tillers in the second year and by tertiary and quaternary tillers in the third year. The chronological age of flowering tillers varied from 3 to 30 months, however the greatest percentage of fertile tillers included those produced by the end of the previous calendar year. In the year of sowing, tillers produced in September and October produced the most inflorescences while in subsequent years, tillers produced in June and July made a substantial contribution.

Hill and Watkin (1975) in a study of perennial ryegrass, meadow fescue and prairie grass (Bromus unioloides) found that tillers produced during the first four months following an autumn sowing and in the immediate post-harvest period through the autumn of the second year made the most contribution to yield. They noted that these tillers had a lower vegetative mortality rate and that the proportion of reproductive tillers was generally highest among the oldest tillers. The spring formed tillers made a major contribution to the vegetative growth of the plant over summer and early autumn but generally died before winter.

A relationship between inflorescence size and development, and tiller origin during a study of ryegrass, meadow fescue and orchardgrass was observed by Ryle (1964). There was a decrease in the number of spikelets and florets per spikelet which was correlated with a decrease in the number of unexpanded leaf primordia at the shoot apex prior to reproduction. Shoots originating in October and November had about twice as many florets than those arising later.

4. Juvenility, induction and initiation in fescue

The three stages in the flowering cycle of grasses are the juvenile, the inductive, and the initiation stages. Control of flowering involves a series of reactions and responses to environmental conditions. Not all species exhibit all stages or react the same to similar environmental conditions (Calder, 1966). Evans (1964) indicates that perennial grasses requiring vernalization need to be revernalized each year, and that vernalized apices cannot induce other, later-formed apices.

Murray, et al. (1973) exposed field grown red fescue plants to long photoperiods and cool temperatures to initiate floral primordia in an attempt to determine the date of floral induction in the field. The required length of field exposure necessary to induce flowering varied among clones by 30 days. Clones of red fescue exposed to outdoor environment later than March produced no inflorescences and a considerable variation in flowering rates existed between clones (Kim, 1973). He concluded that red fescue required exposure to a cold field environment for inflorescence production, thus tillers produced in early fall are more likely to be fertile.

Bean (1970) noted the presence of a juvenile stage in meadow fescue and tall fescue. After 19 weeks of exposure of 4-leaf red fescue plants to short-day cool-temperature conditions Bean found that only 20% of the plants flowered when placed under continuous day-length.

Meijer (1984) suggests that it is not the duration of the required floral induction period that determines whether early spring tillers of red fescue become fertile but the presence or absence of a juvenile stage where tillers are unable to respond to inductive conditions. He found that an induction period of 12-15 weeks under the appropriate conditions (7°C, 8 hour daylength) was required. Tillers arising closer to the beginning of the vernalization treatment produced fewer inflorescences. Tillers produced after the beginning of the treatment did not flower. He concluded that young tillers and tiller initials cannot be induced and that this demonstrates the presence of a juvenile stage. When compared to late sown bluegrass, tillering rates were higher but tiller fertility was lower in red fescue, while the bluegrass produced fewer tillers in the late autumn and winter but the tillers produced were susceptible to induction and had a high level of fertility.

5. Aerial Tillering

Four types of tillers produced in perennial ryegrass have been described (Minderhoud 1978): (1) normal (unelongated) vegetative tillers with compact internodes and typical leaf and axillary tiller growth, (2) partly elongated vegetative tillers which have 1-3 elongated internodes with axillary tillers typically arising at the upper node, (3) typical elongated reproductive tillers and (4) reproductive tillers with axillary tillers arising at elevated nodes. Tillers formed at nodes above elongated internodes are considered aerial tillers. Others (Lamp, 1952; Langer, 1956; Harberd, 1962; Simons et al., 1974; Chilcote, 1980; Meijer, 1984) have described the presence of aerial tillers under various environmental and management conditions in several species.

Simons et al. (1974) found differences in aerial tillering patterns in two genotypes of S-24 perennial ryegrass, one producing 35% aerial tillers, the other 5%. The clone producing 35% aerial tillers had a lower rate of leaf appearance, longer leaves and more tillers and produced a more dense stand. The percentage of aerial tillers in both clones was increased by spring cutting at a height of 10 cm or by placing mulch around the base of the plants. Aerial tillers were observed growing on the remains of flowering stems following the 10 cm cutting treatment. Low cutting (5 cm) in the spring reduced the proportion of flowering stems and aerial tillers. The percentage of aerial tillers declined as the stand entered the reproductive phase then increased, especially in the mulching and 10 cm cutting treatment. Mulching suppressed the number of total tillers by 20%. The percentage of aerial tillers with more than one elongated internode was greater than the percentage of aerial tillers with only one internode elongated and increased during the experiment.

In a tiller labeling study, Lamp (1952) noted that all vegetative tillers with basal internode elongation of Bromus inermis present in the fall were dead at harvest. He attributed this to winter mortality. Shoots emerging in spring and early summer exhibited internodal elongation whereas shoots emerging after harvest (mid-July) did not show elongation. Langer (1956) observed the presence of elongated vegetative tillers formed prior to August. When the tiller resumed growth after harvest, short internodes were formed. He also observed that these tillers did not survive through the winter as well as unelongated tillers. Both Lamp and Langer suggest that vegetative internode elongation is a daylength response.

Chilcote et al. (1980) observed the presence of aerial tillers in Festuca rubra during studies of post harvest management. Many tillers which developed in the unburned plots in the autumn were of the aerial type. Aerial tillers were not present in the post harvest burn treatments. Meijer (1984) found that Festuca rubra produced aerial tillers when high seeding rates were used, fewer aerial tillers were produced at low seeding rates.

The presence of aerial tillers can have negative effects on vegetative tiller number in the following season. Minderhoud (1978) observed that aerial tillers seemed to suppress normal vegetative tiller formation at the base of the stem, a restrictive reaction similar to that imposed by a normal flowering culm. The ability of an aerial tiller to root (depending upon the length and stiffness of the elongated internode, and placement of the tiller within the plant) determines whether these tillers will act as pseudostolons to enable the spread of the clone. He suggests that aerial tillers are more sensitive to negative environmental factors (frost, drought, unfavorable soil conditions).

Space planted clones of Festuca ovina were studied by Harberd (1962) who described the species as non-spreading due to intravaginal tiller growth. One clone was identified where the lowest stem internodes were elongated so that the tiller producing nodes were held in a dome some distance from the crown. The result of this growth pattern was to allow this particular clone to spread more rapidly than other clones.

II. Effect of Management Practices on Tillering and Seed Production

1. Burning--Species and plant form interactions

Many scientists have studied the effects of burning on native and introduced species in grasslands and rangelands. The results of Curtis and Partch (1948) are typical of these investigations. They studied the potential for reestablishing native prairie species in heavy bluegrass sod through annual burning. Spring burning reduced the bluegrass cover to 1/5 of the pre-burn level through the reduction of both old litter and new stems. Certain prairie grasses were favored by burning while others were reduced in size and cover. Ehrenreich and Aikman (1963) also noted the decline in bluegrass following the burning of native prairies. They suggest the decline in bluegrass is due to injury to crowns and shallow rhizomes. Bluegrass starts spring growth earlier while most prairie grasses are still dormant and is therefore more subject to damage during spring burning of native prairies. They conclude that the extent of injury to bluegrass would depend upon the time of burning, temperature of the fire, amount of fuel and the burning conditions.

In a study of slash pine burning, Lemon (1949) noted that species which are resistant to burning had similar morphological forms. Both *Aristida stricta* and *Sporobolus curtissi* had: leaf meristems located 1.5 inches or more below the soil; close fitting sturdy leaf sheaths that protect live leaf bases from fire; and are densely packed near the ground so that oxygen to support the fire is lacking. Hopkins, et al. (1948) agreed that most burn damage occurred in species which maintain a dormant condition in above ground stems or crowns. Conrad and Poulton (1966) studied plant associations in N.E. Oregon. They observed that Festuca idahoensis (Idaho fescue) was more critically affected by burning than Agropyron spicatum (bluebunch wheatgrass) and attributed the difference in burning sensitivity to plant form. The fescue has a compact root crown area with budding areas at or above the ground level whereas the wheatgrass produces short rhizomes that produce buds below the ground surface where they are less damaged by fire. Countryman and Cornelius (1957), noted similar reductions in Idaho fescue following burning of a Northern California range.

Lloyd (1968, 1972) studied the effects of fire on a Derbyshire grassland and noted the presence of many dead stems of Festuca ovina following burning, compared to Helictotrichon pratense. He suggests that Festuca ovina is easily damaged by fire because of the location of dormant shoot apices just above the soil level and its loosely tussocked growth habit. The Helictotrichon pratense shoot apices are protected by closely fitting tough leaf sheaths and by the compact arrangement of the tillers in the tussock. Most grass species in this association were able to regrow following burning but whole tussocks of Festuca ovina were killed. The result of burning was to select for the more densely tussocked Helictotrichon pratense while reducing the amount of Festuca ovina.

Intra-species response to burning was studied by Beaty et al. (1978) in switchgrass (Panicum virgatum). Certain ecotypes were tuft formers with intravaginal tillering and few short rhizomes while others were sod formers due to a higher percentage of extravaginal tillering. Tuft formers had an elevated crown center 10-13 cm higher than the crown edge. The investigators observed that more of the tufted types died following burning and suggest that this was due to the susceptibility of the higher crown buds to fire.

2. Burning--effects on tillering

Several investigators report that burning increases the rate of tiller appearance on those species which are not severely injured by burning. Burton (1944) found that burned plots of southern grasses started growth earlier. Dormant season burning of native grasses in Iowa (Ehrenreich and Aikman, 1963) generally resulted in an earlier initiation of vegetative growth by 2 to 3 weeks while on the central Missouri prairie, Andropogon gerardi and A. scoparius resumed growth 7 to 10 days earlier (Kucera and Ehrenreich, 1962). Penfound and Kelting (1950) also found earlier growth and better forage utilization in A. scoparius pastures following winter burning. Living shoot biomass increases and a more rapid phenological development were observed as the result of burning big bluestem-Indian grass communities in Illinois (Hadley and Kieckhefer, 1963). Flowering occurred 7 to 10 days earlier in this study. O'connor and Powell (1963) observed that a greater number of tillers were produced on Chionochloa rigida (narrow-leaved snow tussock) following early spring burning in New Zealand. Burnt tussocks tended to have shorter lighter leaves but more tillers (a 50% increase) so the total leaf weight was the same as in the unburned plots.

Late summer (post-harvest) burning has produced similar effects. Chilcote et al. (1980) and Kim (1973) observed that tillering of burned clones was much more rapid than in unburned clones of Festuca rubra and certain other cool season grasses. Tillers in the burned clones were produced at a higher density and were shorter and more prostrate. In spite of clonal reduction due to burning, tiller number per unit area exceeded that of unburned by December due to greater axillary tiller production in the burned clones.

3. Burning--effects on fertile tiller production and seed yield

Burton (1944) observed that burned plots of southern grasses produced more, although somewhat smaller, panicles. Musser (1947) attributed increased yields in post harvest burned red fescue to a reduction in plant disease. He noted that spring burning did not increase yields. Even though the density of bluegrass was decreased due to prairie burning, the flowering stem numbers remained constant or increased slightly (Curtis and Partch, 1948). In their 1950 study of Andropogon gerardi, Curtis and Partch concluded that increased flowering was due to the removal of the insulating blanket of litter and old stems which allowed the plants to initiate growth earlier and produce a favorable carbohydrate reserve prior to floral initiation. Ehrenreich and Aikman (1963) noted an increase in number and height of flower stalks after burning native prairie species. They also attribute these changes to earlier vegetative growth. Lloyd (1968) observed increases in seed yield of Helictotrichon pratense and other minor species the second summer after spring burning in the Derbyshire plant community while Festuca ovina showed no significant variation in inflorescence production. Old (1969) found that early spring burning stimulated flowering and total dry matter accumulation in four prairie grasses. Old concluded that the flowering response of plants was controlled by environmental conditions at the beginning of the growing season rather than at the time of flower stalk production.

Canode (1965) indicates that a decline in seed production of many perennial grasses occurs as the age of the stand increases. In his study, burning of the straw and stubble of Agropyron intermedium in early September was effective in maintaining high seed production. He attributes this to the stand thinning effect of burning which resulted in reduced lodging. Pumphery (1965) studied post harvest burning in Kentucky bluegrass and red fescue. He concluded that the best treatment for maintaining seed yield was to remove residue through burning or mechanical means prior to fall regrowth. Removal after regrowth started severely reduced seed yields the following year.

Kim (1973), Stanwood (1974), and Chilcote et al. (1980, 1981) have studied post harvest management effects of burning in cool season grasses in Oregon. Burning increased seed yields dramatically in red fescue and Chewings fescue. This increase in seed yield is the result of a significantly greater number of panicles per plant although the total number of tillers per plant in the spring was not significantly different. They suggest that the increased number of panicles per plant was the result of a more favorable microclimate, more axillary tiller production, and a greater number of younger tillers with high photosynthetic efficiency exposed to floral inductive conditions. Nordestgaard (1980) found a similar increases in red fescue seed yields in Denmark due to burning, especially in older stands.

4. Clipping--effects on fertile tiller production and seed yield

Many studies of various clipping, cutting or stand thinning treatments have been made to determine the effects of removing live plant tissue and litter on seed production. Pumphrey (1965) found that complete mechanical post harvest residue removal prior to fall regrowth was as effective as burning in maintaining high seed yields in Kentucky bluegrass and red fescue. Partial removal (by baling and removing straw) had an intermediate effect between no removal and complete removal. The effect of clipping on red fescue was studied by Sharp (1964). Various treatments consisting of top clipping, side clipping and no clipping were examined. No effect was found the first year after seeding. Sharp suggests that sod binding does not reduce yields until the second and subsequent years. In these years, yields were maintained at a high level by the removal of all vegetative growth to within three inches of the ground following harvest. Side clipping had no significance whether alone or in combination with top clipping.

Kim (1973) observed that while burned treatments provided the lowest vegetative tiller density and highest fertile tiller density, mechanically removed treatments resulted in the highest vegetative tiller density and a fertile tiller density similar to burned treatments. Unburned control plots were between burned and mechanically removed in the number of vegetative tillers present and had the lowest fertile tiller density. Seed yield was highest in burned, lowest in the control and intermediate between burned and control in the mechanical straw removal plots. Stanwood (1974) noted that when residue was mechanically removed there was less axillary tillering and a reduced number of fertile tillers when compared to burned plots. Chilcote, et al. (1981) summarizing several years of work in Oregon, concluded that mechanical residue removal (close-clip and vacuum) was superior to flail chop treatments but not as effective as burning in increasing seed yields. They suggest that the more completely the residue is removed, the better the seed yield will be.

Lloyd (1972) compared the effect of early spring burning and clipping on a *Helictotrichon pratense-Festuca ovina* grassland. While burning increased the number of inflorescences in *H. pratense* and severely injured the *F. ovina*, clipping had no effect on inflorescence production in either species. In a study of four prairie grasses in Illinois, Old (1969) found that flowering and dry matter production was stimulated by early spring cutting and litter removal but to a less extent than burning. Similar findings were made by Penfound (1964), O'connor and Powell (1963), Curtis and Partch (1950) and Ehrenreich and Aikman (1963).

Branson (1953), studying the effects of grazing on various grasses noted that elevated growing points occurred in different species at different times during the growing season. He concluded that stand and species losses due to grazing were dependent upon the location of the growing point and the ratio of fertile to vegetative tillers. Minderhoud (1978) and Simons et al. (1974) conclude that aerial tillers are easily damaged by grazing or clipping. Simons et al. further suggest that the percentage of aerial tillers can be increased by lax (10 cm) cutting and can be reduced by close cutting or grazing. They suggest that the percentage of cut flowering stems on which aerial tillers can form should be reduced to reduce the number of sites on which aerial tillers can form.

Canode (1965) found that removing every other foot of row by mechanical means improved seed yields equal to burning in sod bound Agropyron intermedium and the effect of burning and thinning were additive. Chiseling did not produce seed yields as high as burning or mechanical thinning.

5. Burning method

The method of post harvest burning has been studied. Properly managed machine burning has produced seed yields in red fescue equal to open burning (Youngberg, 1980).

III. Microclimate Effects of Management Treatments

Many researchers have measured changes in microclimate conditions resulting from residue removal through clipping or burning and suggest that these microclimate changes may be responsible, in part, for changes in tillering habit and seed yield.

1. Light intensity

Ryle (1967) studied the effects of reduced light on inflorescence development in temperate grasses through the use of shading treatments. Shading delays or inhibits the onset of reproduction, reduces the proportion of fertile tillers, and decreases the size of inflorescences. There were differences in the effect of reduced light intensities on different species. Old (1969), applied mulch to burned plots and observed that flowering was inhibited but the effect depended upon the time of mulching and the amount of litter applied. In greenhouse experiments, Old found that artificial shade in the first 2 1/2 months of the growing season would decrease flowering in August. Kim's (1973) results with mulching burned plots were less conclusive but artificial shading reduced seed yield in burned and mechanically removed plots but did not appreciably change seed yield in control plots. Curtis and Partch (1950) also found that placing mulch over burned plots would reduce the level of flowering but the burned plots still responded better than the clipped plots. They suggested that there must be some additional response to burning than strictly the effect of litter removal. Weaver (1952) found that non-mulched plants produced new shoots about three weeks earlier. Mulching reduced dry matter yield and reduced basal diameter of individual plants. Non-mulched shoots were taller with more unfolded leaves. Simons et al. (1974) found that mulching increased the percentage of aerial tillers similar to lax clipping.

Ensign et al. (1983) compared mechanical clipping at three heights (2.5, 7.6, 15.2 cm) with shading, burning and no removal treatments in Kentucky bluegrass. Tiller numbers from plants clipped at the lower two heights were comparable to tiller numbers of plants shaded at the 30% level. Tiller numbers from plants clipped at 15.2 cm and plants with no residue removal were comparable to plants shaded at the 67% level. Leaf and sheath length were inversely related to the level of residue removal and shading. Seed yields for the artificially shaded plants were 51-55% less than the no removal treatment. They concluded that reduced light penetration could change plant growth and reduce seed production potential.

