AN ABSTRACT OF THE THESIS OF

William C. Young III for the degree of Master of Science

in Crop Science presented on July 29, 1980

Title: Grazing Duration Effects on Seed Yield of Annual Ryegrass (Lolium multiflorum L.)

Redacted for privacy

Abstract Approved:
D. O. Chilcote

Spring grazing of annual ryegrass (*Lolium multiflorum* L.) seed fields with sheep is a common practice in the Willamette Valley of Oregon. However, the effect of grazing on seed yield in Oregon has not previously been investigated. This experiment was designed to determine the effects of duration of spring grazing annual ryegrass with sheep on vegetative growth, reproductive development, seed yield and yield components.

A two year field study was conducted in 1978 - 79 on fall seeded annual ryegrass grazed the following spring at a constant stocking rate. Treatments consisted of different grazing durations and an ungrazed control. Sod strips were removed throughout the spring to measure changes in vegetative growth, and quadrats were taken at seed maturity to examine several seed yield components.

Results indicate no effect on the number of plants per unit area, however, increased grazing duration resulted in a significantly greater number of vegetative tillers per plant. The number of fertile tillers at harvest were significantly greater in the grazed treatments than in the non-grazed treatments. However, the percentage of vegetative tillers which became reproductive were significantly lower in the longer grazing treatments. No effect on seed yield or total plant dry weight at harvest was observed for either year. In 1978, grazing through early April significantly reduced seed weight per 400 seeds but did not effect the number of spikelets per spike or the number of fertile florets per spikelet. In contrast, similar grazing duration in 1979 did not effect seed weight per 400 seeds but did significantly reduce the number of spikelets per spike and the number of fertile florets per spikelet.

It was concluded that grazing fall seeded annual ryegrass into early/mid-April will not reduce seed yield, although alterations in the components of seed yield and yield component compensation can be expected.

Grazing Duration Effects on Seed Yield of Annual Ryegrass (*Lolium multiflorum* L.)

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1981

APPROVED:

Redacted for privacy

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Date thesis is presented July 29, 1980

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ACKNOWLEDGEMENTS

The author would like to express his sincere thanks to his major professor, Dr. David O. Chilcote, for the interest, guidance, and support given throughout the duration of this study. Appreciation is expressed to Drs, Rod V. Frakes, Glenn A. Klein, and Stanley Miller for their interest as advisors on the graduate committee.

A special debt of gratitude is owed to Mr. Henry O. Pfenning and Mr. Larry Pfenning, who generously provided their land and animals so that this study could be undertaken.

The author would also like to express his thanks to Mrs. Doris Aponte and Mrs. Beth Nickolson for their help in the preparation of this manuscript. For his technical advice on the use of equipment and facilities, I am indebted to Mr. Carroll C. Moon.

Finally, I am grateful to my wife, Carol, for her invaluable confidence and support.

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Grazing Duration Effects on Seed Yield of Annual Ryegrass (*Lolium multiflorum* L.)

LITERATURE REVIEW

Using annual ryegrass fields for both grazing and seed production has become a common practice in the Willamette Valley of Oregon. The effects of grazing on subsequent seed yields have not been carefully examined. Little research data are available to guide seed producers in the selection of the most efficient management systems for this dual utilization.

Cutting or grazing prior to internode extension results in the removal of leaf material only, and subsequent regrowth arises from the extension of leaf primordia from the terminal meristem and from the meristems of axillary tillers (10). The terminal meristems remain undamaged because of their location near or below the soil level and thus below the cutting or grazing height (10). Defoliation by grazing may delay but not prevent maturation if the growing point is left intact. Food reserves in the stubble and roots of annual ryegrass are more abundant in the cooler climate which prevails in the plant's early development, with more rapid new growth following clipping (8). Leaf appearance on the main stem and tillering are accelerated by the warmer temperatures accompanying spring development (6), and despite large differences in the time of tiller origin, winter and early spring tillers of annual ryegrass initiate floral primordia within a relatively short period. Ear emergence follows a similar pattern (15).

Once internode extension has begun, cutting or grazing may remove the terminal meristem and unexpanded leaves which remain (10). Cutting normally results in the removal of all growth above a given height, whereas, grazing is more selective, and although simulation of grazing is difficult, clipping has been used to study effects of stage and intensity of defoliation. Maeda and Ehara (11) reported that the effect of clipping to a height of 2 cm to remove the growing point early in the plants' development, produced more tillers than clipping to a height of 6 cm at the same stage of development while leaving the growing point intact. Furthermore, removing the main stem increased the number of tillers and heads, with the effect decreasing from early growth until there was no effect after heading (3). Herron (9) working in Oregon with annual ryegrass and sheep, investigated closing dates of mid-April and early May and reported an increased number of fertile tillers. However, significant reductions in seed yield were observed which were attributed to reduced spike length and a decreased number of spikelets per spike, florets per spikelet and seed weight (9). Similarly, workers in Great Britian have shown that fertile tillers were not significantly influenced by cutting annual ryegrass as late as May 21, although seed yield declined significantly (4).

The research reported here was designed to examine the effects on seed yield of different grazing durations using sheep under field conditions. Effects on growth, development, seed yield and yield components were determined.

MATERIALS AND METHODS

A field experiment was conducted for two crop years (1977 - 78 and 1978 - 79) on an Amity silt loam soil typically used for annual ryegrass production. The field was located approximately 7 km. east of Salem, Oregon. In both years post-harvest residue was burned prior to seeding. In mid-September 11.2 kg/ha of annual ryegrass seed was planted on 17.8 cm drill spacings with 35.9 kg/ha of nitrogen and 44.8 kg/ha of phosphate applied. An additional 78.5 kg/ha of nitrogen were spring applied following the removal of sheep.

Four treatments were arranged within four replications in a completely randomized block design. In 1977 - 78 treated plots were 9.14 m wide x 30.48 m long, and all treatments were confined to a corner of the field approximately 1.0 hectare in size. In 1978 - 79 experimental plots were 3.05 m wide x 9.14 m long and each replication was selectively placed where the most unifrom stand prevailed. In both years' treatments were imposed by fencing the area to exclude sheep. Treatments were selected to investigate the effect of commercial grazing practices on annual ryegrass fields in the Willamette Valley. An ungrazed control was fenced prior to sheep being brought into the field and subsequent treatments were imposed by fencing to exclude sheep following the prescribed grazing period. Ewes and lambs were allowed to freely graze all areas outside of the fenced treatments. The stocking rate was adjusted over time as the grazing area was reduced so as to keep stocking rate uniform. Thus, the effects observed are the result of the duration of grazing.