2. Soil and air temperature

Kim (1973) reported differences between burned and unburned treatments in soil temperature at a soil depth of 2.5 cm. Both the day and night temperatures were lower than the unburned plots, however the temperature fluctuation between day and night temperatures was greater in the burned plots. At the ground level, day temperatures of the unburned plots were higher while nighttime temperatures were lower. These measurements were taken during the fall regrowth period. Weaver and Roland (1952) found much reduced soil temperatures under mulch and suggested that a thick stand of grass would have much the same effect in reducing soil temperatures. Ehrenreich noted that soil temperature was inversely related to the amount of litter present and that the higher soil temperatures were due to the removal of insulating litter and exposure of the dark soil surface to solar radiation. Old (1969) reported an increase in temperature from 50 cm above ground to 5 cm below ground following burning. Old concluded that this temperature has a direct effect by increasing photosynthetic efficiency and by the stimulation of the microbial release of nitrogen and phosphorus. Chilcote et al. (1980) suggests that a greater diurnal temperature variation would reduce respiration and contribute to more effective floral induction.

3. Soil moisture

Penfound and Kelting (1950) noted little change in soil moisture after burning. Weaver and Roland (1952) studied the effects of mulch on the interception and retention of moisture. Mulch intercepts water and allows it to evaporate before reaching the soil but also aids in water infiltration if the amount of rain is sufficient to penetrate the litter. Soil water evaporation is much less under the mulch. Ehrenreich (1963) found that soil moisture remained adequate in burned plots but suggested that burning could be a factor in areas where soil moisture is limiting. This moisture depletion would be caused by greater transpiration from more rapidly developing vegetation and greater evaporation from the soil surface. Ensign et al. 1983 found that soil moisture was not affected by the level of shading in a year when soil moisture was limiting but was reduced over other treatments by close clipping, burning and limited shading when sufficient moisture was present.

4. Nutrient cycling

Ehrenreich (1963) reported an increase in phosphorus in the top .75 inch of soil following burning. He suggested that this may be important if the natural level of phosphorus is low and may contribute to more rapid plant development and earlier maturity. He observed a slight increase in pH but no effect of burning on soil volume weight, pore space, exchangeable potassium, nitrate production or total sub-surface organic matter. Curtis and Partch (1950) noticed a small additional increase in flower production when residue from a clipped plot was burned and the ashes spread over the plot. Lloyd (1971) observed that substantial losses of nitrogen, phosphorus and potassium occur in the smoke. Potassium is readily leached from ash but phosphorus and calcium are less soluble. There was a short lived increase of phosphorus in plant tissue and in one case an increase in nitrogen. Lloyd concluded that the effects of fire are unimportant relative to the damage caused to the plants and the alterations in the physical environment. Boerner (1982) suggests that since fire affects above ground tissues and detritus, the impact on grasslands which have most nutrient storage below ground is limited. Boerner agrees with Lloyd by suggesting that grass plant responses to burning are primarily a result of microclimate alteration.

IV. Comparison of Hard Fescue and Chewings Fescue

A considerable difference of opinion exists in the naming and classification of variations within the portion of the *Festuca* genus known as the fine fescues. This group consists of the fine bladed, cool season *Festuca* species which are adapted for turf and some erosion control and range uses. This study is concerned with two members of this group known commonly as Chewings fescue and hard fescue.

1. Hard fescue

Hubbard (1954) describes hard fescue (*Festuca longifolia* Thuill.) as a densely tufted perennial, 15-70 cm high with erect culms or culms bent slightly at the base. Hard fescue is further described as drought resistant, widespread in Europe and is commonly sown on road banks, parks and sports fields in well drained stony or sandy soils. Hubbard suggests that the name *F. duriuscula* has been improperly applied to this grass.

Hafenrichter, et al (1968) states that hard fescue (*Festuca ovina* var. *duriuscula* (L.) Koch) is a variety of sheep fescue (*Festuca ovina* L.). Hubbard (1954) would divide sheep fescue (*F. ovina* L.) and hard fescue (*F. longifolia* Thuill.) into separate species of very fine leaved fescues. Hafenrichter states that this introduced species is widespread in the United States intermountain area and is adapted to well-drained medium acid to mildly alkaline soils of relatively low fertility. Principle uses include cover for erosion control, recreation areas and livestock grazing. Hafenrichter notes that hard fescue is slow to establish but once established is long lived with especially high root production.

Meyer (1985) describes hard fescues as "survivors" because of their ability to tolerate dry infertile soils and shade and because of their improved disease resistance when compared to commonly grown cultivars of Chewings and creeping red fescues. Improved hard fescue cultivars are more persistent in turf and have a reduced rate of vertical growth compared to other fine fescues. The germination and establishment rates of hard fescue are slower than Chewings and creeping red fescues. Advantages to using hard fescue cultivars in turf include: their ability to retain an attractive deep green color in summer and under moderate drought conditions, their ability to produce suitable turf under low maintenance, and their resistance to diseases such as red thread, dollar spot, rust fungi and powdery mildew.

Hard fescues are recognized as easily damaged by post harvest burning of seed fields (Youngberg, 1980). This limits their commercial availability since seed production decreases after 2 or 3 years (Meyer, 1982). Breeding work is being done to select clones which will have improved seed yields over a longer period of time in the absence of field burning.

2. Chewings Fescue

Described by Hubbard (1954) as a densely tufted perennial, 20-60 cm high, Chewings fescue (*Festuca rubra* L. subsp. *commutata* Gaud.) is distinguished from red fescue (*F. rubra* L.) by the absence of creeping rhizomes. The name "Chewings fescue" is from a Mr. Chewings who first sold seed in New Zealand. It is now widely distributed due to its use as a turf grass. Other names associated with Chewings fescue are *F. fallax* Thuill. and *F. rubra* var. *fallax* Hack. (Beard, 1973).

Chewings and red fescues are similar in turf performance, both producing a fine textured dense turf. Chewings fescue tolerates closer mowing than creeping or spreading red fescues but are similar in to the creeping or spreading types in fertility requirements, shade tolerance and disease resistance. Chewings is described as being an aggressive turf former which may be competitive with Kentucky bluegrass in mixtures (Meyer 1982). Red fescues require more moisture than hard fescues and are suitable for soil conservation uses where sufficient moisture is present (Hafenrichter, et al. 1968).

Several studies (Kim, 1973; Stanwood, 1974; Chilcote et al., 1980, 1981) have evaluated the effect of field burning on seed production in red and Chewings fescues. These studies indicate that burning increases seed yields or maintains seed yields at high levels over the length of the stand. Post harvest burning has become the standard practice in red and Chewings fescue seed production in Western Oregon. These studies are discussed in detail elsewhere in this review.

MATERIALS AND METHODS

This study was conducted on Field 7, Range 7 of the Schmidt Experimental Farm Unit of the Hyslop Field Laboratory located near Corvallis, Oregon during the 1980-1981 growing season. This range was planted in June, 1979, with 7 hard fescue, Chewings fescue and red fescue cultivars for the purpose of evaluating different post-harvest residue management techniques.

The following cultural practices were applied after planting:

March 27, 1980--Spot sprayed with glyphosate
March 28, 1980--21-0-0 at 67 kg ha^{-1}
April 17, 1980--Spot sprayed with glyphosate
April 17, 1980--0.28 kg ha^{-1} dicamba + 0.56 kg ha^{-1} 2,4-D

On July 1, 1980, seed moisture levels were determined for all cultivars. Based on seed moisture levels and visual observations of maturity, Waldina and Scaldis hard fescue and Koket Chewings fescue were selected for this study. These cultivars appeared to mature at about the same time and were representative of commonly grown commercial cultivars of hard and Chewings fescue.

The field was harvested on July first. Components of yield were determined for the three cultivars selected for this study. The field was then flail chopped and excessive stubble was removed prior to applying the treatments.

I. Experimental Design and Treatments

The experiment was designed as a split plot with four replications. The three cultivars were main plots and post harvest management treatments were sub-plots. The four post harvest management treatments were applied as follows:

1. Early Crewcut: Applied on July 10, 1980. This treatment was a close clip and vacuum treatment applied using a machine which clipped then removed all plant material to a height of 2.5-5.0 cm above the soil surface. Previous research (Kim, 1973; Chilcote, 1980) indicated that this treatment is similar to field burning in its effects on seed yield and has been the best non-burn residue management treatment.

2. Late Crewcut: Applied on October 3, 1980 in the same manner as the early crewcut treatment. Late treatments were applied in order to study the effect on development of tillers initiated later in the growing season.

3. Early Burn Treatment: Applied on August 20, 1980. A propane fired, forced air field sanitizing machine was used to simulate open burn field conditions. Machine burning has been shown to be as effective as open burning of red fescue and has the advantage of applying a more uniform treatment than an open field burn. All remaining plant material was burned completely or charred to ground level (Figure 1). This treatment was designed to simulate an open field burn which is a normal management practice in red fescue and Chewings fescue seed fields.

4. Late Burn: Applied on September 26, 1980 in the same manner as the early burn treatment.

II. Cultural practices

During the growing season the following cultural practices were

Figure 1. Application of early burn treatment, August 20, 1980.

employed:

October 10, 1980--16-20-0, 67 kg N ha^{-1}
October 22, 1980--Simazine, 80W, 2.5 kg ha^{-1}
March 13, 1981--Ammonium nitrate, 106.5 kg ha^{-1}
April 17, 1981--Spot sprayed with glyphosate.

III. Description of Cultivars

Cultivars selected for this study were Waldina and Scaldis hard fescue and Koket chewings fescue. Scaldis and Waldina (Festuca longifolia Thuill.) are both prostrate in form with a dark green leaf color. Waldina is slightly earlier in maturity and slightly shorter than Scaldis when grown under Netherlands conditions. Waldina has further been described as faster in emergence and stronger in vigor when compared to Scaldis (Glas, 1978). Both cultivars are comparable to other hard fescues in their response to burning under field conditions in that seed production is reduced following burning. Even though some new selections (e.g. Aurora) seem promising in the increased number of fertile tillers produced and less reduction in yield as the stand matures these new selections respond negatively to field burning in a manner similar to Scaldis and Waldina (Meyer, 1986).

Koket (Festuca rubra L. subsp. Commutata Gaud.) is reported to be typical of the early maturing, high yielding Chewings fescues. It is relatively quick to establish and responds positively to field burning by maintaining high yields through the length of the stand. Management of this cultivar is said to be similar to other chewings fescue cultivars (McCarthy, 1986).

IV. Sampling, Measurements and Evaluation

Hard and fine fescues produce a relatively large population of tillers per unit area compared to other species such as ryegrass or orchardgrass. Samples representing strips of row sufficient to provide 200-400 tillers for counting and analysis were selected at random and removed from the field on November 7, and December 30, 1980, February 15, May 1, and June 15, 1981. The samples were held in refrigerated (7°C) storage until sample analysis could be completed. During sample analysis, the row strips were measured to determine the unit area being sampled. The soil was moistened, if necessary, so that intact tiller units could be separated from the soil.

Data collected included total tiller units, total tillers, basal units, basal tillers, aerial units, aerial tillers, multiple units, multiple tillers, leaf length, sheath length, length of first internode and dry weight (dried at 80°C for 24 hrs). From this data, calculations were made for tillers per basal, aerial and multiple tiller units, and dry weight per tiller. Tillers were further classified as fertile or vegetative in the May and June samples and similar data was collected on both fertile and vegetative tillers. All tiller counts and measurements were made on tillers which were visible to the naked eye with a minimum amount of dissection.

Sampling methods remained consistent throughout the experiment except for the collection of harvest data. Plots were harvested by removing 929 cm^2 quadrants on July 1, 1981. Seed yield, number of fertile tillers per unit area, 1000 seed weight and seeds per fertile tiller were determined.

Analysis of variance and protected least significant differences were calculated when appropriate. In the case of aerial tiller measurements where few tillers or no tillers were present in some samples a square root transformation (square root of X + 0.5) was used to give meaningful results (Steel and Torrie, 1960).

Statistical analysis was done with the aid of the MSUSTAT program (Lund, 1985) developed at Montana State University.

RESULTS

The early crewcut treatment, applied July 11, removed all residue and plant material to 2.5-5.0 cm (Figure 2). Variation in cut height was due to irregularities in the soil surface, differences in crown elevation, and tiller orientation in relation to direction of travel of the cutting machine. Longer stubble remained on the edges of the plant oriented in the opposite direction of machine travel. Small vegetative tillers at the edges of plant rows survived the crewcut treatment.

Immediately after harvest the plot area was flail chopped to cut and distribute the remaining stubble uniformly across the plot. This treatment, through the redistribution of harvest litter on a more or less uniform basis, may have reduced the number of plants which were completely destroyed by burning because of excessive fuel. Plant mortality in both varieties was probably less than expected under grower field conditions but the uniformity of regrowth was increased across the plots.

The early burn treatment, applied August 20, destroyed most of the remaining harvest litter and green material (Figure 3). Where old stem bases remained, new tillers emerged within two weeks (Figure 4). Following burn treatment, new emerging tillers were generally of the basal type.

New tillers emerged almost immediately following crewcutting, and after two weeks most plants had actively growing tillers. One month after treatment, tillers had 2-3 leaves and some axillary tiller development had extended above cutting height (Figure 5).

Figure 2. Waldina immediately after early crewcut treatment, July 10, 1980.

Figure 3. Waldina plot after early burn treatment, August 20, 1980.

Figure 4. Waldina row section after early burn treatment, August 20, 1980. Individual plants with some unburned old stems.

Figure 5. Waldina after early crewcut treatment, August 16, 1980. Aerial tiller regrowth observed from old stems, some basal regrowth where old stems are less dense.

Where present, aerial tillers were more common in the hard fescue cultivars. Most Chewings fescue tillers were basal type with few elongated internodes although some were observed (Figure 6). Many hard fescue tillers were produced on old stems above elongated internodes (aerial tillers) (Figure 7) and many tiller units of both species produced both aerial and basal types (Figures 8, 9).

Although new tillers emerged following the early burn and early crewcut treatments, significant regrowth did not occur until late September (four weeks after treatment) following cooler temperatures and fall rains. Late burn and late crewcut treatments were applied September 26 and October 3, respectively, after more vigorous regrowth stared. Photographs on October 6 show the regrowth on the early crewcut (Figure 10), early burn (Figure 11), and the experimental plot with all treatments applied (Figure 12).

Approximately one month after the late treatments were applied, sufficient regrowth had occurred on the majority of the plants to provide plant material for tiller evaluation. The first counts were made on November 7.

The growing season was slightly below normal in precipitation during July-October, 1980 and above the 30-year average (+9.04 cm) during December (Appendix, Table 45). Precipitation during January-April was below the 30 year average and May-June slightly above. Temperatures were near normal except for slightly higher (1.44^{o}C) minimums during November and December, 1980.

Figure 6. Koket tiller with elongated internode after early crewcut treatment, August 16, 1980.

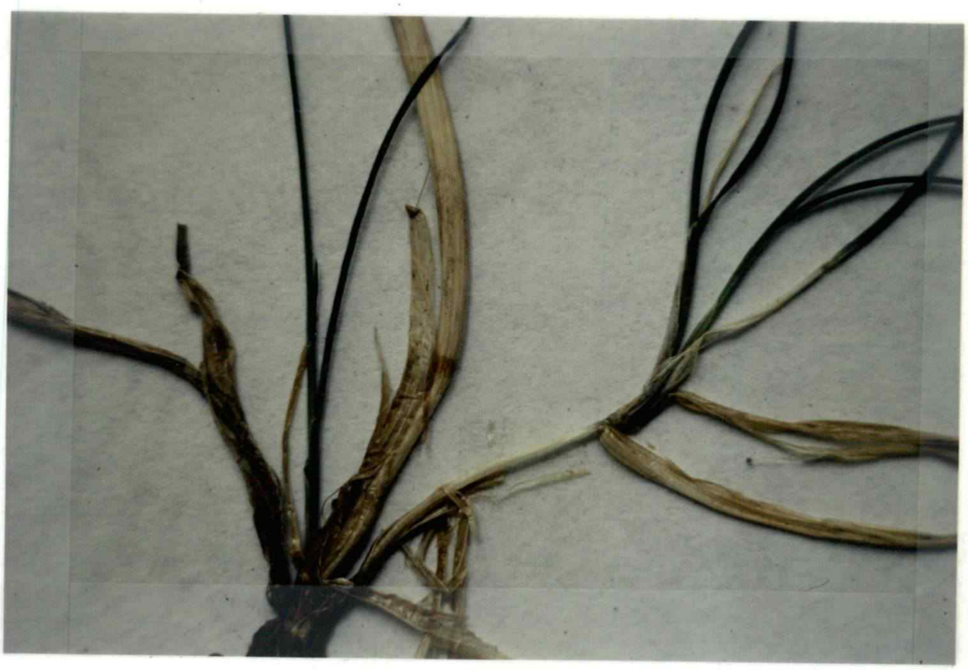

Figure 7. Scaldis tiller unit after early crewcut treatment, August 16, 1980. Both aerial (right) and basal (left) tillers were observed on one tiller unit.

Figure 8. Waldina tiller units after early crewcut treatment, August 16, 1980. Right tiller unit was more closely cut, has basal tillering. Left is from row edge with both aerial and basal tillers.

Figure 9. Waldina tiller after early crewcut treatment, August 16, 1980. Tiller was 16 cm. long, escaped crewcut treatment. Top three nodes shown, all with aerial tillers.

Figure 10. Koket plot after early crewcut treatment, October 6, 1980.

Figure 11. Koket plot after early burn treatment, October 6, 1980. Yellow markers were an attempt to label tillers, labeling proved unsatisfactory due to high tiller mortality during handling.

Figure 12. Plot after all treatment applications, October 6, 1980. Foreground to first flag: border (flail chop), early crewcut, late crewcut, early burn, late burn. Koket strip in center, hard fescue cultivars on either side.

I. Tillers Per Unit Area

1. Total tillers

Tiller development in each of the cultivars and management treatments followed the normal pattern of increasing during the fall and winter, reaching a maximum in the early spring, then declining until harvest (Table 1). The burn treatments reduced the number of tillers per unit area and delayed new tiller formation, particularly the later burn (Figure 13).

Table 1. Total tillers dm^{-2} by cultivar and management, all sample dates, 1980-81.