Laboratory dissection of primary tillers classified the stages of development and were used to determine exclosure dates. The first exclosure was made after the initiation of the primary tillers but prior to internode elongation. The second exclosure was made after internode elongation began and allowed the removal of the growing point of many primary tillers. The third grazing period was terminated by the removal of sheep from the field and represented the greatest defoliation severity allowed, with a larger number of apices removed. Throughout each treatment, grazing pressure provided vegatation removal to a height of 2 - 3 cm.

A stocking rate of 25 ewes per hectare plus their lambs was selected for the experiment during 1978, while a reduced stocking rate of 17 ewes per hectare plus lambs were choosen for grazing during 1979. Sufficient rain and moderate temperatures during the 1977 - 78 winter provided abundant forage and allowed for the heavier stocking rate. By contrast, unseasonably cold and dry weather during the 1978 - 79 winter reduced available spring forage resulting in a reduced stocking rate. Furthermore, grazing began about two weeks later in 1979, but was allowed to continue for two weeks beyond the last closing date in 1978.

The dates of treatment exclosures for 1978 and 1979 were as follows:

1978

G_0	Not grazed
G_1	Grazed February 22 through March 8
G_2	Grazed February 22 through March 29
G_3	Grazed February 22 through April 5

1979

G_0	Not grazed
G_1	Grazed March 7 through March 26
G_2	Grazed March 7 through April 9
G_3	Grazed March 7 through April 18

Several vegetative characteristics were measured on a 500 cm^2 sample taken by cutting a 10 cm x 50 cm strip from each treatment on several sampling dates throughout the spring. These included the number of plants, number of tillers per plant, tiller stem base diameter, specific leaf weight, and the percent nonstructural carbohydrates in the stem bases. At seed maturity, seed yield, total dry weight, straw weight, the number of fertile tillers, number of spikelets per spike, fertile florets per spikelet and seed weight per 400 seeds were all determined from 929 cm^2 samples.

The number of plants per 500 cm^2 were obtained after washing soil from the sampled area. Vegetative tillers per plant were counted, roots were removed and discarded, and tiller stem base diameters were size classed using a wire gauge indicator.

Stem bases were removed and prepared for an analysis of total nonstructural carbohydrates (primarily fructosans). To reduce respiratory losses, respiratory enzymes were denatured by a 30 second exposure in a microwave oven. Stem bases were then oven dried and ground to 40 mesh screen size. An extraction and estimation of water soluble carbohydrates using anthrone reagent followed, and data were expressed as a percent of total stem base dry weight.

Leaf area of the total sample area was measured in cm^2 using an area meter. Leaf tissue was subsequently oven dried and weighed. Specific leaf weight was calculated as milligrams per cm^2 for each observation.

Total above ground biomass was harvested in 929 cm^2 samples at seed maturity in order to examine changes in total dry weight, straw weight, seed yield, and changes in the components of seed yield.

The number of fertile tillers per unit area was counted, ten random spikes were selected and the number of spikelets per spike were recorded from this subsample. The spikes from each observation were hand threshed and cleaned with a seed blower, and clean seed yield was recorded. Four lots of 100 seeds each were counted and weighed for each seed weight observation. The combined weight of 400 seeds was used in the analysis of variance. Fertile florets per spikelet were calculated as the total number of seeds divided by the total number of spikelets. Final observations were the percent germination of each lot of 100 seeds and an estimate of seedling vigor. Seedling vigor was measured as seedling length seven days after being placed in the germinator.

The analysis of variance was performed on all data. The F test and least significant differences at the five percent level of probability (L.S.D. .05) were used to determine differences among treatment means.

RESULTS AND DISCUSSION

The results are from different durations of grazing with a uniform stocking rate of sheep. Growth responses due to grazing treatments in 1979 were essentially identical to those observed in 1978, and the discussion follows the changes in vegetative characteristics with a graphic presentation of treatment effects observed in 1978. However, because of differences in the components of seed yield observed across years, a more detailed discussion contrasting the reproductive responses between years is presented.

Plant Number

The presence of sheep does not appear to effect the number of plants per unit area in the field even with a stocking rate that equals or exceeds commercial grazing practices. Plant numbers did fluctuate within each treatment (Fig. 1), but stand injury due to grazing was not evident based on the first and last sampling date. Furthermore, there was no significant difference in the number of plants per 500 cm^2 on the last sampling date. The plant population observed from sampling was equivalent to 8.75×10^6 plants per hectare.

Tillers Per Plant

In figure 2 the number of tillers per plant for each treatment are plotted across several sampling dates. Observations made from tiller dissections indicated that grazing beyond mid-March resulted in the

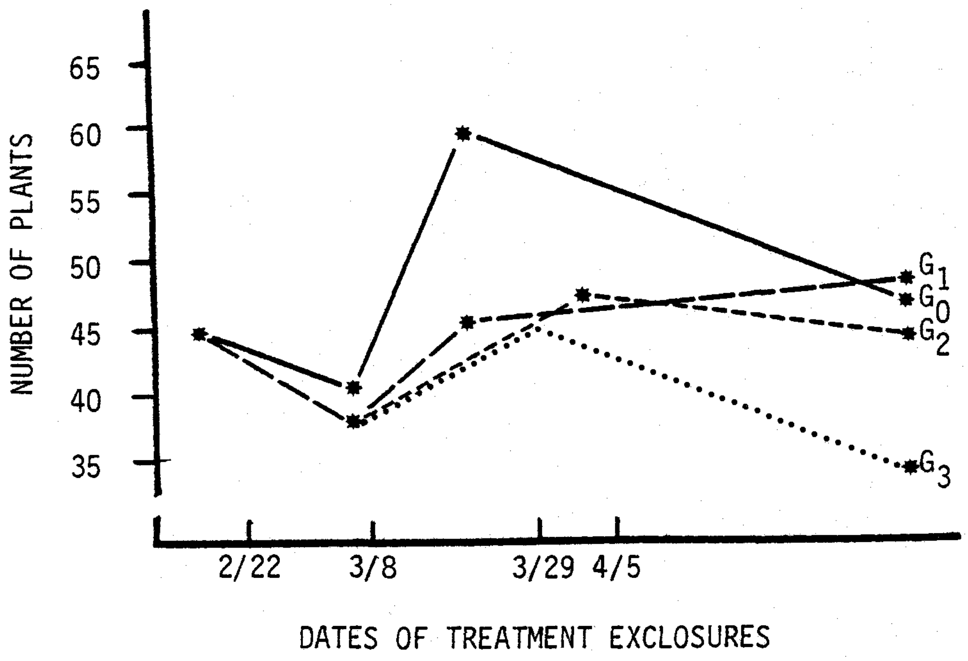

FIGURE 1. Number of plants per 500 cm^2 at several sampling dates as influenced by grazing duration treatments (G) in 1978.

*Indicates sampling date.

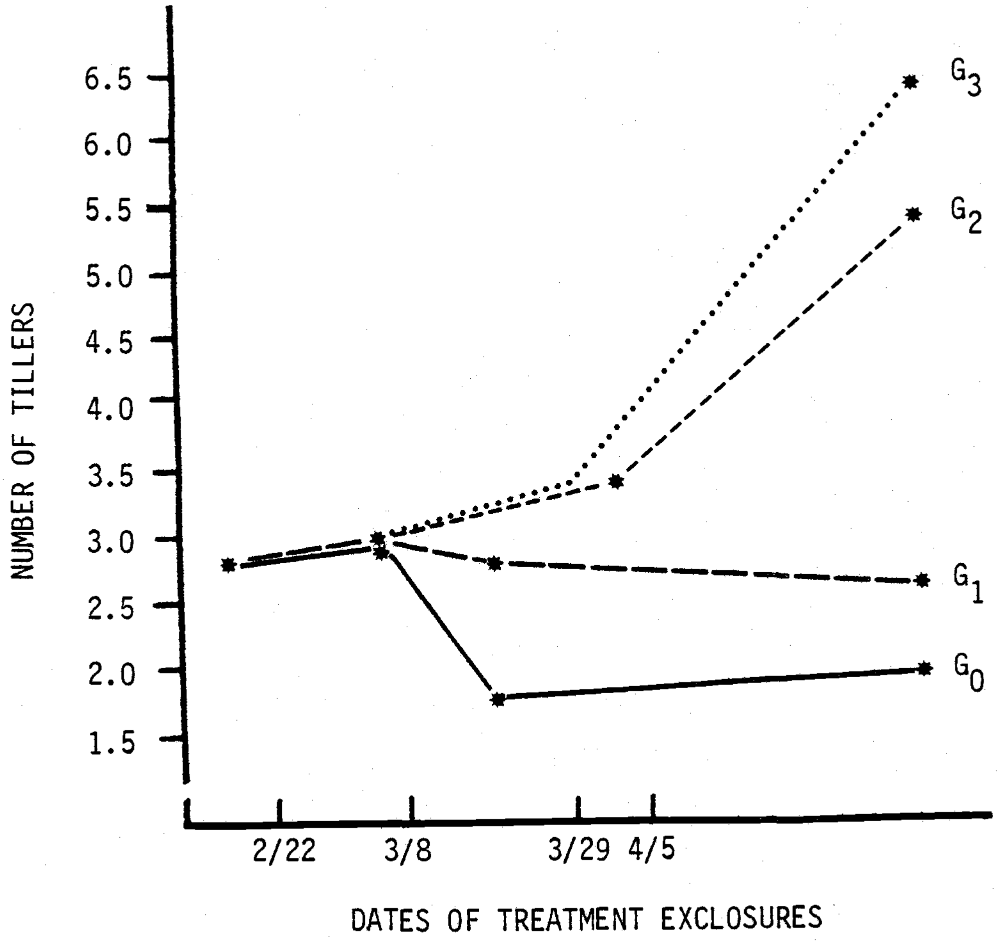

FIGURE 2. Number of tillers per plant at different sampling dates as affected by duration of grazing treatments (G) in 1978.

*Indicates sampling date.

removal of many terminal meristems. The increasing number of tillers per plant in treatments G_2 and G_3 have resulted from the release of axillary tiller buds accompanying the removal of terminal meristems. Treatments G_2 and G_3 with five to six tillers per plant were found to be significantly different from treatments G_1 and G_0 with two to three tillers per plant. Thus, an increased number of vegetative tillers per plant resulted in an increased tiller density in the later grazed treatments. While treatments G_2 and G_3 are both increasing in tiller number per plant, treatment G_0 can be seen to significantly decrease. This is because of tiller senescence, a result of very early self shading that occurred because of canopy development. However, treatment G_1 was closed prior to internode extension and terminal meristems were not removed. No significant differences in tillers per plant were observed within this treatment, although a slight increase followed by a leveling off of tiller production can be seen. A more open canopy for a longer period of time likely allowed more light penetration and greater survival of basal tillers.

Tiller Size

Mean diameters of the tiller stem bases became significantly smaller in the later grazed treatments. Three levels of significance can be observed in figure 3 for the data collected on the last date. The removal of the terminal meristem and the release of axillary buds resulted in a stand comprised of a greater number of smaller tillers. Canode and Law (5) working with Kentucky bluegrass (*Poa pratensis* L.), have shown that smaller tillers have a much lower level of panicle production even though temperature and photoperiod were adequate for