Treatment	Date				
	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	137.3	232.0	335.8	311.0	299.9
Scaldis	97.9	190.3	346.8	333.9	293.9
Koket	87.8	192.6	368.1	237.0	148.9
LSD P <0.05		NS		26.9	26.6
Management					
E-burn	99.2	206.3	392.5	337.3	266.2
L-burn	50.5	135.8	309.9	312.6	262.9
E-ccut	170.0	241.9	326.7	253.1	212.5
L-ccut	110.9	235.9	371.9	273.0	248.7
LSD P <0.05		37.7		21.5	NS
C x M	*		**		

* Interaction significant P <0.05
** Interaction significant P <0.01

There was a significant cultivar x management interaction on November 7. The early crewcut treatment had the greatest tiller development and the late burn the least (Table 2). The early burn and crewcut treatments were intermediate in tiller development. The late

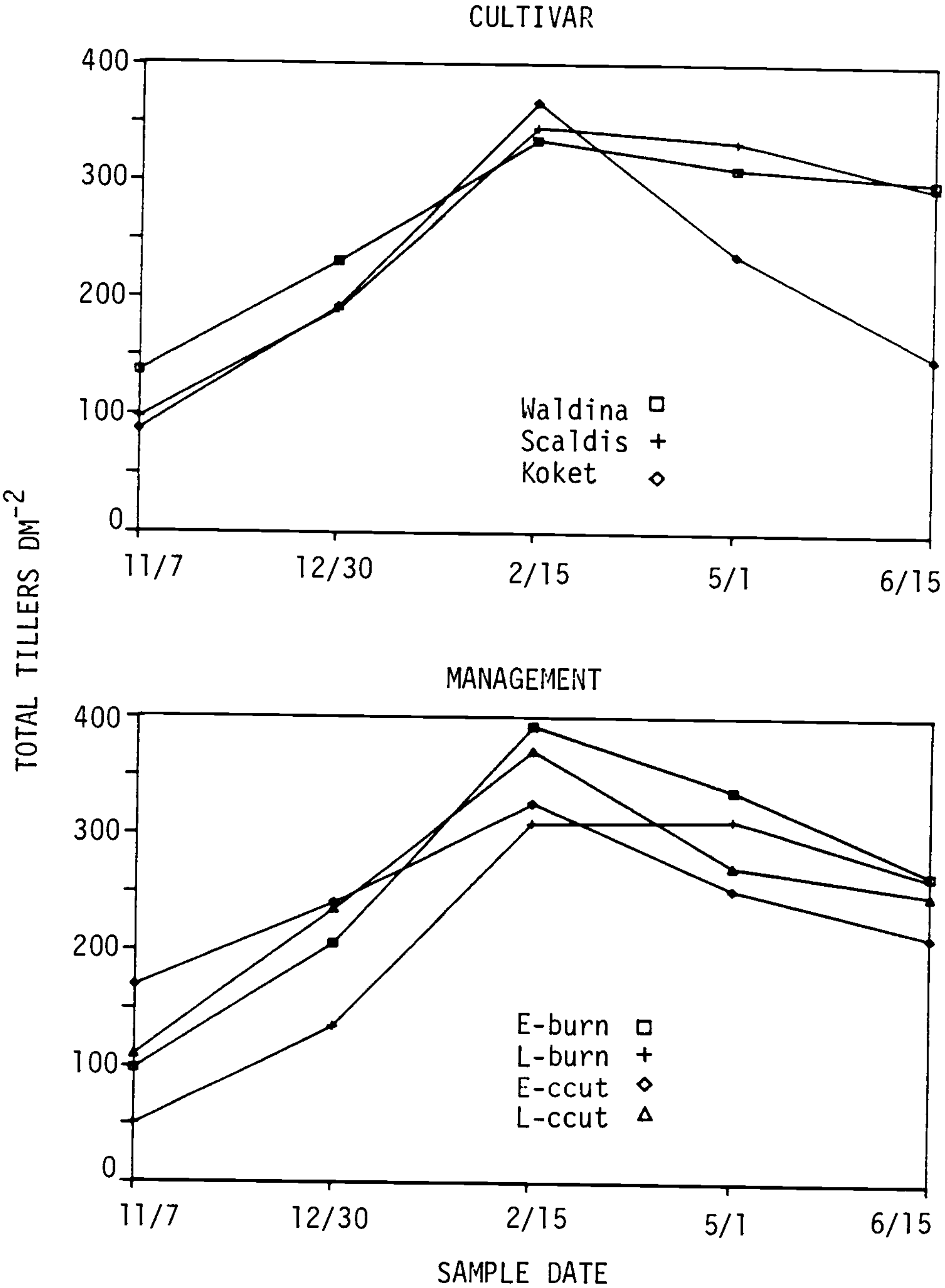

Fig. 13. Total tillers in response to cultivar and management, all sample dates, 1980-1981.

burn delayed formation of new tillers.

Table 2. Total tillers dm^{-2} within cultivars, November 7, 1980.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	122.3	67.6	107.7
L-burn	54.8	47.2	49.4
E-ccut	219.9	177.1	113.0
L-ccut	152.3	99.7	80.8

LSD P <0.05 for means within cultivars = 49.9

The hard fescues had a greater number of tillers in early November following the crewcut treatments than the Chewings fescue.

By the end of December, sufficient regrowth had occurred in the early burn and late crewcut treatments so that no significant difference in total tiller number among cultivars was observed. The late burn had 40% fewer tillers than the other management treatments at this stage of growth.

All cultivars reached the highest tiller population observed during the crop year at the February observation. Tiller populations as a result of management was also highest except for the late burn treatment which peaked in May.

The cultivar x management treatment interaction was highly significant (P <0.01) in February. The greatest number of tillers in the hard fescue cultivars was from the late crewcut treatment (although not significant P <0.05 in Waldina) while the early burn produced the largest number in the Chewings fescue, Koket (Table 3). There was no difference in total tiller number in response to management (except the late crew cut in Scaldis which was higher). In Koket Chewings fescue the early burn management had 94% more tillers than the early crewcut. This is agreement with observations of Chiclote et al. (1980).

Table 3. Total tillers dm^{-2} within cultivars, February 15, 1981.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	329.6	301.9	546.1
L-burn	280.8	314.1	334.9
E-ccut	356.0	341.7	282.4
L-ccut	376.9	429.5	309.3

LSD P <0.05 for means within cultivars = 103.7

Both cultivar and management differences were significant on May 1. Tiller population declined from February 15 to May 1 in all three cultivars and in all treatments except the late burn. Koket Chewings fescue had the highest number of tillers in February and the lowest in May. The two hard fescue cultivars also had fewer total tillers in May but the loss was less dramatic than in the Chewings fescue.

The early burn management treatment produced the highest number of tillers and was significantly different from the early and late crewcut treatments. The early crewcut management resulted in the fewest tillers per unit area in May.

By mid-June the greater tiller mortality in the burn treatments erased the management treatment results observed on May 15.

Between May 1 and June 15 total tiller number in the hard fescue cultivars declined relatively little and there was no difference in the tiller population at harvest. On the other hand, the tiller population in Koket Chewings fescue declined 47% from May 15 and 60% from February 15.

Differential response due to cultivars and management were observed during the growing season as tillers developed and died due to competition and other factors. Koket Chewings fescue recovered from the burn treatments earlier in the season. The hard fescues recovered from the burn more slowly but attain the same maximum tiller population in mid-Feburary as the Chewings fescue. They maintained a higher tiller population until harvest.

2. Basal tillers

Basal tillers are defined as those produced from growing points not elevated (produced above elongated internodes). These tillers are in the best position to survive and contribute to plant vegetative reproduction and seed yield.

Basal tiller number, like total tillers, differed with cultivar, management, and there was a cultivar x management interaction over the course of the growing season. By November 7, highly significant differences in basal tiller number were observed between management treatments but none due to cultivars (Table 4). The late management treatments had only 43% as many basal tillers as the early treatments and this difference carried into the December 31 sampling date (Figure 14). By February 15, the early burn treatment had 30% more tillers than the other treatments.

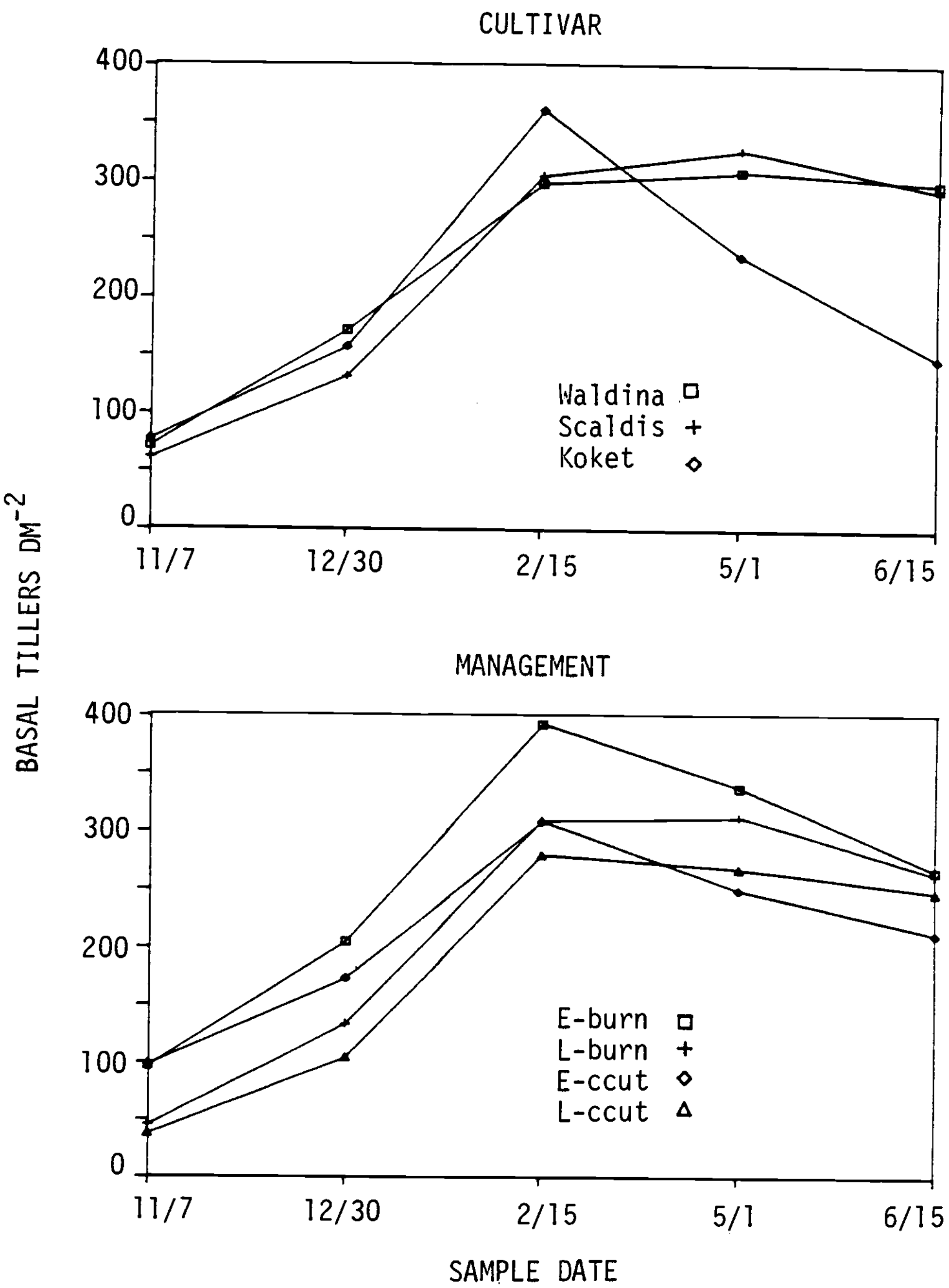

Fig. 14. Basal tillers in response to cultivar and management, all sample dates, 1980-1981.

Table 4. Basal tillers dm^{-2} by cultivar and management, all sample dates, 1980-81.

Treatment	Date: Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	71.4	172.5	299.5	309.7	299.2
Scaldis	61.5	133.0	306.5	328.4	293.2
Koket	77.4	158.5	361.7	237.0	148.9
LSD P <0.05	NS	18.1			65.5
Management					
E-burn	97.6	205.5	392.5	337.3	266.1
L-burn	45.6	134.3	309.6	312.6	262.9
E-ccut	99.1	173.8	308.5	249.4	211.7
L-ccut	38.1	105.1	279.8	267.6	247.7
LSD P <0.05	17.1	42.9			NS
C x M			*	*	

* Interaction significant P <0.05

The percentage of basal tillers was lower in the hard fescue across all treatments but the total number of tillers produced in the early crewcut treatment was higher (Table 5). In the Chewings fescue, the total number of tillers was not greatly different in the early crewcut and early burn treatments but the percentage of basal tillers was higher across all treatments. These cultivar x management relationships contributed to the non-significance of differences in cultivars and between early crewcut and early burn treatments. A similar relationship also occurred in the late burn and late crewcut treatments.

In December, the late treatments had a much higher percentage increase in basal tillers than early treatments over that recorded in November.

Table 5. Basal tillers as a percentage of total tillers by cultivar and management, all sample dates, 1980-81.

Treatment	Date: Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
	(%)				
Cultivar					
Waldina	52.1	74.4	89.2	99.4	99.8
Scaldis	68.8	69.9	84.7	98.4	99.8
Koket	88.2	82.3	98.3	100.0	100.0
Management					
E-burn	98.4	99.6	100.0	100.0	100.0
L-burn	90.1	98.9	99.9	100.0	100.0
E-ccut	58.3	71.8	94.4	98.5	99.6
L-ccut	34.6	44.6	75.2	98.1	99.6

Cultivar x management interactions ($P < .05$) were observed in samples collected February 15, 1981. Sufficient numbers of basal tillers were present in the late treatments in the hard fescues that no differences among management treatments were observed in the hard fescue cultivars. In the Chewings fescue, the early burn treatment had the highest number of basal tillers observed during the entire season. In February, basal tiller populations were at the highest level recorded during the growing season for Koket and for the early burn, early crewcut and late crewcut treatments (Table 6).

Table 6. Basal tillers dm^{-2} within cultivars, February 15, 1981.

Treatment	Cultivar: Waldina	Scaldis	Koket
E-burn	329.6	301.8	546.1
L-burn	279.9	314.1	334.9
E-ccut	326.7	319.5	279.4
L-ccut	262.0	290.7	286.6

LSD $P < 0.05$ for means within cultivars = 110.5

Basal tiller populations declined in Koket and in all treatments except late burn between February and May. Basal tiller populations increased slightly or remained the same in the hard fescues and in the late burn treatment. Cultivar x treatment interactions ($P < 0.05$) occurred in the May 1 samples (Table 7).

While the highest basal tiller population occurred in the early burn treatment in all cultivars, there was no significant difference between the early burn and late burn treatments in Scaldis and between the early burn, late crewcut, and late burn treatments in Koket.

In the final sampling prior to harvest, the population of hard fescue basal tillers had declined only slightly from May levels but was reduced by 37% in Koket.

Table 7. Basal tillers dm^{-2} within cultivars, May 1, 1981.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	330.3	403.9	277.6
L-burn	316.7	371.8	249.2
E-ccut	292.1	298.8	157.3
L-ccut	299.8	238.9	264.1

LSD $P < 0.05$ for means within cultivars = 75.7

Since Basal tillers accounted for the largest proportion of total tillers, trends for these populations tend to follow the same seasonal patterns as total tillers.

Early post harvest management treatments favored the development of highest population of basal tillers. This effect carries into the early spring. Later, cultivar x management interactions occur and by June cultivar effects became important as basal tiller populations increased in the late management treatments.

Koket Chewings fescue produced more basal tillers by February than the hard fescue cultivars as a result of the early burn treatment. By the end of the season, Koket had the fewest basal tillers across all treatments. Basal tiller populations in the hard fescue cultivars tended to peak later in the season and did not decline as rapidly as in Chewings fescue, although differences were not always significant.

Cultivar x management treatment interactions in February and May indicate that the three cultivars respond differently throughout the growing season.

3. Basal units and tillers per basal unit

Buds formed in leaf axils of tillers can form additional tillers (axillary tillers). Further tiller formation can occur from axillary tiller buds. Tillers are ranked in order of formation as primary, secondary, tertiary, etc. A tiller unit consists of a primary tiller and subtending axillary tillers which are interconnected through vascular tissue at the stem base. The number of basal units and the number of tillers per basal unit were evaluated to determine cultivar differences and effects of post harvest management.

a. Basal units per unit area. By November, the late crewcut treatment had fewer basal tiller units than the other three management treatments (Table 8, Figure 15). By December the late crewcut basal tiller unit population had increased and was not different from others. There were no significant differences in December.

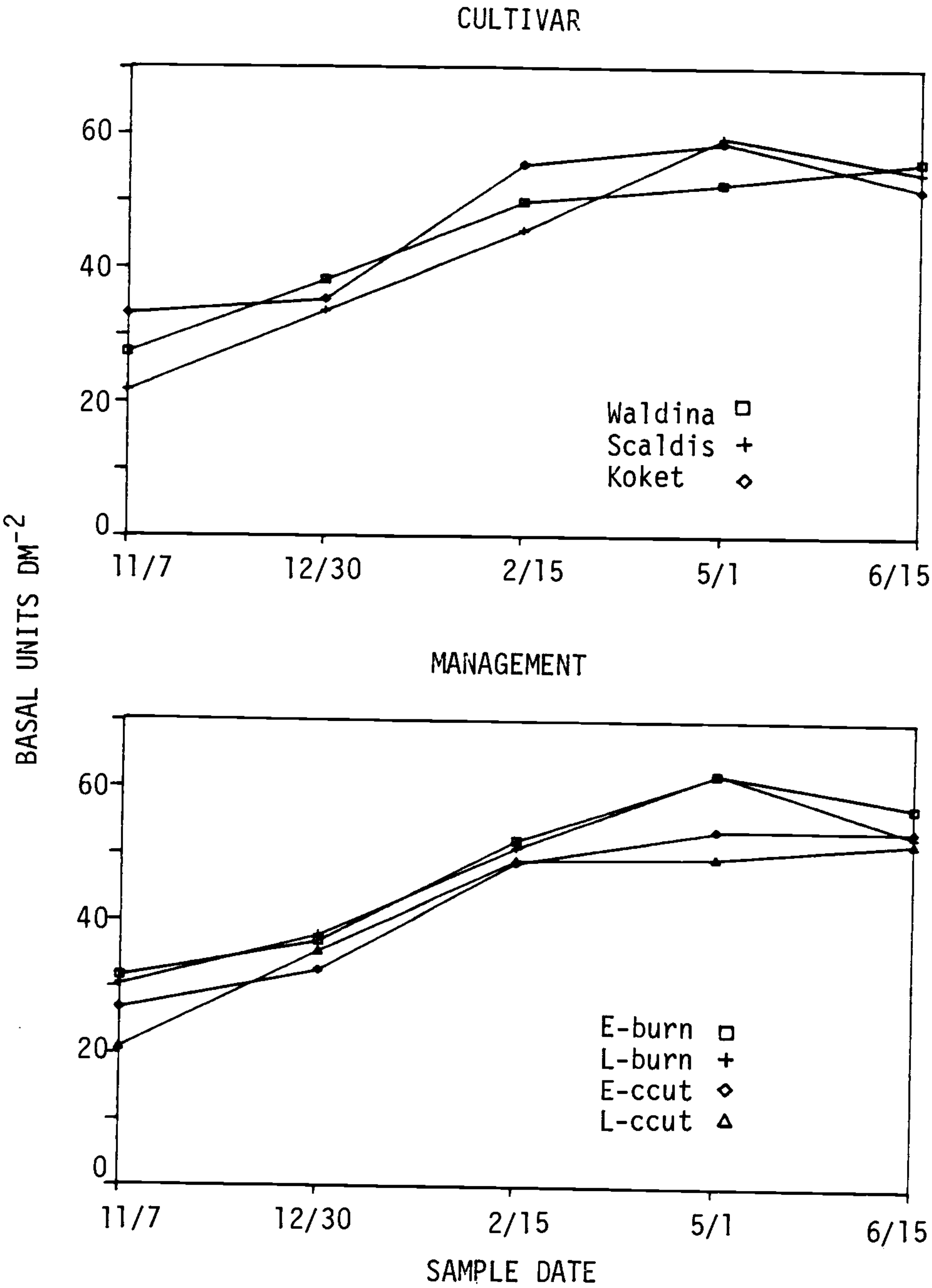

Fig. 15. Basal units in response to cultivar and management, all sample dates, 1980-1981.

Table 8. Basal units dm^{-2} by cultivar and management, all sample dates, 1980-81.

Treatment	Date				
	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
	(%)				
Cultivar					
Waldina	27.5	38.4	50.0	52.7	56.2
Scaldis	21.8	33.8	45.8	59.6	54.4
Koket	33.2	35.5	55.6	58.8	51.9
LSD P <0.05	NS	NS		NS	NS
Management					
E-burn	31.7	37.1	52.4	62.2	57.4
L-burn	30.5	38.1	51.2	62.3	53.1
E-ccut	26.9	32.7	49.0	56.9	53.9
L-ccut	21.0	35.6	49.4	49.8	52.2
LSD P <0.05	8.0	NS		NS	NS
C x M			**		

** Interaction significant P <0.01

A cultivar x management interaction (P <0.01) occurred in February. No management differences were noted in Waldina Chewings fescue (Table 9). In Scaldis, the early burn treatment produced the lowest number of basal tiller units and the late burn the highest. In Koket, the early burn produced the highest number of basal tiller units.

Table 9. Basal tillers dm^{-2} within cultivars, February 15, 1981.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	45.2	40.0	71.9
L-burn	48.0	52.4	53.4
E-ccut	53.1	44.4	49.6
L-ccut	54.0	46.5	47.6

LSD P <0.05 for means within cultivars = 11.8

No differences in basal tiller unit population were noted in May and June samples.

The basal tiller unit population followed a slightly different pattern than total basal tiller population. The number of basal units peaked one or two months later than basal tiller populations. In June, significant differences due to cultivar were observed in basal tiller population but not in basal tiller units.

In Koket, the basal tiller unit population did not decline as rapidly as the very rapid decline in basal tillers between May and June. Other than differences observed due to interactions (February) the cultivars responded in a similar fashion with no obvious difference among cultivars.

The burn treatments tended to produce slightly more basal tiller units early in the autumn.

b. Tillers per basal unit. The number of tillers per basal unit is a measure of the ability to produce axillary tillers which may become fertile or compete with fertile tillers late in the season. Tillers per basal unit were counted at each sample date (Table 10, Figure 16).

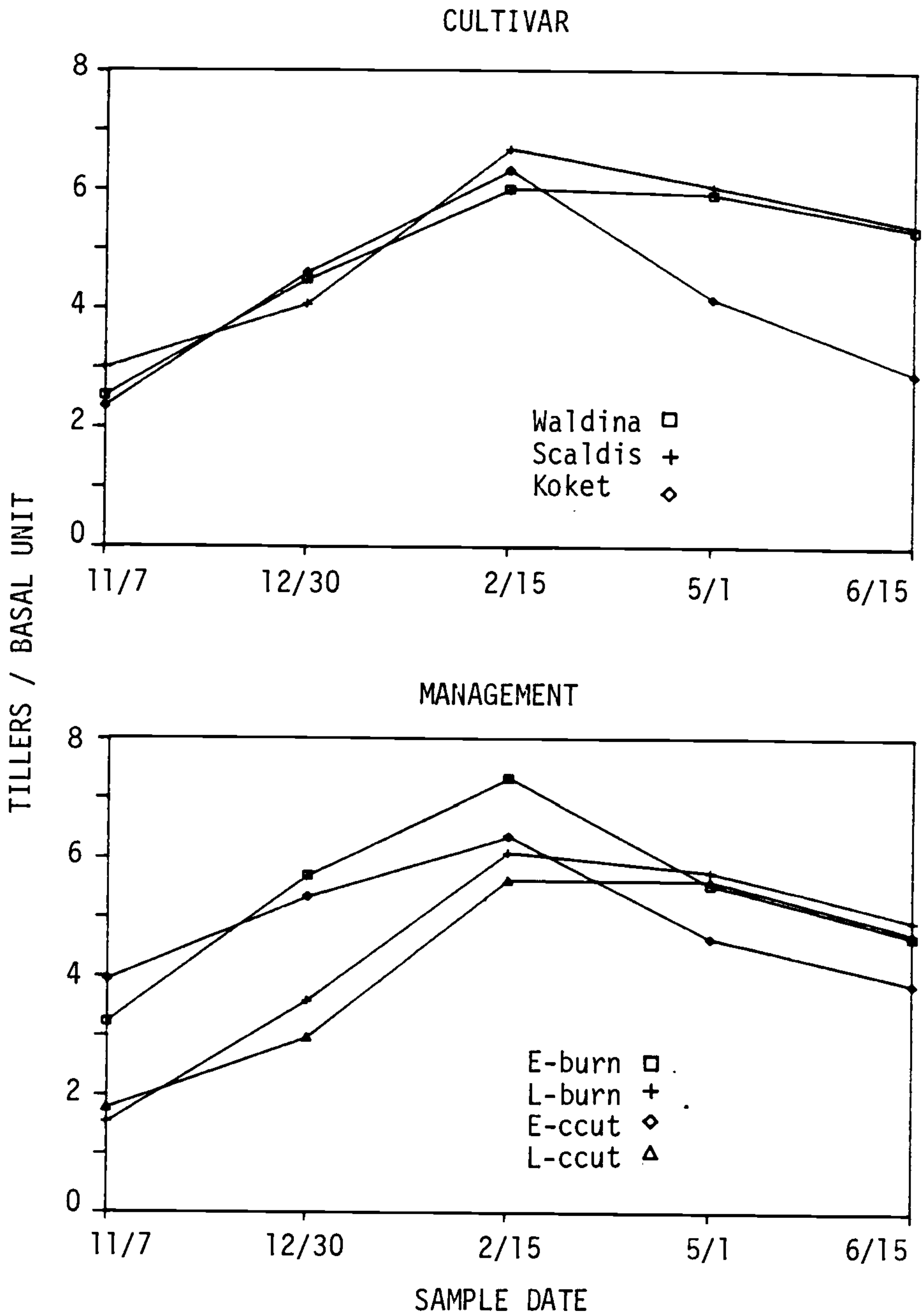

Fig. 16. Tillers per basal unit in response to cultivar and management, all sample dates, 1980-1981.

Table 10. Basal tillers/tiller unit by cultivar and treatment for all sample dates, 1980-81.

Treatment	Date				
	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	2.538	4.509	6.036	5.932	5.341
Scaldis	3.014	4.093	6.702	6.061	5.403
Koket	2.357	4.619	6.346	4.172	2.908
LSD P <0.05			NS	1.096	.680
Management					
E-burn	3.246	5.702	7.344	5.542	4.671
L-burn	1.544	3.600	6.098	5.756	4.931
E-ccut	3.958	5.345	6.368	4.644	3.873
L-ccut	1.797	2.982	5.635	5.612	4.727
LSD P <0.05			.808	.789	NS
C x M	**	*			

* Interaction significant P <0.05
** Interaction significant P <0.01

In November and December, cultivar-treatment interactions ($P < 0.01$ in November, $P < 0.05$ in December) were observed. Treatment means are shown, (Tables 11, 12). In November, the late treatments produced fewer tillers per basal unit than the early treatments but differences within late treatments and early treatments were not observed except in Scaldis. Scaldis produced more tillers per basal unit in the early crewcut treatment than in the early burn treatment.

Table 11. Basal tillers/tiller unit within cultivars, November 7, 1980.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	3.227	3.105	3.406
L-burn	1.637	1.571	1.425
E-ccut	3.495	5.334	3.046
L-ccut	1.795	2.047	1.550

LSD P <0.05 for means within cultivars = 0.9303

The number of tillers per basal unit increased between the November and December sampling. In December, early treatments differed from late treatments in Scaldis. In Koket, the early burn treatment produced more tillers per basal unit than all other treatments. In Koket and Waldina, differences between the late burn and early crewcut treatments were not significant.

Table 12. Basal tillers/tiller unit within cultivars, December 31, 1980.

Treatment	Cultivar		
	Waldina	Scaldis	Koket
E-burn	5.268	5.137	6.700
L-burn	4.027	2.836	3.938
E-ccut	6.022	5.428	4.584
L-ccut	2.717	2.972	3.256

LSD P <0.05 for means within cultivars = 1.252

By February, the number of tillers per basal unit had doubled from the number observed in November (Table 10) except in the early crewcut treatment. Treatment effects were significant ($P < 0.01$). The early burn treatment ranked highest in all cultivars and produced more tillers per basal unit than all other treatments. No differences between cultivars were found.

In May, significant differences ($P < 0.05$) were observed due to cultivars and treatments (Table 10). Fewer tillers per basal unit in Koket accounted for the cultivar differences. A similar situation occurred across treatments when the number of basal tillers in the early crewcut treatment declined from February levels. All other cultivars and treatments had a reduced number of tillers per basal unit but of less magnitude than in Koket and the early burn and early crewcut treatments.

A further reduction in the number of tillers per basal unit occurred between May and June (Table 10). Analysis of June data shows that significant differences ($P < 0.01$) occurred due to cultivar. The reduction of tillers in Koket was greater than the reduction of tillers in the hard fescue and contributed to the higher level of significance found in differences between cultivars in June.

While basal tiller units increased steadily through the season until a peak is reached in May or June, the maximum number of tillers per basal unit occurs in February then declined until harvest.

4. Aerial tillers per unit area

Tillers which originate from growing points located above an elongated internode are considered to be aerial tillers. A multiple aerial tiller was occasionally found in which tillers formed at two or more nodes on the same stem were separated by elongated internodes. These tillers were also counted and evaluated. An analysis of the occurrence of multiple tillers follows this section.

Because of the low frequency or absence of aerial tillering in some samples, a square root transformation (Steel and Torrie, 1960) was used to modify raw data for analysis of variance calculations. Where significant differences are indicated, transformed and actual data are presented.

The actual number of aerial tillers observed during the study are shown (Table 13 and Figure 17) as are aerial tillers as a percent of total tillers (Table 14).

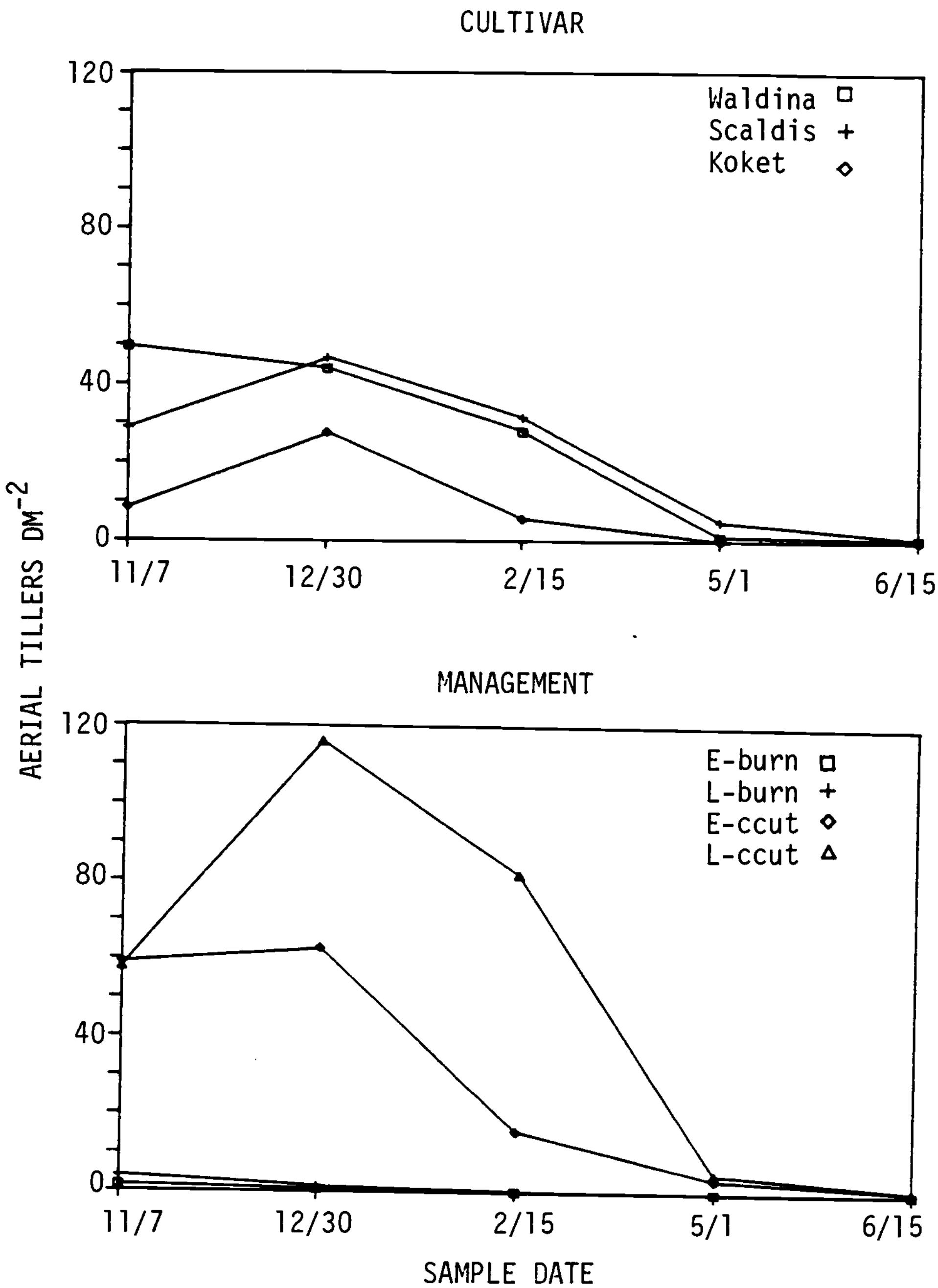

Fig. 17. Aerial tiller production in response to cultivar and management, all sample dates, 1980-1981.

Table 13. Aerial tillers dm^{-2} by cultivar and management, all sample dates, 1980-81.

Treatment	Date Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	49.68	44.07	28.02	1.18	0.68
Scaldis	29.07	46.98	31.52	5.00	0.65
Koket	8.63	27.70	5.80	0.00	0.00
LSD P <0.05		NS			NS
Management					
E-burn	1.52	0.74	0.04	0.00	0.10
L-burn	4.14	1.45	0.30	0.00	0.00
E-ccut	59.20	63.00	15.87	3.39	0.77
L-ccut	57.95	116.15	82.02	4.83	0.89
LSD P <0.05		9.20			NS
C x M	**		**	*	

* Interaction significant P <0.05
** Interaction significant P <0.01

Table 14. Aerial tillers as a percent of total tillers, all sample dates, 1980-81.

Treatment	Date Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
	(%)				
Cultivar					
Waldina	36.3	19.0	8.4	0.4	0.2
Scaldis	29.7	24.7	9.1	1.5	0.2
Koket	9.8	14.4	1.6	0.0	0.0
Management					
E-burn	1.5	0.4	< 0.1	0.0	< 0.1
L-burn	8.2	1.1	0.1	0.0	0.0
E-ccut	34.8	26.0	4.9	1.3	0.4
L-ccut	52.3	49.2	22.1	1.8	0.4

A cultivar x management interaction was observed in November ($P < 0.01$). Within the hard fescue cultivars, the two burn treatments had fewer aerial tillers than the crewcut treatments. In Koket, the early crewcut treatment was not significantly different from the burn treatments or the late crewcut treatment (Table 15).

Table 15. Aerial tillers cm^{-2} within cultivars with transformed values, November 7, 1980. Ranked lowest to highest within cultivars.

Treatment	Aerial tillers Trans.	Aerial tillers Actual
Waldina		
E-burn	0.7352	0.0405
L-burn	0.7851	0.1164
L-ccut	1.1760	0.8830
E-ccut	1.2980	1.1848
Scaldis		
E-burn	0.7113	0.0059
L-burn	0.7154	0.0118
L-ccut	1.0490	0.6004
E-ccut	1.0810	0.6686
Koket		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
E-ccut	0.7552	0.0703
L-ccut	0.8932	0.2978

LSD $P < 0.05$ for transformed means within cultivars = 0.1410

In December there were significant differences due to treatment ($P < 0.01$) but not for cultivars (Table 16). An increase in the number of aerial tillers occurred in the Scaldis and Koket cultivars in the crewcut treatments. The effect of this increase was to eliminate the cultivar x management interaction observed in November. The burn treatments had similar aerial tiller populations. Differences were observed between the two crewcut treatments and between the crewcut and burn treatments.

Table 16. Aerial tillers cm^{-2} by cultivar and management with transformed values, December 31, 1980.