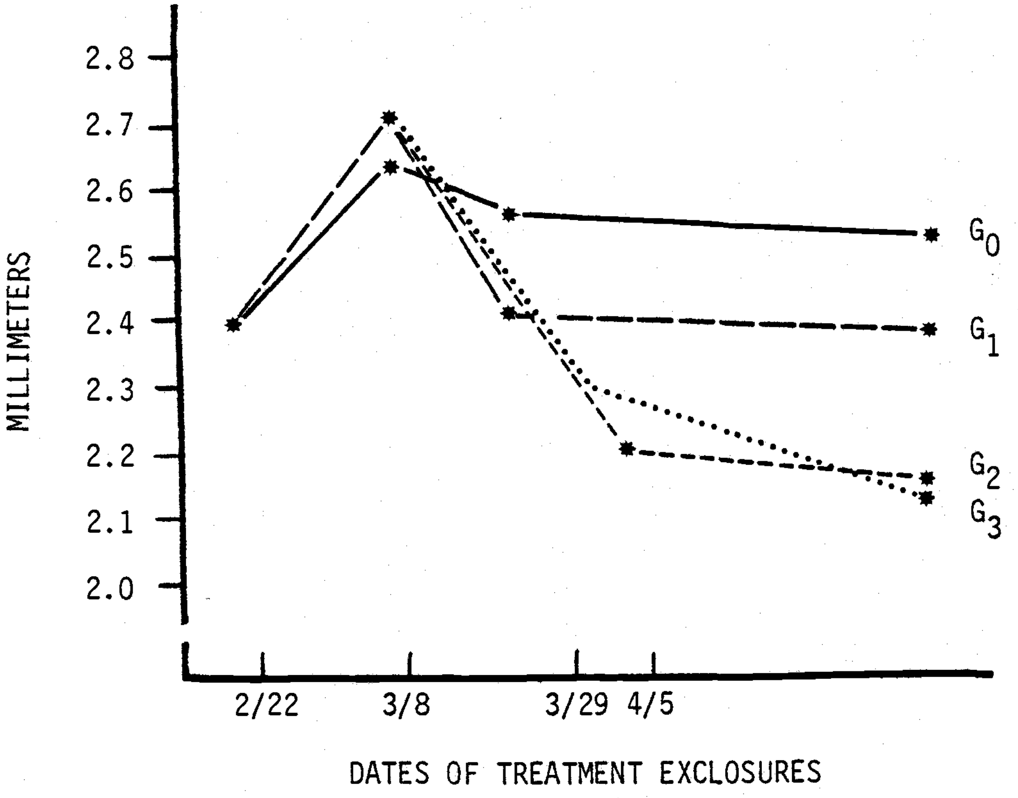

FIGURE 3. Diameter of tiller stem bases at several sampling dates as affected by grazing duration treatments (G) in 1978.

*Indicated sampling date.

induction. Similarly, we observed that when the total number of vegetative tillers on our last sampling date were compared with the number of fertile tillers at harvest, the percent of tillers in the later grazed treatments that became reproductive were significantly less than those for treatments G_0 or G_1 (Table 1). We attribute this to inter-tiller competition for available resources as light, moisture and nutrients became increasingly limited as the canopy developed.

Leaf Area

In figure 4 leaf area per 500 cm^2 is plotted across several sampling dates for each grazing treatment. The G_0 line is actually plotting ungrazed growth and treatments G_1, G_2 and G_3 are plotting regrowth after grazing. Leaf area is significantly reduced by grazing, however, the net assimilation of photosynthate by the total canopy may not be significantly different. Ungrazed growth in the control has resulted in early self shading and poor utilization of light energy. Newer leaf tissue in the grazed treatments could show greater net carbon exchange rates characteristic of younger leaf tissue. These leaves would be developed under a greater light intensity and possibly preconditioned to allow greater photosynthetic rates. Furthermore, the greater number of tillers being developed per plant in the later grazed treatments maintains a strong sink for photosynthate. Thus reduced leaf area does not necessarily imply reduced photosynthate availability for subsequent development.

Specific Leaf Weight

Having recorded the dry weight of leaf area measured at each

Table I. Total number of vegetative tillers on the last spring tillers sampling date compared with the number of fertile tillers at harvest in two years. Date are also expressed as a percent of vegetative tillers which became reproductive as influenced by grazing duration treatments.

	Total Vegetative Tillers		Total Fertile Tillers		Percent of Vegetative Tillers Which Became Reproductive	
	----------Number/929 cm^2----------				%	
Treatment	1978	1979	1978	1979	1978	1979
G_0	166	223	102	150	62	68
G_1	234	252	121	161	51	63
G_2	449	301	131	179	29	60
G_3	430	380	139	188	32	51
$L.S.D._{.05}$	59	70	18	NS	11	11

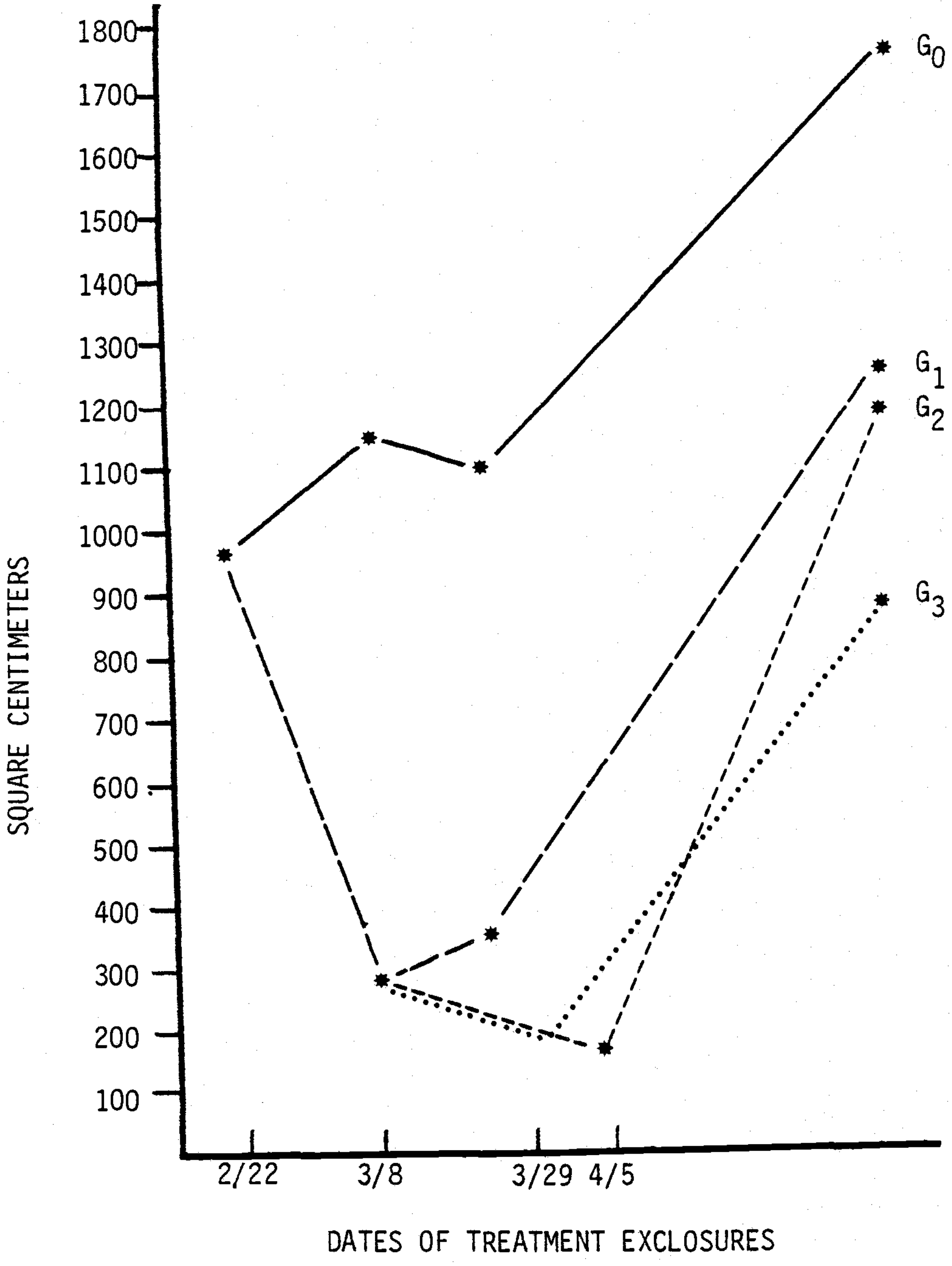

FIGURE 4. Leaf area per 500 cm^2 at several sampling dates as influenced by grazing duration treatments (G) in 1978.