Treatment	Aerial tillers Trans.	Aerial tillers Actual
Cultivar		
Waldina	0.9699	0.4407
Scaldis	0.9848	0.4698
Koket	0.8815	0.2770
LSD P <0.05	NS	
Management		
E-burn	0.7123	0.0074
L-burn	0.7173	0.0145
E-ccut	1.0630	0.6300
L-ccut	1.2890	1.1615

LSD P <0.05 for transformed means = 0.09195

The aerial tiller population was much lower in all cultivars and treatments in February. An interaction ($P < 0.01$) occurred between cultivars and treatments. The February cultivar x management relationships are shown in Table 17. The late crewcut treatment produced the most tillers and was significantly different from other treatments in the hard fescue. No significant differences occurred between treatments in Koket.

Table 17. Aerial tillers cm^{-2} within cultivars with transformed values, February 15, 1981. Ranked lowest to highest within cultivars.

Treatment	Aerial tillers Trans.	Aerial tillers Actual
Waldina		
E-burn	0.7071	0.0000
L-burn	0.7134	0.0089
E-ccut	0.8651	0.2484
L-ccut	1.2480	1.0575
Scaldis		
L-burn	0.7071	0.0000
E-burn	0.7080	0.0013
E-ccut	0.8426	0.2100
L-ccut	1.3540	1.3333
Koket		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
E-ccut	0.7273	0.0290
L-ccut	0.8467	0.2169

LSD $P < 0.05$ for transformed means within cultivars = 0.1737

In May aerial tiller populations further declined from the level observed in February. A significant cultivar x management interaction occurred ($P < 0.05$). No differences were found between treatments in Waldina and Koket. The only observed significance between treatments occurred between the late crewcut and other treatments in Scaldis. These results were expected because of the low number of aerial tillers observed during sampling. No aerial tillers were found in any treatment in Koket. Aerial tillers were found only in the early crewcut treatment in Waldina and in both crewcut treatments in Scaldis (Table 18).

Table 18. Aerial tillers cm^{-2} within cultivars with transformed values, May 1, 1981. Ranked lowest to highest within cultivars.

Treatment	Aerial tillers Trans.	Actual
Waldina		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
L-ccut	0.7071	0.0000
E-ccut	0.7402	0.0479
Scaldis		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
E-ccut	0.7448	0.0547
L-ccut	0.8072	0.1516
Koket		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
E-ccut	0.7071	0.0000
L-ccut	0.7071	0.0000

LSD $P < 0.05$ for transformed means within cultivars = 0.0503

In June, no significant differences were found due to cultivars, treatments or cultivar x management interactions. The only aerial tillers observed during sampling were found in the two crewcut treatments in Scaldis and in the late crewcut treatment in Waldina. Fewer aerial tillers were found in June in these treatment than in May.

5. Multiple aerial tillers per unit area

Stems were observed on which tillers were produced at more than one node with elongated internodes separating the tiller growing points. These generally occurred on old stems remaining after the crewcut treatments but were also observed in the late burn treatment.

They were a relatively unimportant component (Table 19) of the total tiller population and were not observed after February.

Table 19. Multiple aerial tillers as a percent of total tillers for all sample dates on which multiple tillers were found, 1980-81.

Treatment	Date: Nov. 7	Dec. 31	Feb. 15
Cultivar			
Waldina	4.7	2.4	< 0.1
Scaldis	3.0	0.7	0.0
Koket	0.8	0.0	0.0
Management			
E-burn	0.0	0.0	0.0
L-burn	0.5	0.0	0.0
E-ccut	2.6	0.4	0.0
L-ccut	8.2	2.3	< 0.1

Table 20. Multiple aerial tillers cm^{-2} by cultivar and treatment for all sample dates on which aerial tillers were found, 1980-81.

Treatment	Date: Nov. 7	Dec. 31	Feb. 15
Cultivar			
Waldina	0.0649	0.0562	0.0020
Scaldis	0.0297	0.0127	0.0000
Koket	0.0071	0.0000	0.0000
LSD P <0.05	NS	NS	NS
Management			
E-burn	0.0000	0.0000	0.0000
L-burn	0.0023	0.0000	0.0000
E-ccut	0.0438	0.0091	0.0000
L-ccut	0.0911	0.0840	0.0025
LSD P <0.05	NS	*	NS

No significant differences were noted for cultivars and treatments in the number of multiple aerial tillers in November (Table 20).

In December, a significant difference ($P < 0.05$) was found between management treatments (Table 21). All treatments showed a reduced multiple aerial tiller population when compared with the previous sampling. Multiple tillers were not found in Koket or in the burn treatments.

Table 21. Multiple aerial tillers cm^{-2} by cultivar and treatment, December 31, 1980.

Treatment	Aerial tillers Trans.	Aerial tillers Actual
Cultivar		
Waldina	0.7458	0.0562
Scaldis	0.7160	0.0127
Koket	0.7071	0.0000
LSD $P < 0.05$ for transformed means NS		
Management		
E-burn	0.7071	0.0000
L-burn	0.7071	0.0000
E-ccut	0.7135	0.0091
L-ccut	0.7642	0.0840
LSD $P < 0.05$ for transformed means = 0.0441		

Multiple aerial tillers were present only in Waldina and in the late crewcut treatment. Due to the small number of tillers found, differences between cultivars and treatments were not statistically significant. Multiple aerial tillers were not present in samples taken May and June.

Aerial tiller populations follow a different trend through the growing season than observed in basal and total tillers. In addition to being relatively less important than basal tillers in the total tiller population, the highest population of aerial tillers was observed early in the season (November and December sampling). This tiller population declined to the point where very few aerial tillers were observed in June. Multiple aerial tillers account for a very small percent of the total tillers, reach their population peak in November and decline until none were found after February.

Cultivar x management interactions were observed in November, February and May in aerial tillers. Within cultivars, fewer tillers were observed in the burn treatments but the difference between the burned treatments and the early crewcut treatment was not always significant. By February the reduction in the aerial tiller population within cultivars produced non-significant differences for all treatments within Koket and by May only treatments in Scaldis showed any significant differences. In December, significance was observed due to treatments across all cultivars in aerial and multiple aerial tiller populations. While cultivar differences were complicated by cultivar x management interactions, Koket had a consistently lower aerial and multiple tiller population than the hard fescue cultivars.

II. Basal Internode Elongation

The distance between the soil level and the lowest node on which tillers were formed was measured. Since basal tillers are formed at nodes at or below the soil level, figures greater than zero indicate the presence of aerial tillers and indicate the average basal internode elongation in the stand. Basal internode length may be important in describing the ability of aerial tillers to root from aerial nodes, in translocating substances necessary for growth and inhibiting tiller formation at nodes on the culm base. Unfortunately, little is known about the physiology of vegetative stem elongation and the effects of this elongation on subsequent plant growth. Basal internode elongation was not observed in many vegetative tiller samples after February. Selected data for December and February are presented to show differences within cultivars due to treatment (Table 22).

Table 22. Tillering node height from ground (includes both aerial and basal tillers) by cultivar and treatment, selected sample dates, 1980-81.

Treatment	Date	
	Nov. 7	Feb. 15
	(cm)	
Cultivar		
Waldina	0.7589	0.1931
Scaldis	0.6773	0.2377
Koket	0.2036	0.0546
LSD P <0.05		
Management		
E-burn	0.0144	0.0000
L-burn	0.0951	0.0000
E-ccut	0.8642	0.7335
L-ccut	1.4740	0.6599
C x M	**	**

** Interaction significant P <0.01

A cultivar treatment interaction ($P < 0.01$) was found in November and February. Basal internode elongation occurred in all treatments within the hard fescue cultivars but was observed only in the Koket late crewcut treatment (Table 23). In Waldina and Scaldis, basal internode elongation was generally of less magnitude in the burn treatments than in the crewcut treatments although differences were not always significant.

Table 23. Tillering node height from ground (cm) and transformed values within cultivars (includes both aerial and basal tillers), November 7, 1980. Ranked lowest to highest within cultivars.

Management	Cultivar					
	Waldina		Scaldis		Koket	
	Trans.	Actual	Trans.	Actual	Trans.	Actual
E-burn	0.7251	0.0258	0.7193	0.0174	0.7071	0.0000
L-burn	0.8877	0.7380	0.7193	0.0174	0.7071	0.0000
E-ccut	1.4350	1.5592	1.3620	1.3550	0.7071	0.0000
L-ccut	1.4400	1.5736	1.5400	1.8720	1.2340	1.0228

LSD P <0.05 for transformed means within cultivars = 0.6963

A cultivar x management interaction (P <0.01) was also observed in February (Table 24). Elongated internodes were not observed in the burn treatments in any cultivar or in the early crewcut treatment in Koket. Differences in basal internode length occurred between the early crewcut and late crewcut treatments in the hard fescues.

Table 24. Tillering node height from ground (cm) within cultivars (includes both aerial and basal tillers), February 15, 1981. Ranked lowest to highest within cultivars.

Management	Cultivar					
	Waldina		Scaldis		Koket	
	Trans.	Actual	Trans.	Actual	Trans.	Actual
E-burn	0.7071	0.0000	0.7071	0.0000	0.7071	0.0000
L-burn	0.7071	0.0000	0.7071	0.0000	0.7071	0.0000
E-ccut	0.7712	0.0948	0.7934	0.1295	0.7071	0.0000
L-ccut	1.1460	0.8133	1.2280	1.0080	0.8576	0.2355

LSD P <0.05 for transformed means within cultivars = 0.1355

The amount of basal internode elongation reflects the number of aerial tillers present and the length of elongation of the aerial pedestal. Basal internode length seems to be dependent upon the time of treatment and the species being treated. Average basal internode length decreases as the season progresses as the number of aerial tillers decreases. Basal internode length may be an important factor in determining the ability of aerial tillers to root from the tillering node.

III. Vegetative Tiller Leaf Number

The number of leaves per vegetative tiller were determined for the five sampling dates (Table 25).

Table 25. Leaf number per vegetative tiller by cultivar and treatment, all sample dates, 1980-81.

Treatment	Date				
	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	3.344	3.232	3.165	2.875	2.594
Scaldis	3.264	3.228	3.219	2.881	2.888
Koket	4.496	3.580	3.683	2.425	2.813
LSD P <0.05		NS	0.177	0.233	NS
Management					
E-burn	3.946	3.202	3.381	2.867	2.908
L-burn	3.161	3.179	3.238	2.867	2.825
E-ccut	4.179	3.744	3.512	2.508	2.858
L-ccut	3.518	3.262	3.292	2.667	2.467
LSD P <0.05		0.261	NS	0.207	0.212
C x M	**				

* Interaction significant P <0.05
** Interaction significant P <0.01

A significant (P <0.01) interaction occurred in tiller leaf number in November (Table 25). No treatment differences were found within the two hard fescues but significant differences were observed between all treatments in Koket (Table 26). In Koket, the early crewcut treatment produced the highest number of leaves per tiller followed by the early burn treatment. Koket tended to produce more leaves per tiller for any given treatment than the hard fescues.

Table 26. Leaf number per tiller within cultivars, November 7, 1980. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-burn	3.125	L-burn	2.982	L-burn	3.375
L-ccut	3.232	L-ccut	3.304	L-ccut	4.018
E-ccut	3.500	E-ccut	3.340	E-burn	4.893
E-burn	3.518	E-burn	3.429	E-ccut	5.697

LSD P <0.05 for means within cultivars = 0.4819

Effects due to treatment were significant (P <0.01) in December (Table 25).

The early crewcut treatment produced more leaves per tiller across the three cultivars while the number of leaves per tiller was not different among the remaining treatments. No differences were observed due to cultivars or interactions although the differences due to cultivar were almost significant (P = 0.0537).

In February, differences due to treatment were not significant but more leaves per tiller were found in Koket than in the hard fescues (P <0.01). There was a slight reduction in the number of leaves per tiller in the early crewcut treatment while in the late crewcut and both burn treatments, leaf numbers increased when compared to the December sample.

Cultivar and treatment differences (P <0.01) were observed in May (Table 25). Koket had fewer leaves per tiller than the hard fescue cultivars, the opposite of the results observed in February. Among treatments, the early crewcut treatment had the lowest number of leaves per tiller with no differences found in the remaining treatments. Earlier in the season (December sample) the early crewcut treatment had the highest number of leaves per tiller. The number of leaves per tiller declined in all cultivars and treatments from February observations.

Differences due to treatment (P <0.01) were observed in June when the late crewcut treatment had fewer leaves per tiller than all other treatments. The number of leaves per tiller appeared to increase slightly in the early crewcut treatment and decline slightly in the late crewcut treatment leading to the different results in May and June. In Koket, the number of leaves per tiller increased from May levels. This increase coupled with a decrease in leaves per tiller in Waldina resulted in no differences due to cultivar.

Vegetative tiller leaf numbers are generally higher earlier in the season and decline as harvest approaches. The highest number of leaves per tiller was observed in November for all cultivars and for all treatments except late burn. The highest number of leaves per vegetative tiller in the late burn treatment occurred in February. The late burn treatment also had the lowest November-June fluctuation in leaves per tiller. Koket had the highest number of leaves per vegetative tiller early in the growing season, the lowest number in

May, and in June, Koket did not differ from the hard fescues.

IV. Vegetative Tiller Leaf Blade Length

The length of the longest fully expanded leaf blade was measured during sampling (Table 27). Early and mid-season interactions and differences due to cultivar and treatment were observed.

Table 27. Vegetative tiller leaf blade length (cm) by cultivar and treatment, all sample dates

Treatment	Date: Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	7.140	7.132	7.142	17.53	27.43
Scaldis	7.677	7.323	8.077	19.52	32.66
Koket	8.023	7.857	9.510	25.33	39.71
LSD P <0.05		0.459		1.591	4.970
Management					
E-burn	7.753	7.716	8.210	21.34	33.27
L-burn	7.929	7.483	7.390	18.73	32.99
E-ccut	8.119	7.826	10.16	23.71	34.57
L-ccut	6.653	6.724	7.211	19.38	32.23
LSD P <0.05		0.718		2.480	NS
C x M	*		*		

* Interaction significant P <0.05

In November (Table 28) the early crewcut treatment produced longer leaves in Koket than in all other treatments. The early burn treatment had longer leaves than the crewcut treatments in Waldina while the early crewcut treatment was similar to the early and late burn treatments in Scaldis.

Table 28. Vegetative leaf blade length within cultivars (cm), November 7, 1980. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-ccut	6.203	L-ccut	6.850	L-ccut	6.904
E-ccut	6.793	E-burn	7.600	E-burn	7.686
L-burn	7.591	L-burn	7.768	L-burn	8.429
E-burn	7.793	E-ccut	8.489	E-ccut	9.703

LSD P <0.05 for means within cultivars = 1.050

Koket continued to have the longest leaves among the cultivars in December (Table 27) while the late crewcut had the shortest leaves among the management treatments.

A second cultivar x management interaction was observed in February (Table 29) when the early crewcut treatment produced longer leaves in all cultivars but the rankings of the other treatments differed.

Table 29. Vegetative leaf blade length within cultivars (cm), February 15, 1980. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-ccut	5.661	L-ccut	7.400	L-burn	7.839
L-burn	6.843	L-burn	7.488	L-ccut	8.572
E-burn	7.489	E-burn	7.543	E-burn	9.597
E-ccut	8.577	E-ccut	9.877	E-ccut	12.03

LSD P <0.05 for means within cultivars = 1.058

Late in the season, Koket continued to produce the longest leaves among the cultivars but differences due to treatment declined in importance.

Not only does Koket produce more leaves per tiller but the leaves are longer. These longer leaves suggest a more efficient canopy early in the season but later in the season they may be responsible for higher vegetative tiller mortality because of shading effects.

V. Fertile Tiller Leaf Number and Flag Leaf Length

Data collected in May suggests that differences occur in the number of leaves, flag leaf length and length of fertile tillers (Table 30). Interactions (P <0.01 for leaf number, P <.05 for flag leaf and fertile tiller length) were observed in these variables.

Table 30. Fertile tiller leaf number, flag leaf length and length by cultivar and treatment, May 1, 1981.

Treatment	Leaves/ Fertile Tiller	Fertile Tiller Length	Flag Leaf Length
Cultivar			
Waldina	1.953	35.08	5.548
Scaldis	1.807	38.29	7.039
Koket	1.566	53.79	9.017
Management			
E-burn	1.995	41.32	7.482
L-burn	1.683	38.68	7.749
E-ccut	1.729	48.22	7.120
L-ccut	1.695	41.32	6.455
C x M	**	*	*

* Interaction significant P <0.05
** Interaction significant P <0.01

In Koket, the number of leaves per fertile tiller is higher in the burn treatments than in the crewcut treatments (Table 31). No differences were found in Scaldis but in Waldina the early burn treatment produced more leaves per fertile tiller than the late burn and early crewcut treatments.

Table 31. Number of leaves per fertile tiller within cultivars, May 1, 1981. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-burn	1.388	L-ccut	1.633	E-ccut	1.287
E-ccut	1.875	E-burn	1.734	L-ccut	1.350
L-ccut	2.100	L-burn	1.837	E-burn	1.800
E-burn	2.450	E-ccut	2.025	L-burn	1.825

LSD P <0.05 for means within cultivars = 0.4147

The only difference observed in flag leaf length in the hard fescues was in Scaldis where the late-burn treatment had a longer flag leaf than all other treatments (Table 32). In Koket, the early burn treatment produced a longer flag than the late crewcut treatment but did not differ from the early crewcut and late burn treatment.

Table 32. Fertile tiller flag leaf length (cm) within cultivars, May 1, 1981. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-burn	5.025	E-burn	6.145	L-ccut	7.565
L-ccut	5.236	E-ccut	6.476	E-ccut	9.085
E-ccut	5.800	L-ccut	6.564	L-burn	9.250
E-burn	6.133	L-burn	8.971	E-burn	10.17

LSD P <0.05 for means within cultivars = 1.761

Fertile tillers were longer in the Koket crewcut treatment than in any other treatments (Table 33). No differences were found in

Scaldis but both crewcut treatments were longer than the burn treatments in Waldina.

Table 33. Length of fertile tillers (cm) within cultivars, May 1, 1981. Ranked lowest to highest within cultivars.

Cultivar					
Waldina		Scaldis		Koket	
L-burn	29.54	L-ccut	35.91	L-burn	48.34
E-burn	30.82	L-burn	38.17	L-ccut	49.96
L-ccut	38.09	E-burn	39.09	E-burn	54.06
E-ccut	41.88	E-ccut	40.00	E-ccut	62.80

LSD P <0.05 for means within cultivars = 6.139

Significant cultivar x management interactions indicate that the three cultivars respond differently to the four treatments. More leaves per fertile tiller were produced in Koket as a result of both burn treatments but the late burn treatment produced the fewest leaves per tiller in Waldina while the early burn and late crewcut treatments produced the highest number of leaves per tiller. No clearcut differences were observed in Scaldis. Burning treatments seem to enhance the number of leaves per fertile tiller in Koket but no obvious trend can be recognized across the hard fescue cultivars.

The differences due to cultivars in flag leaf length are less obvious than are the differences in number of leaves per tiller. The two burn treatments were similar to the early crewcut treatment in flag leaf length. Management treatments do not affect flag leaf length in either hard fescue cultivar.

Management treatment altered fertile tiller length in Koket and Waldina but not Scaldis. Koket produces longer tillers than the hard fescues which may have some effect on the shading or inhibition of vegetative tillers.

VI. Inflorescence Emergence

Inflorescences which were fully emerged above the flag leaf were counted during the May sample (Table 34, Figures 18-20).

Table 34. Fully emerged inflorescences dm^{-2} by cultivar and treatment, May 1, 1981.

Treatment	Fully Emerged Tillers	June Fertile Tillers
		(%)
Cultivar		
Waldina	8.34	20.0
Scaldis	5.55	15.3
Koket	13.63	28.3
Management		
E-burn	11.78	28.0
L-burn	1.57	4.5
E-ccut	16.81	31.8
L-ccut	6.88	18.4
C x M	**	

** Interaction significant P <0.01

Significant (P <0.01) cultivar x management interactions were found during data analysis (Table 34). More fully emerged inflorescences were formed in the early crewcut treatment than the other treatments in Waldina but was not different from the early burn or late crewcut treatments in Scaldis (Table 35). In Koket, the late burn treatment produced fewer fully emerged inflorescences than the other treatments. The late crewcut treatment had a higher number of fully emerged inflorescences than the late burn treatment but fewer than the early treatments. There was no significant difference between the early burn and early crewcut treatments.

Table 35. Fully emerged tillers cm^{-2} within cultivars, May 1, 1981.

Treatment	Transformed	Actual
Waldina		
L-burn	0.7230	0.0227
E-burn	0.7387	0.0457
L-ccut	0.7532	0.0673
E-ccut	0.8403	0.2061
Scaldis		
L-burn	0.7136	0.0092
L-ccut	0.7303	0.0333
E-burn	0.7602	0.0779
E-ccut	0.7771	0.1039
Koket		
L-burn	0.7179	0.0154
L-ccut	0.7792	0.1072
E-ccut	0.8347	0.1967
E-burn	0.8591	0.2381

LSD $P < 0.05$ for transformed means within cultivars = 0.0441

In June, no significant differences were found in the number of fertile tillers per unit area, therefore differences found in the number of fully emerged inflorescences in May was due to delayed tiller emergence in response to post harvest management rather than differences in the number of inflorescences present. The early burn treatment and early crewcut treatments were not significantly different in Koket. These treatments had more emerged inflorescences than the late burn and late crewcut treatments. The two hard fescue cultivars reacted differently to treatments in the number of fully emerged inflorescences. Significant differences occurred between the

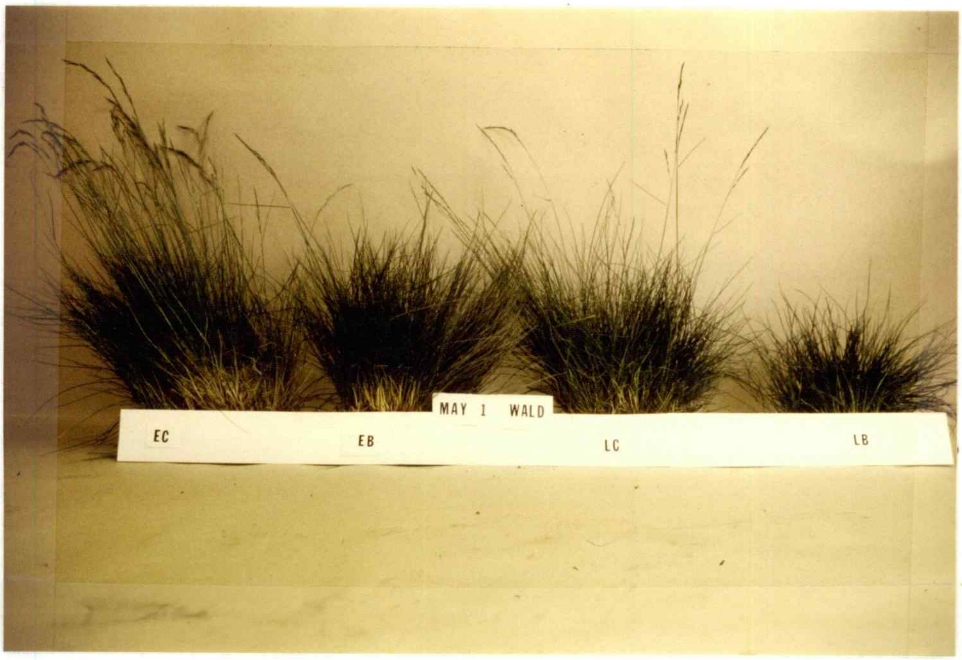

Figure 18. Waldina, May 1, 1981, all management treatments shown. Left to right: early crewcut, early burn, late crewcut, late burn.

Figure 19. Koket, May 1, 1981, all management treatments shown. Left to right: early crewcut, early burn, late crewcut, late burn.

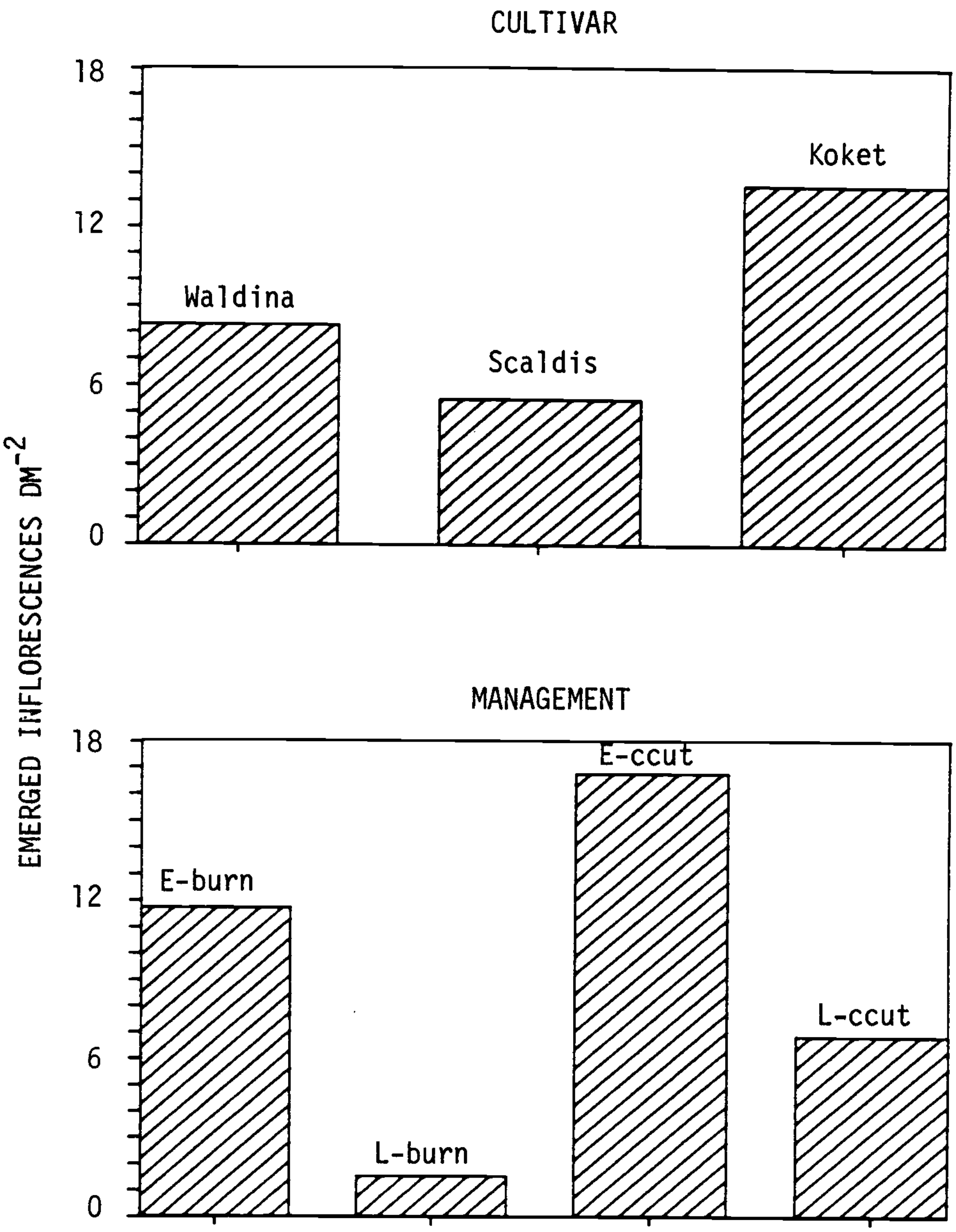

Fig. 20. Emerged inflorescences in response to cultivar and management, May 1, 1981.

early crewcut and all other treatments in Waldina while in Scaldis, the early crewcut treatment was not different from the early burn treatment. The late burn and crewcut treatments delayed inflorescence emergence in all cultivars.

VII. Fertile and Vegetative Tillers

Tillers were classified as vegetative and fertile for the June 15 sample date. Comparisons were made on the unit area and tiller unit basis (Figures 21-24).

Table 36. Inflorescences and vegetative tillers per unit area and per tiller unit, June 15, 1981.

Treatment	Tillers (dm^{-2}) Vegetative	Fertile	% Fertile	Tillers per tiller unit Vegetative	Fertile
Cultivar					
Waldina	258.3	41.7	13.9	4.65	.7047
Scaldis	258.0	35.9	12.2	4.80	.6156
Koket	100.7	48.2	32.4	2.11	.7969
LSD P <0.05	54.0	NS		0.65	NS
Management					
E-burn	224.2	42.0	14.7	3.95	.7188
L-burn	227.5	35.3	13.4	4.34	.5958
E-ccut	159.7	52.9	24.9	3.05	.8354
L-ccut	211.2	37.4	15.0	4.07	.6729
LSD P <0.05	52.5	NS		0.88	NS

1. Tillers per unit area.

Koket Chewings fescue had fewer vegetative tillers and a higher percentage of inflorescences than the hard fescue cultivars (Table 36). The late crewcut treatment produced fewer vegetative tillers than the other management treatments.

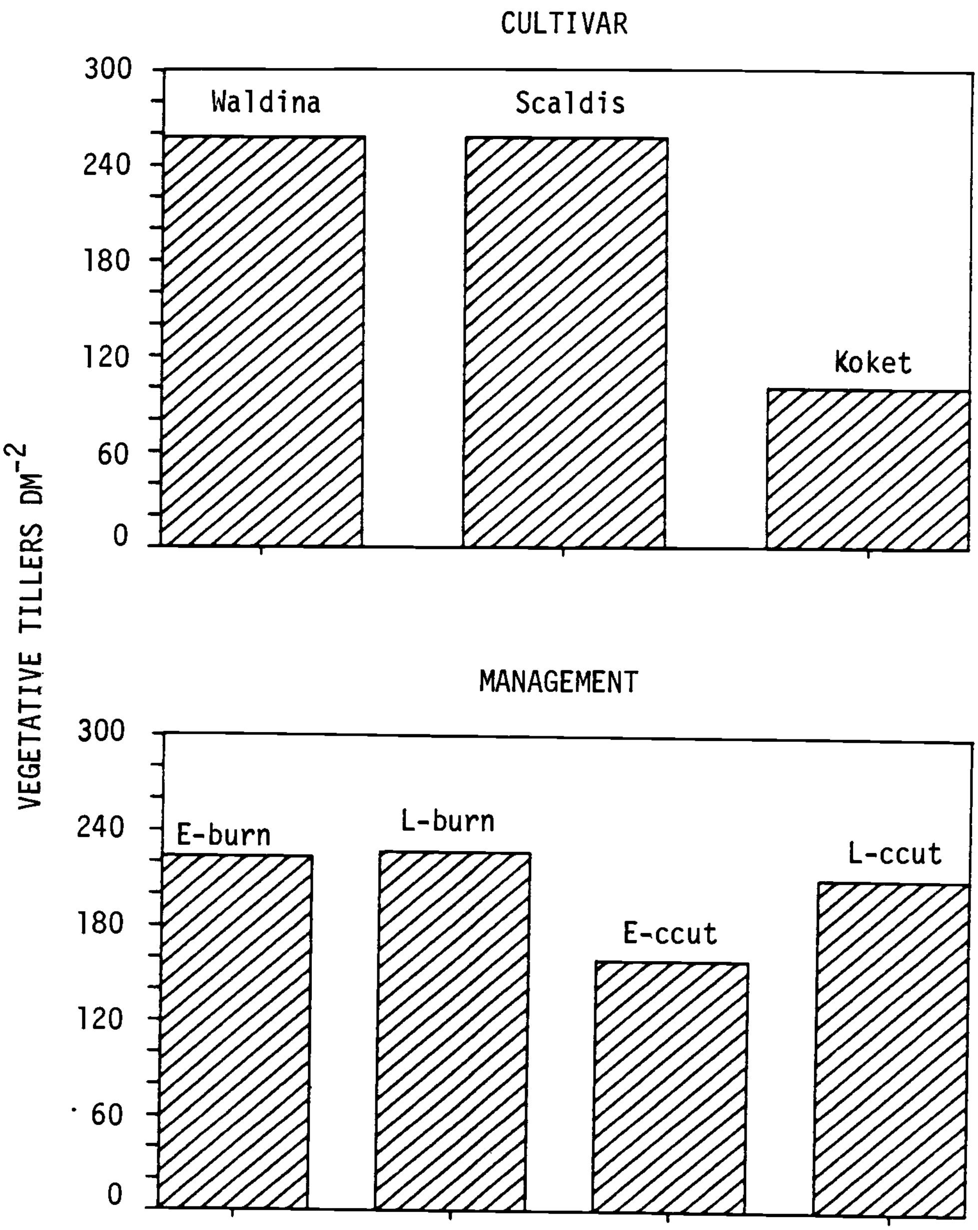

Fig. 21. Vegetative tiller number in response to cultivar and management, June 15, 1981

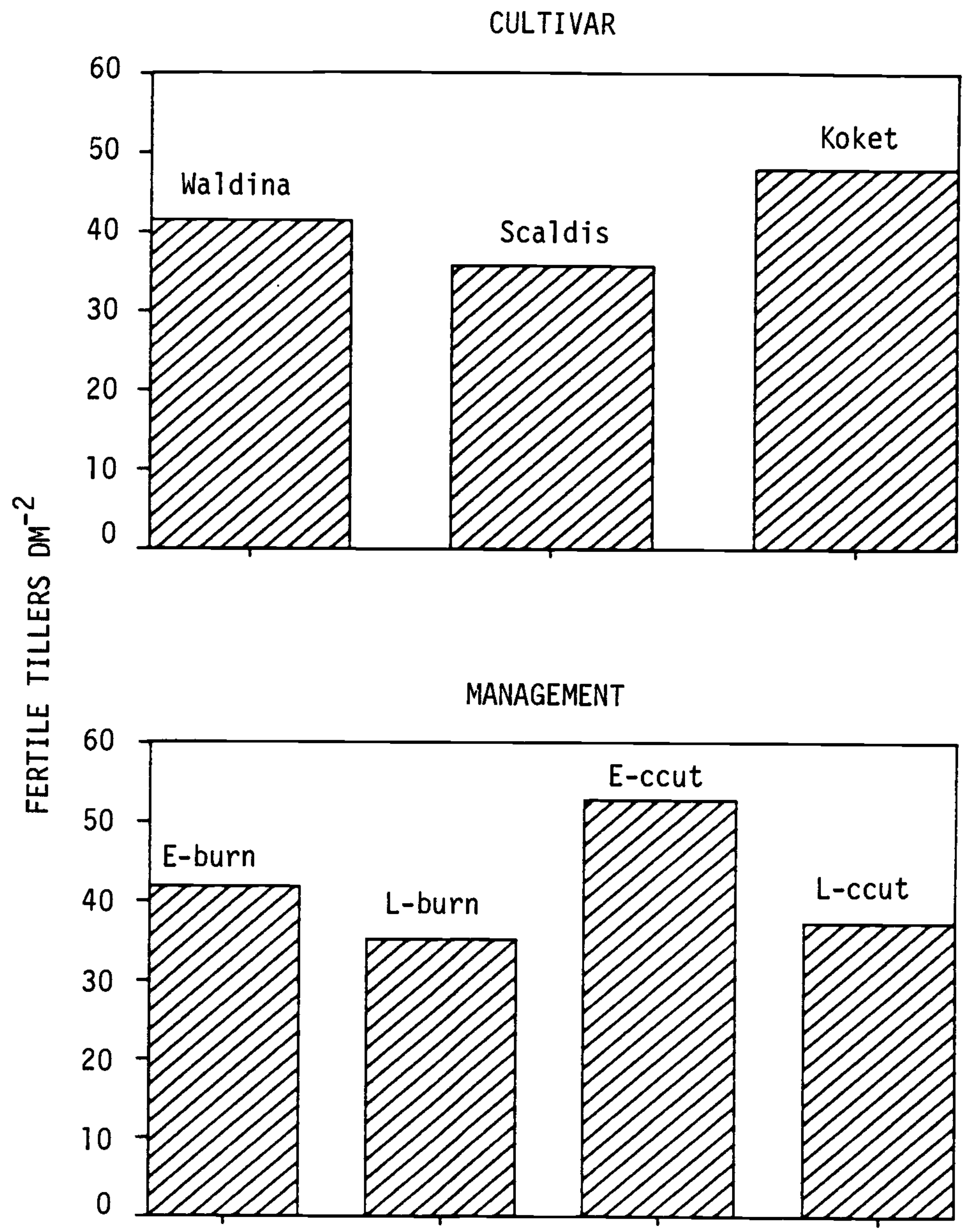

Fig. 22. Fertile tiller number in response to cultivar and management, June 15, 1981.