*Indicates sampling date.

sampling date we calculated the specific leaf weight for each treatment. It is apparent that specific leaf weight is significantly altered by prolonged grazing (Fig. 5), and that in each grazing treatment following the removal of sheep and subsequent regrowth, specific leaf weight declines. The greater specific leaf weight seen in treatments G_0 and G_1 may be the result of photosynthate accumulation in the leaf tissue. This is frequently apparent when sink strength is reduced, as could be accompanying their lower number of tillers per plant. Continued tiller development in the later grazed treatments maintains a strong sink which may reduce accumulation of photosynthate in leaf tissue. Thus where no defoliation occurred or lenient grazing is allowed, tiller development soon subsides and with reduced sink strength photosynthate could accumulate in the leaf tissue. Note that in treatment G_1 specific leaf weight begins to increase (Fig 5) at the same time tiller development subsides and canopy closure and self shading occurred (Fig. 2). The lighter, thinner leaves in treatments G_2 and G_3 may also be a result of increased growth rate brought on by increasing day length and temperature. Furthermore, because of the greater number of tillers and the intense sinks of developing intercalary meristems in elongating stems and developing inflorescences, a better balance between sources and sinks may have occurred in the later grazed treatments.

Percent Water Soluble Carbohydrates

An additional source of carbohydrates to that from current photosynthesis is stem base accumulated fructosans. Milthorpe (12) has concluded that although there is little real evidence of the exact role played by these substances in regrowth, it seems likely that these

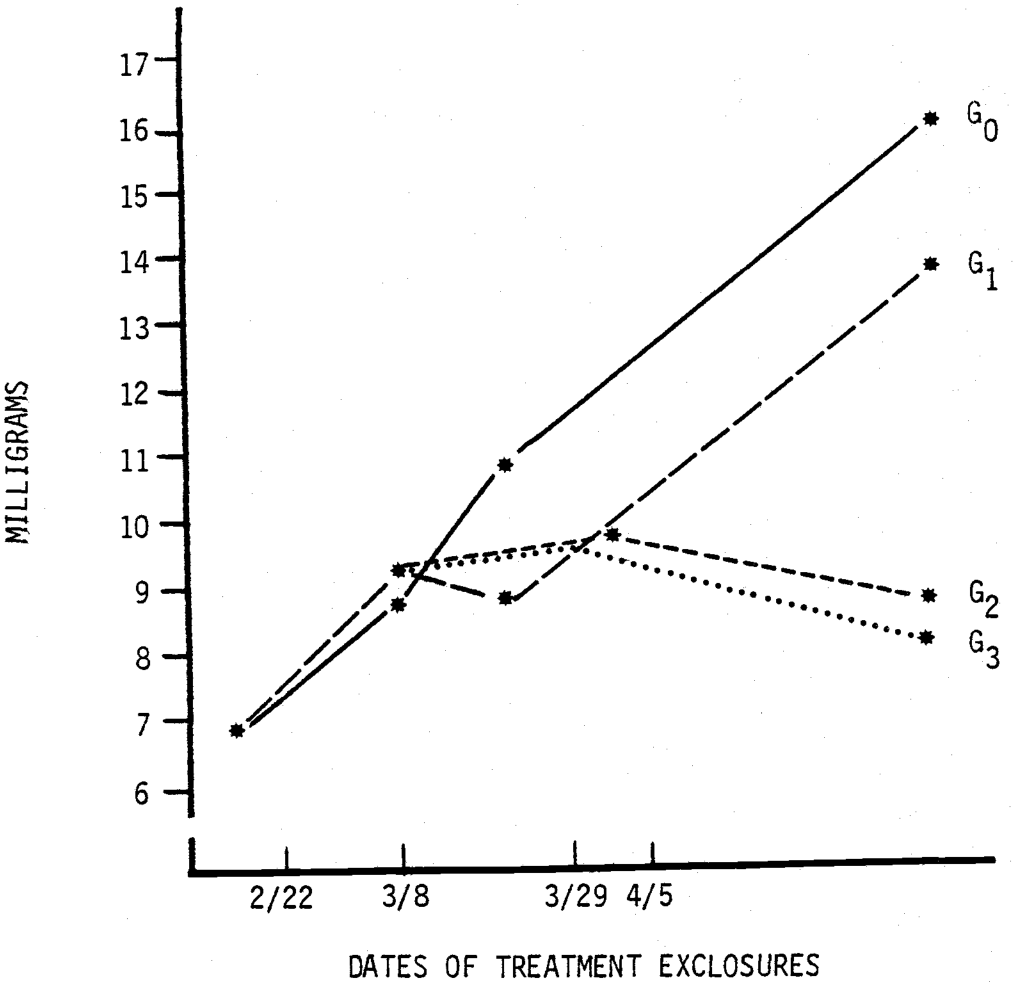

FIGURE 5. Specific leaf weight (mg/cm^2) at several sampling dates as affected by duration of grazing treatments (G) in 1978.

*Indicates sampling date.

components form part of the same metabolic pool as current photosynthate based on their substantial decrease in concentration which always follows defoliation. Data presented in figure 6 shows this characteristic decline following a partial defoliation. However, it is thought that the only period when stored carbohydrates contribute significantly to growth is in the first few days following defoliation. The relative contribution to new growth depends largely on the amount of current photosynthesis (12).

Dry Matter Production

Examining the mean weight of dry matter in seed and straw we see that dry matter was not effected even where the greatest duration of grazing was allowed (Table 2). No differences were observed in the straw weight or in total dry weight. However, in both years a slight increase appeared to be associated with a lenient grazing period (treatment G_1).