Figure 23. Scaldis, June 15, 1981, all management treatments shown. Left to right: early crewcut, late crewcut, early burn, late burn.

Figure 24. Koket, June 15, 1981, all management treatments shown. Left to right: early crewcut, late crewcut, early burn late burn.

The number of inflorescences per unit area was not changed in response to cultivar or management. However, while collecting yield data using larger sample areas (see Components of Yield) differences in number of inflorescences per unit area were observed.

2. Tillers per tiller unit.

The size of the plants at maturity as measured by number of inflorescences per tiller unit in June was not affected by cultivar or treatment.

The hard fescue cultivars had more vegetative tillers per tiller unit than Koket Chewings fescue which had only 45% as many vegetative tillers per tiller unit as the average of the hard fescue cultivars. This population of vegetative tillers is largely responsible for the differences observed between cultivar tiller population in June.

Aerial tillers accounted for less than 0.4% of the tiller population in any cultivar or treatment in June. No differences were observed due to cultivar or treatment in number of aerial tillers or tillers per aerial unit.

VIII. Components of Yield, Pre- and Post Treatment

Harvest data collected prior to the initiation of this study represents the first seed crop taken from the research area. Koket Chewings fescue seed yield was 50% greater than the average of the hard fescue cultivars (Table 37). The greater seed yield was due primarilty to a 42% greater mean seed weight for the Koket cultivar.

Table 37. Components of yield pretreatment harvest, July 1980.

Cultivar	Seed Yield	Fertile Tillers dm^{-2}	Seeds/ Fertile Tiller	Seed Weight/ Tiller	1000 Seed Wt.
	(gm^{-2})			(mg)	(g)
Waldina	56.81	415.5	17.23	13.67	0.8117
Scaldis	68.57	370.1	20.19	18.80	0.9367
Koket	94.33	331.4	22.98	28.50	1.2420
LSD P <0.05	23.22	NS	NS	5.83	0.0795

Koket Chewings fescue produced a 51% higher seed yield (P <0.01) in 1981 than the hard fescue cultivars (Table 38). The seed yield was highest (P <0.01) in the early crewcut and early burn management treatments. The early burn was intermediate between the early and late crewcut treatments and not significantly different from either. The two late management treatments produced similar, low, seed yields.

Table 38. Components of yield July 1981 harvest.

Treatment	Seed Yield	Fertile Tillers dm^{-2}	Seeds/* Fertile Tiller	Seed* Weight/ Tiller	1000 Seed Wt.
Cultivar	(gm^{-2})			(mg)	(g)
Waldina	85.12	212.4	59.15	41.03	0.6965
Scaldis	91.90	190.1	57.15	50.79	0.8888
Koket	133.32	260.9	51.46	50.99	0.9893
LSD P <0.05	20.41	53.0	4.98	6.99	0.0869
Management					
E-burn	108.1	238.1	54.27	46.28	0.8599
L-burn	90.7	168.8	63.87	53.44	0.8531
E-ccut	116.4	257.4	53.09	45.88	0.8598
L-ccut	98.5	220.4	52.46	11.80	0.8600
LSD P <0.05	16.3	35.3	7.74	6.05	NS

* Calculated data.

The superior seed yield in Koket Chewings fescue was due primarily to the greater number of inflorescences per unit area and a heavier mean seed weight. Scaldis hard fescue was intermediate in mean seed weight and had a higher yield of seed per tiller than Waldina.

The early crewcut and early burn management treatments produced the highest seed yields through a greater number of inflorescences per unit area. Although the late burn produced the fewest inflorescences, there was compensation by more seed per tiller.

IX. Dry Matter Production

1. Dry weight per unit area

Total dry matter was determined by oven drying and weighing tiller samples. The greatest amount of dry matter accumulated in the early crewcut treatments in November and December (Table 39, Figure 25). Early burn and early crewcut were not significantly different but produced more dry matter than the late burn.

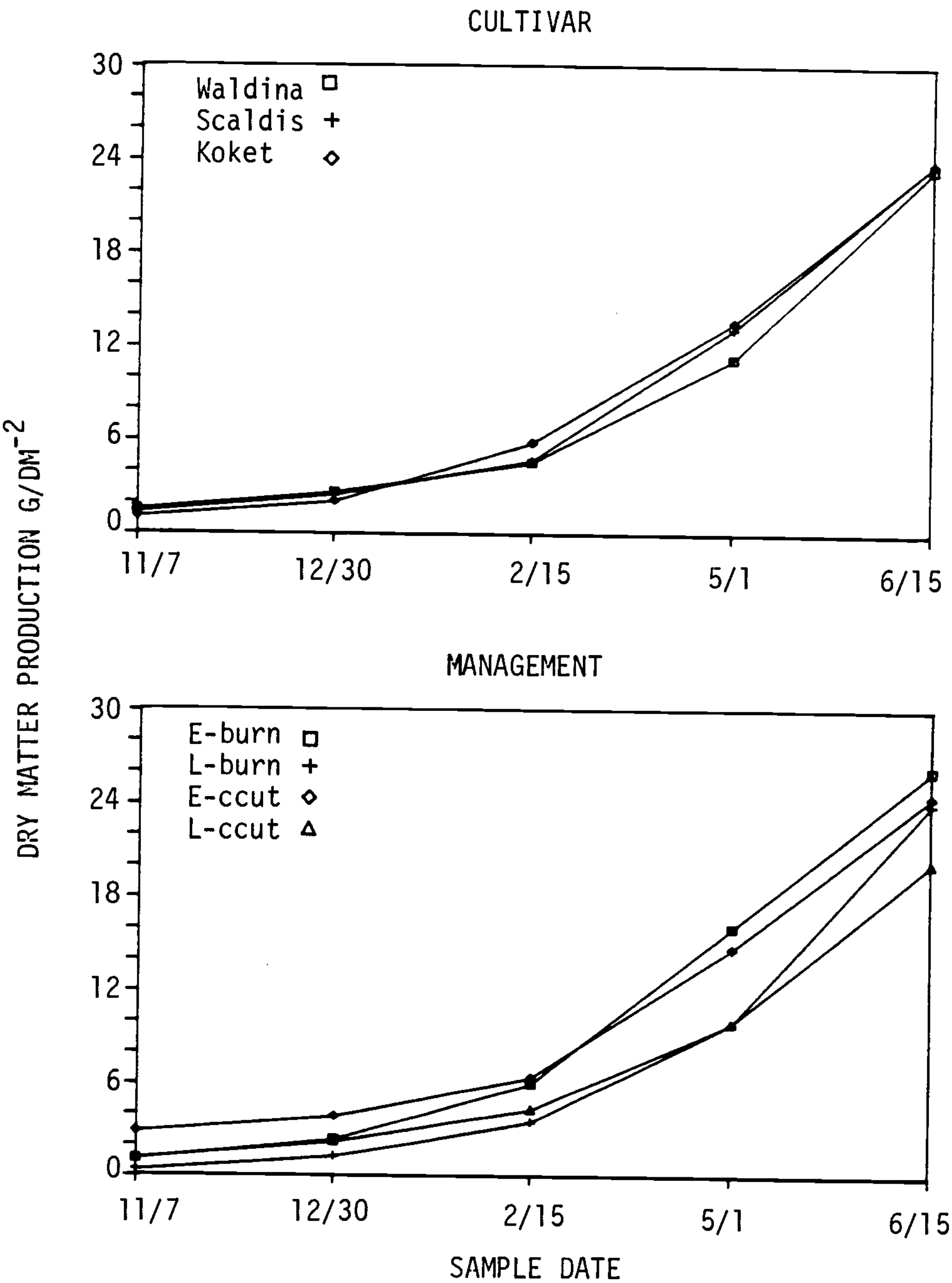

Fig. 25. Dry matter per unit area in response to cultivar and management, all sample dates, 1980-1981.

Table 39. Dry matter production (g dm^{-2}) by cultivar and treatment for all sample dates, 1980-81.

Treatment	Date				
	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	1.58	2.72	4.66	11.29	23.54
Scaldis	1.42	2.55	4.78	13.24	23.93
Koket	1.10	2.12	5.91	13.65	23.90
LSD P <0.05	NS	NS		NS	NS
Management					
E-burn	1.08	2.42	6.04	16.14	26.23
L-burn	0.38	1.29	3.56	9.99	24.10
E-ccut	2.87	3.89	6.47	14.80	24.56
L-ccut	1.13	2.26	4.39	9.99	20.27
LSD P <0.05	0.46	0.65		2.65	NS
C x M			*		

* Interaction significant P <0.05

A significant interaction (P <0.05) between cultivars and treatments occurred in February. The early burn treatment produced the most dry matter and the late treatments produced the least dry matter in Koket (Table 40). In Waldina and Scaldis the late burn, late crewcut and early burn treatments are not significantly different. The early crewcut treatment differs from only the late burn treatment in Scaldis and from both burn treatments in Waldina.

Table 40. Dry weight (g dm^{-2}) within cultivars, February 15, 1981. Ranked lowest to highest within cultivars.

Waldina		Scaldis		Koket	
L-burn	3.16	L-burn	3.95	L-burn	3.56
E-burn	4.16	L-ccut	4.16	L-ccut	4.13
L-ccut	4.89	E-burn	4.82	E-ccut	6.80
E-ccut	6.42	E-ccut	6.21	E-burn	9.15

LSD P <0.05 for means within cultivars = 2.15

Significant differences (P <0.01) due to treatment effects were found in May. The late treatments had less dry matter than the early treatments (Table 39). No differences were observed between early crewcut and early burn treatments or between late crewcut and late burn treatments. These results differ from the November and December data in which the late burn treatment was lowest, the early crewcut treatment was highest and no difference was observed between the early burn and late crewcut treatments.

No significant cultivar or treatment differences were found in dry matter per unit area in June.

2. Dry weight per tiller

Dry weights per individual tillers were collected during sampling. The results would have been more meaningful if dry weights had been collected by class of tiller (aerial, basal, fertile, vegetative). However the results do show that tiller dry weights vary among cultivars and treatments on some sampling dates (Table 41, Figure 26).

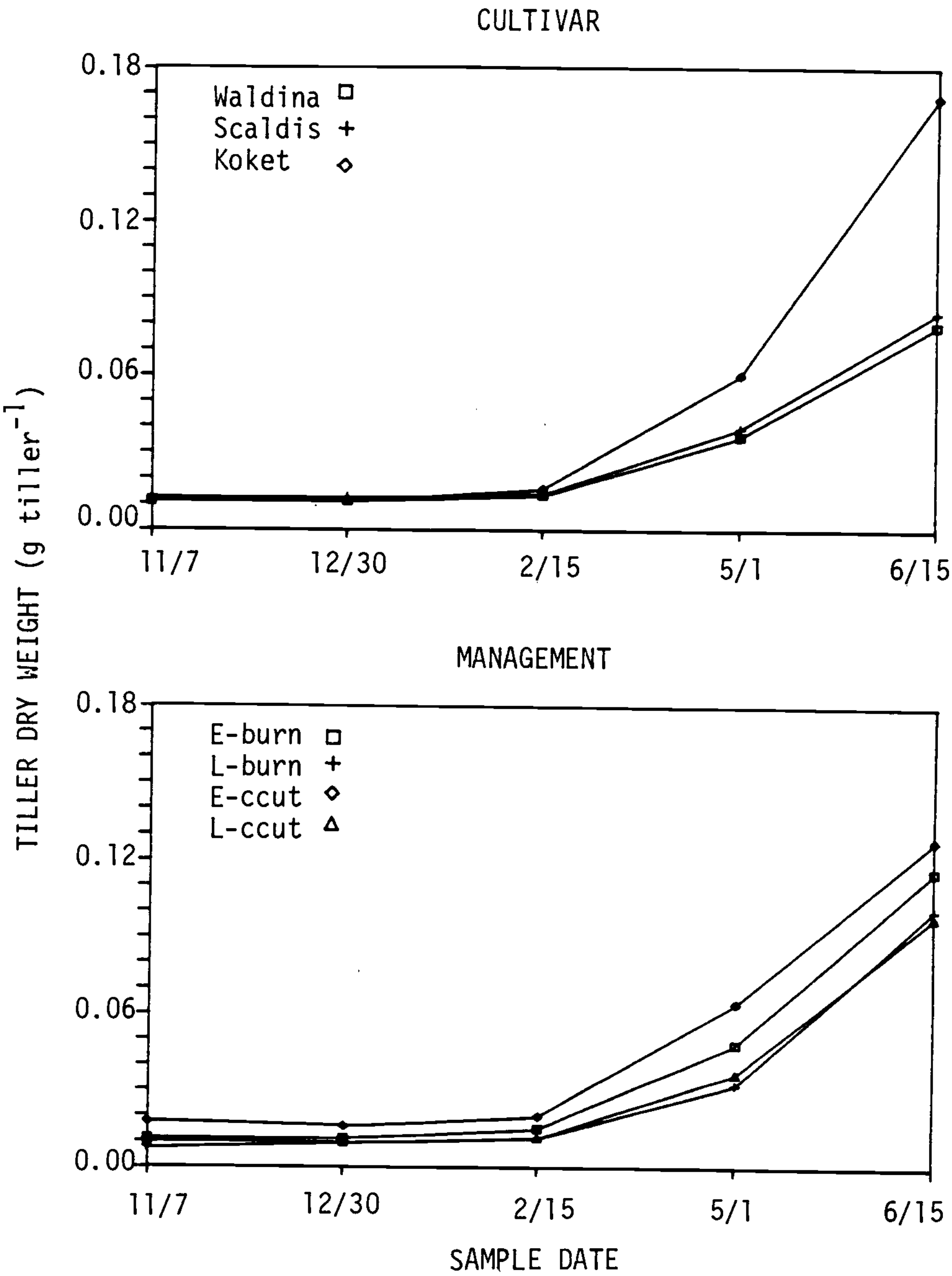

Fig. 26. Tiller dry weight in response to cultivar and management, all sample dates, 1980-1981.

Table 41. Tiller dry weight (g tiller^{-1}) by cultivar and treatment for all sample dates.

	Date				
Treatment	Nov. 7	Dec. 31	Feb. 15	May 1	Jne. 15
Cultivar					
Waldina	0.0109	0.0112	0.0137	0.0367	0.0799
Scaldis	0.0128	0.0129	0.0144	0.0400	0.0851
Koket	0.0113	0.0114	0.0163	0.0607	0.1687
LSD P <0.05		NS			0.0271
Management					
E-burn	0.0112	0.0116	0.0153	0.0486	0.1163
L-burn	0.0074	0.0098	0.0116	0.0327	0.1015
E-ccut	0.0177	0.0162	0.0203	0.0648	0.1284
L-ccut	0.0103	0.0098	0.0120	0.0371	0.0986
LSD P <0.05		0.0020			0.0227
C x M	**		**	**	

** Interaction significant P <0.01

In November a cultivar x management interaction (P <0.01) was observed. The early crewcut treatment had a higher tiller dry weight than all other treatments in Scaldis and Koket but was not different than early burn in Waldina (Table 42).

Table 42. Tiller dry weight (g tiller^{-1}) within cultivars, November 7, 1980. Ranked lowest to highest within cultivars.

Waldina		Scaldis		Koket	
L-ccut	0.0083	L-Burn	0.0078	L-burn	0.0062
L-burn	0.0083	E-burn	0.0122	E-burn	0.0089
E-burn	0.0126	L-ccut	0.0135	L-ccut	0.0091
E-ccut	0.0146	E-ccut	0.0176	E-ccut	0.0209

LSD P <0.05 for means within cultivars = 0.0033

A significant difference (P <0.01) due to treatments was noted in

December. The early crewcut treatment produced tillers with the highest dry weight across all cultivars (Table 41).

In the significant cultivar x management interaction (P <0.01) observed in February, the early crewcut treatment produced the highest tiller dry weights in Waldina and Koket but was not different from the early burn treatment in Scaldis. The early burn treatment had the same dry weight per tiller as the late crewcut treatment in Koket and the late crewcut and late burn treatments in Waldina (Table 43).

Table 43. Tiller dry weight (g $tiller^{-1}$) within cultivars, February 15, 1981. Ranked lowest to highest within cultivars.

Waldina		Scaldis		Koket	
L-burn	0.0110	L-ccut	0.0095	L-burn	0.0108
E-burn	0.0127	L-burn	0.0130	L-ccut	0.0135
L-ccut	0.0130	E-burn	0.0167	E-burn	0.0166
E-ccut	0.0182	E-ccut	0.0184	E-ccut	0.0242

LSD P <0.05 for means within cultivars = 0.0032

A similar cultivar x management interaction (P <0.01) occurred in May. The early crewcut treatment produced tillers with the highest dry weights in Waldina and Koket but was not different from the early burn treatment in Scaldis (Table 44). The early burn treatment now ranked above the late crewcut and late burn treatments in Koket but was not different than these treatments in Scaldis and Waldina.

Table 44. Tiller dry weight (g $tiller^{-1}$) within cultivars, May 1, 1981. Ranked lowest to highest within cultivars.

Waldina		Scaldis		Koket	
L-burn	0.0269	L-burn	0.0331	L-burn	0.0380
L-ccut	0.0307	L-ccut	0.0340	L-ccut	0.0465
E-burn	0.0360	E-burn	0.0447	E-burn	0.0652
E-ccut	0.0531	E-ccut	0.0482	E-ccut	0.0930

LSD $P < 0.05$ for means within cultivars = 0.0117

Effects due to cultivars ($P < 0.01$) and treatments ($P < 0.05$) were significant in June. Koket produced tillers with the highest dry weight. The late crewcut, late burn and early burn treatments produced tillers with similar dry weights. The early crewcut treatment tiller dry weight was higher than in the late treatments but not different from early burn tiller dry weight.

Although the tiller population increases and declines as the growing season progresses, total dry weight per unit area increases through the entire season. Individual tiller dry weights increase slowly between November and February and more rapidly between February and June.

DISCUSSION

Post harvest residue management treatments result in immediate (fall and winter) and long term (spring and summer) effects on tillering patterns in many grass species. The object of this study was to observe and describe tillering patterns in cultivars of two species which are known to react differently to field burning.