Components of Seed Yield

A significantly greater number of fertile tillers (spikes) per unit area were present at harvest in the grazed treatments, a result of the overall increase in tillering where grazing was allowed (Table 1). This effect has previously been reported (3, 10, 11) and it is apparent also that removing the terminal meristem by late grazing results in more fertile tillers than early grazing without removing the terminal meristems. The heavier stocking rate in 1978 removed the terminal meristems from all primary tillers in treatments G_2 and G_3. However, in 1979 because of the lower stocking rate, some primary tillers maintained their terminal meristems which apparently inhibited subsequent tiller development on that plant. The effect of this differential grazing

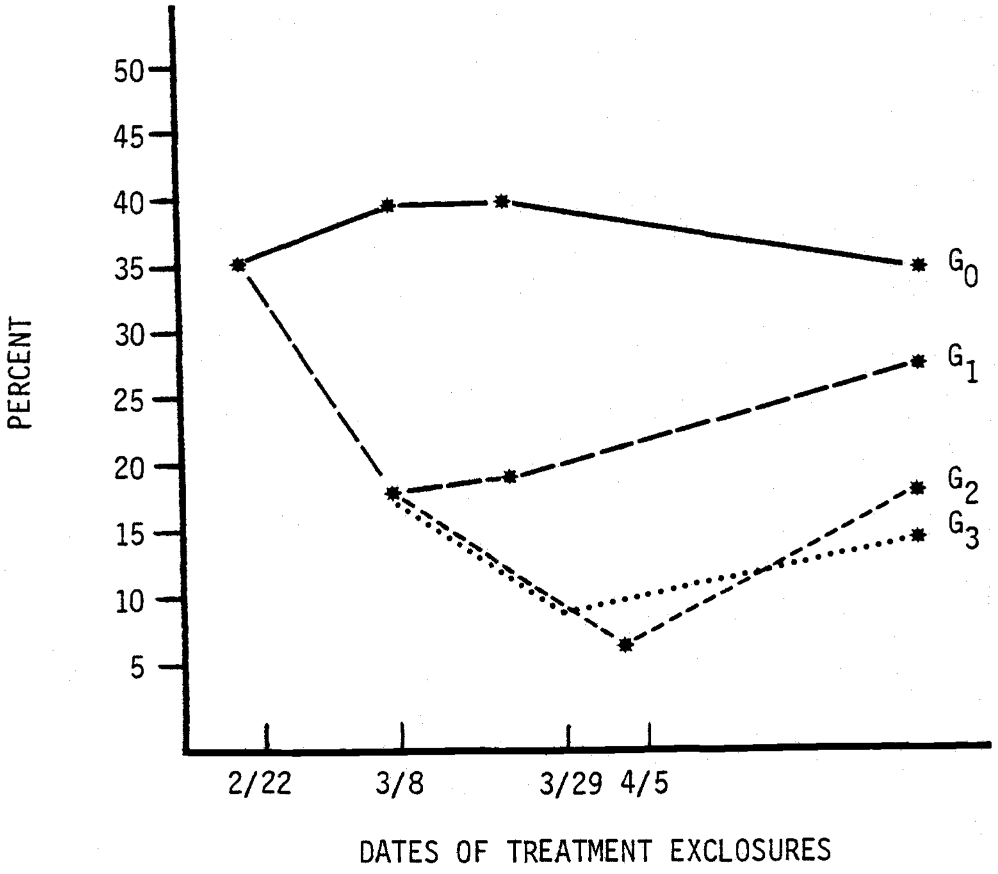

FIGURE 6. Water soluble carbohydrate in stem bases expressed as a percent of total stem base dry weight as affected by grazing duration treatments (G) in 1978.

*Indicates sampling date.

Table 2. Dry matter distribution at harvest as influenced by grazing duration treatments in two years; expressed as grams per 929 cm^2.

	Seed Yield		Straw Weight		Total Dry Weight	
Treatment	1978	1979	1978	1979	1978	1979
G_0	24.1	23.1	79.4	67.9	103.5	91.0
G_1	29.9	27.9	81.8	72.5	111.7	99.5
G_2	24.9	22.4	73.2	63.4	88.1	85.8
G_3	25.9	23.4	68.6	64.9	96.9	88.2
L.S.D.$_{.05}$	NS	NS	NS	NS	NS	NS

pressure is thus seen to be on tiller density. However, an increased tiller density does not necessarily result in a greater number of fertile tillers at harvest. A much lower percentage of vegetative tillers became reproductive in treatments G_2 and G_3 in 1978 because of increased inter-tiller competition and subsequent tiller mortality. The resulting effect is a reduced number of fertile tillers at harvest when compared with 1979.

Although the number of fertile tillers are greater in 1979 (when compared with 1978), the significant reduction in the number of spikelets per spike and fertile florets per spikelet result in a reduced number of seeds per head (Table 3). Reduced spikelets and florets per head in 1979 may be related to their later development and more rapid entry into the spikelet initiation phase of development. The differences in spikelet numbers could arise from a fewer number of leaf primordia accumulated at the shoot apex of those tillers arising at later dates. This would be consistent with a reduced period for differentiation due to later development and concomitant warmer temperatures. Similarly, the date of tiller origin appears to affect the number of florest developed by each spikelet branch (13). Thus seeds per head on the earlier formed tillers could be greater because of the increased number of spikelets and the greater number of florest being developed. Our data suggests that grazing beyond the end of March will have a deleterious effect on the number of spikelets and florest developed per tiller. This also concurs with the finding that the total number of florets in the main stem ears of ryegrass decreases as daylength and temperature are increased (13).

A final observation concerning any analysis of seed yield components is the individual seed weight. Within the inflorescence of ryegrass,

Table 3. Seed yield components as influenced by grazing duration treatments in two years.

Treatment	Number of Spikelets Per Spike		Number of Fertile Florets Per Spikelet		Seed Weight Per 400 Seeds (g)	
	1978	1979	1978	1979	1978	1979
G_0	22.3	21.0	4.2	3.2	1.04	.94
G_1	21.8	20.4	4.3	3.6	1.08	.94
G_2	22.0	18.2	3.9	3.1	.93	.90
G_3	19.6	18.7	3.8	2.8	.97	.95
L.S.D.$_{.05}$	NS	1.2	NS	.40	.06	NS

The basal spikelets develop slightly heavier seed than the more terminal ones, and within spikelets, seeds from the basal florets are heavier than comparable ones developed in terminal florets (2). It has further been observed that the earliest ears to emerge develop the heaviest seed (2), and that seeds of annual ryegrass formed under lower temperature regimes are larger than seeds formed in warmer environments (1). It has also been observed that below a certain tiller density, increasing yield of the individual shoots fail to compensate for the diminished population, while above a threshold density the population fails to compensate for the low yield of the individual (14). Thus, Salisbury (14) believes that variability in seed size is largely influenced by competition for food between the florets of the plant. In 1978 our results showed treatments G_2 and G_3 produced lighter seeds in relation to treatments G_0 and G_1, perhaps a result of their later development and the increased competition for available substrate. A greater number of florets per head accompanied by a reduced number of days for grain filling in these treatments resulted in reduced seed weight. In contrast, a greater number of fertile tillers in 1979 with a reduced number of florets per head, created a better intra-plant balance of sources and sinks and no reduction in seed weight occurred. These results concur with Donald (7), who has shown that intra-plant competition during the later stages of seed development primarily affect seed size and seed number per inflorescence. Thus in 1978 spikelet numbers were maintained on the later grazed treatments as the total number of fertile tillers being developed were less than for similar treatments in 1979. However, as flowering and seed set occurred the intra-plant competition became more intense, and reduced seed weight occurred.

Although evidence of both inter- and intra-plant competition is presented, it is difficult to separate these effects. Donald (7) has observed a wide range of plant densities over which near maximum seed yields were recorded. This illustrates the extent to which changing competition tends to modify the number of inflorescences or the number of seeds per spike to such levels as to maintain near constant seed production per unit area. Thus, balancing the stocking rate and duration of grazing to achieve a moderate increase in tillers formed early in the spring should optimize the number of fertile tillers. A concomitant optimizing of spikelets per spike, florets per spikelet and seed weight due to plant component compensation should maintain seed yields near maximum.

Germination and Seedling Vigor

Previous results have shown that ryegrass seed harvested near maximum weight will achieve maximum germination values (2). Since plots were harvested at maximum seed weights (40% moisture content) no differences were expected. Table 4 shows that no deleterious effect on germination resulted, however, a slight increase in treatment G_3 in 1979 was observed. A subsequent observation on the effect of seedling vigor showed no significant differences from grazing duration (Table 4).

Table 4. Germination and vigor characteristics of harvested seed as influenced by grazing duration treatments in two years.

	Percent Germination (%)		Seedling Vigor (cm)	
Treatment	1978	1979	1978	1979
G_0	90.95	96.30	2.64	2.95
G_1	85.80	95.70	2.67	3.21
G_2	87.05	96.90	2.85	2.71
G_3	91.65	98.40	2.84	2.77
$\text{L.S.D.}_{.05}$	NS	1.34	NS	NS

CONCLUSION

The results of this study show that grazing fall seeded annual ryegrass through early/mid-April will not deleteriously effect seed yield. However, when grazing is prolonged so as to remove the terminal meristems an increased stand density due to an increase in tillering is expected. This increased tillering initiates a complex interaction between inter-plant and intra-plant competition which can have a significant effect on the components which comprise seed yield. There appears to be a wide range over which numbers of fertile tillers, spikelets per spike, fertile florets per spikelet, can be combined to attain maximum seed yields. This suggests that considerable flexibility in managing spring grazing is available to seed producers in the Willamette Valley because of yield component compensation. Recognition of these possible changes will be helpful in applying proper management for high seed yield. Knowing what to expect from different durations of grazing increase the potential forage value derived by allowing maximum grazing prior to closing the field for seed production. However, additional information concerning stocking rate and duration of grazing interactions would be useful.

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APPENDIX

APPENDIX

Literature Review

The ensuing review of the literature reflects the effects of grazing or clipping annual ryegrass, annual cereal grasses and perennial forage grasses grown for seed production.

The use of grass seed stands for forage as well as seed production is practiced in many regions. However, investigations have primarily dealt with the effect of clipping or grazing on perennial grass species. These studies have used clipping at fixed intervals to simulate winter or spring grazing regimes. The few researchers using animals to apply grazing treatments chose high stocking rates to complete grazing in a short time, rather than allow lenient grazing to predetermined dates. Other investigators have looked at the effect of clipping or grazing annual cereal grasses.

Annual ryegrass has been described as a cool season annual which makes excellent nutritious pasture for early grazing (1). Camlin and Steward (4) assessed ten cultivars of annual ryegrass over two seasons under a cutting regime and cattle grazing system and reported good correlation between the two managements. However, cutting results in the removal of all growth above a given height where as grazing is more selective, with younger tissues being preferred to older stems and leaves (22).

Cooper (6) has shown that leaf appearance on the main stem and tillering of annual ryegrass are accelerated by warmer temperatures, but neither is affected by a photoperiod over 9 to 24 hours. He also noted that plants become ripe to flower very soon after germination, require no exposure to low temperatures, and will form seed heads in any photoperiod from 9 to 24 hours. Evans (10) reported a slight increase in days to earing of annual ryegrass where no vernalization had occurred. Wilson (29) found that despite large ranges in the time of tiller origin, winter and early spring tillers of annual ryegrass initiated floral primordia within a relatively short period. Ear emergence followed the same pattern, however, mean leaf number at ear emergence decreased with tillers of later origin. He also noted that high nitrogen promoted earlier floral initiation, ear emergence, and a greater percentage of fertile tillers.

Cutting or grazing prior to internode extension results in the removal of leaf material only, and subsequent regrowth arises from the extension of leaf primordia from the terminal meristem and from the meristems of axillary tillers (18). Once internode extension has begun, cutting or grazing may remove the terminal meristem and unexpanded leaves which remain (18). Asano and Chujo (2) reported that removing the main stem of annual ryegrass increased the number of tillers and heads, with the effect decreasing from early growth until there was no effect after heading. Cooper and Saeed (5) found that annual ryegrass continues heading throughout the summer even under two week cutting intervals. However, the production of new vegetative tillers are severely curtailed, suggesting that the extensive head production may lead to a withdrawal of food reserves from the roots. Maeda and Ehara (21) showed that clipping annual ryegrass to a 2 cm. height, which removed most of the growing points, produced more tillers than clipping to a 6 cm. height. Ehara and Maeda (8), again working with annual ryegrass, observed that as new shoot growth started following clipping there was a rapid reduction of reserves in the stubble and roots.

Bean, et al. (3) in Great Britian emphasized that under good conditions annual ryegrass is capable of rapid production of new tillers in the spring. Actual inflorescence numbers were not significantly reduced by cutting as late as May 21. However, seed yield declined significantly because of the reduced size of the inflorescence. They stated that annual ryegrass can be grazed until the end of April without suffering yield loss, provided the crop is adequately supplied with nitrogen. Herron (15) working in Oregon with annual ryegrass and sheep, investigated closing date of mid-April and early May and reported an increased number of fertile tillers. Significant reductions in seed yield were observed which were attributed to reduced spike length and a decreased number of spikelets per spike, florets per spikelet, and seed weight. Hill (16) observed similar responses when three New Zealand ryegrass species were grazed beyond September 29 (March 29 in the United States).