I. Fall and Winter Tiller Development

To maximize seed production, a field should be managed to provide a sufficient number of tillers of the appropriate size and type to be induced during the period in which environmental conditions are favorable for induction. Meijer (1984) found that high fertility in red fescue could be expected from tillers emerging in mid-November and that earlier (summer) and later (spring) tillers produced fewer seed heads. Others (Langer and Lambert, 1959; Lambert and Jewiss, 1970; Hill and Watkin, 1975) have found that fertile tiller production is dependent upon autumn formed tillers and the position of the tiller in relation to other tillers. Main stem (primary) tillers are more likely to become fertile than later formed axillary tillers. An excessive number of tillers may impede inflorescence production (Meijer, 1984) as will the accumulation of litter (Old, 1969; Weaver and Roland, 1952). The burn and crewcut management treatments applied during this study have provided the best compromise of residue removal and tiller population management on several grass species in Oregon (Youngberg, 1980) but burning has not proved to be beneficial to hard fescue seed production.

In this study, differences in cultivar response (cultivar x management) interactions were observed during data analysis for many of the variables measured. These interactions suggest that the three cultivars reacted differently to the application of post harvest management. In most cases where interactions were noted the two hard fescue cultivars (Scaldis and Waldina) responded similarly while Koket Chewings fescue expressed a different reaction to a given management.

The early burn and early crewcut treatments removed the spring formed vegetative tiller population. The late burn and late crewcut treatments removed not only the spring formed tillers that survived the summer but also destroyed tillers which had been formed in the late summer and early fall.

The hard fescue samples were much easier to pull apart than the Koket samples indicating a more loosely tufted growth habit. The remaining Koket stubble was much stiffer and more closely packed. The more loosely tufted habit of the hard fescues made them more subject to crown damage during burning. Old stems seemed to protect the fine fescue crown and fire did not penetrate as deeply into the crown. Although changes in clonal population were not a part of this study, death of hard fescue clones appeared to be slightly greater than death of Chewings fescue clones. Under commercial field conditions, where more fuel is present to support a hotter fire, hard fescue may be more subject to injury than Chewings fescue.

The Waldina hard fescue cultivar can be characterized as very aggressive in early (pre-November) tiller production (Tables 1,2) when compared to Scaldis hard fescue and Koket Chewings fescue. Koket has the ability to produce approximately equal numbers of tillers following the early crewcut, early burn, and late crewcut treatments while the hard fescues do not recover as rapidly from the early burn and late crewcut treatments. The effect of the early burn, early crewcut and late crewcut treatments is similar across all cultivars in December indicating that the hard fescues do recover from the early burn treatments but later in the season than Koket. The ability of the early burn treatment to stimulate tillering in Koket is further illustrated by data collected in February (Table 3). Due to the total destruction of fall produced tillers, the late burn treatment has fewer tillers than the other treatments in December, however this difference diminishes as the season progresses.

Both hard fescue cultivars seem to have the ability to produce as many total tillers as Koket following the early crewcut treatment and Waldina can produce as many or more total tillers under the early burn treatment by November. Differences among cultivars in the number of total tillers produced are further reduced in December. The production of total tillers under the early burn and crewcut treatments does not seem to be a limiting factor in the seed yield of either of these species.

The total tiller population can be divided into tiller units which can be classified as aerial or basal. Within units, tillers may be classified as primary or axillary. Tillers may be grouped as vegetative or fertile tillers as the season progresses. A study of tiller development is not complete unless the components of the tiller population are examined individually.

Aerial tillers have been observed in turf and seed production fields and reported by several researchers (Chilcote, 1980; Minderhoud, 1978; Simons et al. 1974) but the relationship between aerial tillers and seed yield has not been fully investigated. About one third of the hard fescue tiller population and one tenth of the Chewings fescue tiller population consisted of aerial tillers in November (Table 13,14). More aerial tillers were observed in the crewcut treatments than in the burn treatments. Fewer aerial tillers were found in Koket compared to the hard fescues, and in the burn treatments in Scaldis and Waldina leading to cultivar x management interactions. The aerial tiller population declines in both number and percent of total tillers as the season progresses, becoming relatively unimportant after February. Multiple aerial tiller units contributed only a small number of tillers to the total tiller population in the study, although Simons, et al. (1974) found these to be more important in certain genotypes of ryegrass.

The implications of the higher level of aerial tillers in the hard fescues relates to the ability of the aerial tiller to survive and contribute to yield and to its effect on basal tiller development. The decrease in aerial tiller numbers during winter and spring can be attributed to either aerial tiller mortality or to rooting from the tillering node. Aerial tillers which root at the tillering node would subsequently be classified as basal tillers. While many aerial tillers produced aerial roots at tillering nodes above ground level, careful observation during basal tiller counts detected very few basal tillers with old aerial stems attached. Rooting of aerial tillers in hard fescue is probably the exception rather than the rule because of the elevation above the soil, stiffness of the elongated internodes, compactness of the crown, and presence of competing adjacent tillers which support these aerial stems in an upright position. Minderhoud (1978) reported similar findings and agreed with Langer's (1956) suggestion that aerial tillers generally did not survive through the winter because of adverse environmental factors.

The presence of aerial tillers may have a negative influence on the development of basal tillers. Very few aerial tiller units were observed with subtending basal tillers attached at ground level. This observation agrees with Minderhoud (1978) who suggested that aerial tillers suppress the formation of normal vegetative tillers at the base of the stem similar to the restriction imposed by fertile tillers. Light, which is limiting in the Willamette Valley during winter (Chilcote, et al., 1980) may be further reduced by the shading effect of aerial tillers as the aerial tillers form a "secondary canopy" over the developing basal tillers. Competition for substrate may also play an important role in aerial-basal tiller interactions.

The majority of aerial tillers were formed at elevated nodes on old culms. Most of the potential aerial tillering sites were eliminated when older culms were destroyed by the burning treatments which accounted for fewer aerial tillers being observed in the burn treatments. Simons et al. (1974) found that applying mulch to ryegrass increased aerial tillering. Burning may have the opposite effect by removing stems and litter remaining after harvest. If this is the case, burning may cause changes in the microclimate (light intensity, soil temperature, etc.) which would reduce aerial tillering in addition to destroying potential aerial tillering sites.

In general, basal internodes were longer in the hard fescue tiller population (Table 22). Post harvest burning and early crew-cutting caused the least elongation of the basal internodes. This internode elongation reduces the ability of the tillers to root or survive the stress of winter conditions.

Aerial stems do not seem to support fertile tillers. Fertile tiller root systems were developed at nodes on which remnants of basal leaves were attached suggesting that if an elongated aerial stem had been present, aerial roots forming at the tillering node above the aerial stem were able to become established and support development of the fertile stem. However, no fertile stems were observed with portions of old aerial stems attached at the rooting node. Under the crewcut management, particularly in hard fescues, it seems that much of the dry matter production is directed toward the production of aerial tillers which contribute little to seed yield.

No differences were observed in the number of basal tiller units among cultivars in November and December (Table 8). Langer (1956) and Lambert and Jewiss (1970) noted that main stem (primary) tillers were more likely to become fertile. The number of primary tillers, as indicated by the number of tiller units, is not significantly different in November and December, and is not greatly affected by treatments. Therefore, differences in the number of fertile tillers cannot be attributed strictly to differences in the number of primary tillers available for induction. Basal tiller units increase in number as the season progresses. The data indicate that this increase occurs generally across all cultivars and is not much affected by treatments early in the season, the exception being the effect of the burn treatments on Koket between December and February.

Early treatments resulted in more tillers per basal unit than the late treatments (Table 10) but few differences were observed within early or late treatments, the exceptions being between the early burn and early crewcut treatment in the Scaldis November sample and the Koket December sample (Tables 11, 12). By February, all cultivars were similar in the the number of tillers per basal unit with the early burn treatment having more basal axillary tillering than other treatments.

The number of basal tillers per unit area (a function of the number of basal units and the number of tillers per basal unit) also shows the effect of date of treatment in November and December. No clear cut differences emerge in the number of basal tillers in crewcut vs burn or Chewings vs. hard fescue cultivars early in the season. By February, it is clear that the early burn treatment enhances basal tillering in Koket but not in the hard fescues (Table 6).

Basal tillers formed in January and February may not contribute substantially to yield. Meijer (1984) concluded that there is a juvenile stage in red fescue when tillers and tiller initials cannot be induced and that tillers arising closer to the beginning of the vernalization treatment produced fewer inflorescences. Kim (1973) noted that no clones of red fescue exposed to outdoor (Willamette Valley) conditions later than March formed fertile tillers. If tiller age and environmental requirements for floral induction in Chewings and hard fescues are similar to red fescue, the majority of tillers which will become fertile are present in the field in late fall with fertility declining on tillers formed after November. Even if these tillers are induced, the number of spikelets may be reduced over fall formed tillers because of the accumulation of fewer leaf primordia at the stem apex in the newly formed tillers (Ryle, 1964). The rapid flush of growth resulting from the early burn treatment in Koket between December and mid-February may not result in increased yield. A study of floral induction requirements in Chewings and hard fescue cultivars grown under Willamette Valley conditions would provide information useful in evaluating seed production management practices.

Leaf number per vegetative tiller in November is not greatly affected by management in the hard fescue cultivars. In Koket, November leaf number differs in every treatment (Table 26). The ability to produce more leaves may be responsible for the more rapid tillering in Koket between December and February due to more fully expanded leaves, thus more axillary tiller sites and increased availability of substrate. Leaf blade length is also greater in Koket through the course of the growing season (Table 27).

Except for the cultivar x management interaction observed in February no differences were found between cultivars for dry weight on a unit area basis during the course of the study (Tables 39 and 40). Reviewing the individual tiller dry weight measurements for Koket in February (Table 43), the early crewcut treatment produced tillers with significantly higher dry weights than the early burn treatment. The significantly greater total dry weight in the early burn treatment for Koket was due to the number of tillers present rather than a greater dry weight per tiller. Generally, the early crewcut treatment produced tillers with the highest dry weights per tiller early in the season although the early crewcut and early burn treatments were not always different. The higher dry weight in the early crewcut treatment may be due in part to the difficulty in separating live tillers from dead plant material and from the presence of more old culms supporting aerial stems. As may be expected, the late treatments tended to produce tillers with lower dry weights.

II. Spring and Summer Tiller Development

Between February and June, changes occur in tiller development which are related to the production of fertile tillers. Cultivar and treatment effects are still discernible and in some cases become more apparent. The tiller population consists largely of basal tillers. As fertile tillers develop, the appearance of the stand changes and differences in tillering habit between the Chewings and hard fescues are more obvious.

A substantial decline in the Koket total tiller population occurs between February and June compared to a relatively stable hard fescue tiller population. Several researchers (Lamp, 1952; Langer, 1956, 1958; Kim 1973; Meijer, 1984) have found a decrease in the number of tillers during stem elongation. Jewiss (1972) observed that tillering is restricted during periods of stem elongation, probably due to inhibition of tillering by substances produced at meristematic centers in the elongating stem. Ong (1978) found a high mortality rate in small vegetative tillers and suggested shading and nutrient deficiency as contributing factors. This research supports the observed decline in the Koket vegetative tiller population but does not explain the maintenance of a large vegetative tiller population in the hard fescue cultivars (Tables 1, 36). The reduction in Koket basal tiller number was due to a decline in vegetative tillers per basal tiller unit rather than in the number of basal tiller units (Tables 8, 10). Differences in fertile tiller number in June do not suggest that the high number of vegetative tillers present in the hard fescue cultivars was due to the failure to produce a number of fertile tillers sufficient to inhibit vegetative tillering. However trends in tiller emergence (Table 34), and fertile tiller length and flag leaf length length (Table 30) suggest that the hard fescue fertile tillers may be less competitive for light and substrate due to a shorter, slower growth habit.

Emergence, measured by the number of fully emerged fertile tillers during the May sampling compared to the number of fertile tillers in June, is delayed most by the late burn and late crewcut treatments. Early burn and early crewcut tiller emergence did not differ in Koket and Scaldis but did in Waldina. Hadley and Kieckhefer (1963) report that burning can result in earlier flowering in some grass species compared to untreated plots. Burning may enhance fertile tiller emergence when comparing untreated and treated plots but when comparing burned and crewcut treatments the results are less clear, particularly among hard fescue cultivars.

Dry weight per tiller and per unit area increases in spite of reductions in tiller numbers between February and June. Differences among cultivars in dry weight per unit area were not significant in June (Table 39) but differences in dry weight per tiller were (Table 41). In Koket, dry matter was partitioned into fewer tillers, of which 32% were fertile, while in the hard fescues a similar amount of dry matter was partitioned into more tillers of which about 13% were fertile. The decrease in the total number of sinks (vegetative tillers) coupled with a higher percentage of fertile tillers resulted in a rapid increase in fertile tiller weight in Koket and increased the potential for higher yields.

A comparison of the 1980 (pre-treatment) harvest data with the 1981 (post-treatment) harvest data (Tables 37, 38) suggests differences in dry matter partitioning during these two years. Mean seed yield was higher in 1981 although mean seed weight was lower. Among cultivars, the relative ranking of seed yield and 1000 seed weight were similar but there were differences in the rankings of fertile tillers, seed weight per tiller and number of seeds per tiller. Differences in tiller density in the seedling year (1980) compared with the second growing season and differences in climatic conditions may account for as much of this variation as does post harvest residue management.

In this study the early burn treatment did not result in the severe reduction in seed yield or increased plant destruction observed in commercial production fields. The severity of the burn treatments was moderated by the pre-treatment flail chop and removal of excess litter to increase treatment uniformity. Burning may be a practical management technique for hard fescue under carefully controlled conditions. Clipping and even distribution of litter or partial litter removal prior to burning reduces plant destruction and enhances fall tillering over open burn without litter removal. A multi-year study is needed to determine if a modified burn management system will increase or at least maintain fertile tiller number and seed yield over the life of a production field.

The absence of cultivar x management interactions in the 1981 harvest data indicates that all cultivars reacted similarly in seed yield to the management treatments. The superior seed yield of Koket Chewings fescue was due to 30% greater number of fertile tillers per unit area and 25% greater mean seed weight. Differences due to treatment are largely due to the number of fertile tillers present.

The presence of a high number of spring vegetative tillers in the hard fescue cultivars may have affected seed yield. Ong et al. (1978) suggests that vegetative tiller death during during stem elongation is due to the failure of the flowering tillers to support the growth of young, vegetative tillers which are dependent upon the import of assimilates from the primary tiller. This may explain the reduction in vegetative tiller numbers in Koket but does not account for the maintenance of a high vegetative tiller population in the hard fescue cultivars. In some cases, researchers (Clemence and Hebblethwaite, 1984; Ong and Marshall 1975) found that young tillers were a major sink for assimilates from the inflorescence. Marshall (1985) concludes that some degree of competition between vegetative and reproductive sinks for inflorescence produced assimilate could influence the abortion and development of seeds. The hard fescues had 85% more tillers per basal unit on June 15 than the chewings fescue (Table 10). The inter-tiller competition in hard fescue during the pollination and seed filling stages and may have influenced seed number and seed weight.

CONCLUSION

The manner in which the two species differ in their response to post harvest management may be manifestations of alternative survival mechanisms. Chewings fescue is more plastic in its ability to respond to environmental conditions; Koket produced a similar number of tillers in all but the most severe (late burn) treatment whereas the hard fescues did not recover from the treatments as rapidly early in the season. Burn treatments seem to enhance winter tillering in Chewings fescue but not in hard fescue. Koket can shift dry matter production into fertile tillers and heavier seed while the hard fescues maintain more vegetative tillers. The hard fescues produce a higher proportion of aerial tillers (pseudo-stolons) which may be important for species survival and spread under natural conditions where litter is accumulated. Hard fescues have a slower vertical growth rate and are less plastic in their ability to respond to environmental conditions. Chewings fescue has a higher growth rate and may be more dependent upon seed production for species survival under good conditions but is not as well adapted to poor conditions.

Differences in seed yield between species cannot be simply attributed to the availability of early season tillers for floral induction. Yield differences are due to the more subtle effects of inter-tiller competition, dry matter partitioning and the genetic propensity to adjust to the environment and to favor seed production over the maintenance of vegetative tillers.

In Chewings fescue, selections have been made for improved seed yield and turf performance over a much longer period than hard fescues. Because of the recent interest in improved hard fescue cultivars, attention is now being focused on selecting for improved seed yield. Higher yielding cultivars which allocate more dry matter production to fertile tillers under typical management regimes will be required for increased commercialization of hard fescues. However, this study suggests that the possibilities for managing existing cultivars have not been fully explored. Further investigations of modified clipping and burning techniques are indicated by the fact that controlled burning did not reduce the seed yield of the hard fescue cultivars when compared to Chewings fescue.

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APPENDIX

Table 45. July, 1980-June, 1981 monthly mean temperature, total precipitation, 30-year mean, and deviation from long-term means, Corvallis, Oregon.

Month	Temperature (°C)						Precipitation (cm)		
	Minimum Means			Maximum Means			Total		
	30-yr avg	1980-81	Deviation	30-yr avg	1980-81	Deviation	30-yr avg	1980-81	Deviation
July	10.32	11.38	1.05	27.03	26.97	-0.06	0.79	0.61	-0.18
Aug.	10.38	8.49	-1.89	26.92	26.31	-0.61	2.06	0.03	-2.03
Sept.	8.71	8.44	-0.28	24.14	24.70	0.55	3.76	2.44	-1.32
Oct.	5.38	5.22	-0.17	17.93	19.48	1.55	8.61	4.75	-3.86
Nov.	2.89	4.33	1.44	11.27	12.38	1.11	15.67	15.98	0.30
Dec.	1.44	2.89	1.44	8.05	9.16	1.11	19.74	28.78	9.04
Jan.	0.50	1.17	0.67	7.27	8.38	1.11	19.18	5.77	-13.41
Feb.	1.67	1.94	0.28	10.21	9.99	-0.22	12.34	11.28	-1.07
Mar.	2.28	2.66	0.39	12.10	13.82	1.72	11.76	7.62	-4.14
Apr.	3.77	4.77	1.00	15.15	15.21	0.06	6.25	6.02	-0.23
May	6.22	6.77	0.56	18.98	18.09	-0.89	4.88	7.59	2.72
June	9.05	9.05	0.00	22.53	21.20	-1.33	3.05	6.55	3.51
Year	5.22	5.59	0.37	16.82	17.14	0.32	108.08	97.41	-10.67