Using small cereal grain forage for grazing during the early stages of growth is not uncommon in the United States, and research here has shown parallel trends with work done on annual ryegrass. Sprague (28) grazing rye, wheat and oats with dairy cows increased average grain yields 11 to 19 percent when fall grazing was allowed. Spring grazing was detrimental to all grains, but less so for oats, which begun a slower growth in the spring. Fall and spring grazing reduced grain yields but not as severely as spring alone, noting that fall grazing delayed internode elongation in the spring which resulted in less damage to the terminal bud when subsequently grazed in the spring. Spring grazing reduced the number of productive tillers, but fall grazing had no effect. It was further noted that the spike length of wheat and rye was not affected by grazing, thus the weight of seeds per head was most closely related to yield.

Morris and Gardner (23), also working with rye, wheat and oats, studied the effect of duration of clipping. Monthly clipping to March 15 reduced grain yields 75 percent or more. Clipping monthly to February 15 resulted in only slight decreases in all grain yields, however, nitrogen applied to 120 pounds per acre was effective in maintaining oats and rye. Wheat did not respond to the higher level of nitrogen under any clipping treatment.

Gardner and Wiggans (13) studied the effect of clipping April seeded spring oats. Treaments were clipped to 2.54 to 3.81 cm when plants were at the 4 leaf, 5 leaf and 7 leaf stage and resulted in reduced grain yields of 9, 28 and 98 percent, respectively. At all of the clipping stages shoot apices had already transformed into floral primordia, and the effects of clipping were closely related to the position and development of shoot apices. Clipping after the 5 leaf stage removed the floral primordia directly, whereas clipping on or before this stage retarded growth and development of the floral primordia but did not remove them. Recovery by the production of new leaf growth was rapid following clippings which did not remove the shoot apices, suggesting the availability of food reserves stored in the internodes.

Day et al. (7) applied clipping treatments to October seeded barley and found that for grain production it is economically feasible to pasture or clip barley until late January. Significantly, lower yields were reported on plots clipped later than January 19 or on plots not clipped. Each successive clipping resulted in shorter plant heights and reduced lodging.

Perennial ryegrass, like annual ryegrass, is capable of producing large amounts of vegetative growth for livestock (3). However, Evans (10) has shown that Lolium perenne has an obligate requirement of at least two weeks vernalization at 4°centigrade before flowering could take place. The yield of perennial grasses is under the control of the environment, and the final seed yield depends on tiller formation at fairly definite periods, the proportion of these tillers reaching the reproductive state, and the number of florets formed by each inflorescence (20). Hill and Watkins (17) using colored plastic rings to identify tillers of perennial ryegrass at monthly intervals found that those tillers formed during the first four months following an autumn sowing, and those formed in the immediate post-harvest period made the major contribution to seed head numbers and yield at harvest. Only 2 percent of the spring formed tillers contributed to head number at harvest.

Roberts (26) has shown defoliation in October reduced the amount of top growth on the over-wintering plants, lessened the degree of winter burn, and also tended to increase tillering on several perennial grasses. March and April grazing resulted in extending the period of panicle emergence which caused uneven ripening of seed heads and a reduction in seed yield of perennial ryegrass. In a subsequent study, spring grazing of the earlier heading varieties of five perennial ryegrasses reduced the number of inflorescences and seed yield (27). Roberts has concluded that under good environmental conditions for growth grass seed crops can be defoliated in the autumn/winter period until approximately two weeks before the formation of inflorescences without reducing seed yield.

Other research conducted on perennial species are in agreement with the above information. Mulanax (24) working with Linn perennial ryegrass in Oregon, showed trends suggesting that winter clipping or combined winter/spring clipping increased the number of fertile tillers per unit area. Evans (11) found no significant difference in seed yield of either orchardgrass or timothy following autumn/winter cutting treatments compared with no cutting. The general effect of grazing orchardgrass has been to increase the number of fertile tillers while reducing the weight of seeds per 1000 fertile tillers, yet not to the detriment of yield (12, 14, 19, 25). Similarly, Evans (9) showed that clipping Kentucky bluegrass in the late fall increased panicle numbers, decreased weight of seeds per panicle, and increased seed yield. Mulanax (24) also reported a significant seed yield increase of Kentucky bluegrass following a winter/spring clipping regime.

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APPENDIX 1

Table 1. Mean number of plants per 500 cm^2 at indicated sampling dates for each treatment in 1978. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

Treatment	Sampling Dates 2/21	3/9	3/20	4/4	5/9
G_0	45.92	41.75	63.50	-	47.50
G_1	(45.92)	38.91	46.25	-	47.92
G_2	(45.92)	(38.91)	-	48.25	46.83
G_3	(45.92)	(38.91)	-	-	36.83

Table 2. Computed F values from the randomized block analysis of variance for number of plants per 500 cm^2 on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	19.765	0.2975 (NS)
Treatments	3	114.6654	1.7307 (NS)
Error	9	66.2530	
Total	15		

APPENDIX 1 (continued)

Table 3. Mean number of plants per 500 cm^2 at indicated sampling dates for each treament in 1979. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment based on dates of treatment exclosure.

	Sampling Dates							
Treatment	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	37.75	39.58	-	-	30.50			
G_1	(37.75)	34.08	28.84	-	-	28.67		
G_2	(37.75)	(34.08)	37.92	-	-	-	33.92	
G_3	(37.75)	(34.08)	(37.92)	35.00	-	-	-	35.00

Table 4. Computed F values from the randomized block analysis of variance for number of plants per 500 cm^2 on the last sampling date in 1979.

SOV	DF	MS	F
Reps	3	2.7138	0.2352 (NS)
Treatments	3	34.7471	3.0121 (NS)
Error	9	11.5355	
Total	15		

APPENDIX 1 (continued)

Table 5. Mean number of tillers per plant at indicated sampling dates for each treatment in 1978. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment based on dates of treatment exclosure.

	Sampling Dates				
Treatment	2/21	3/9	3/20	4/4	5/9
G_0	2.96	3.19	1.90	-	2.17
G_1	(2.96)	3.18	2.99	-	2.75
G_2	(2.96)	(3.18)	-	3.58	5.40
G_3	(2.96)	(3.18)	-	-	6.47

Table 6. Computed F values from the randomized block analysis of variance for number of tillers per plant on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	0.8478	1.3253 (NS)
Treatments	3	17.1672	26.8361 **
Error	9	0.6397	
Total	15		

APPENDIX 1 (continued)

Table 7. Mean number of tillers per plant at indicated sampling dates for each treatment in 1979. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment based on dates of treatment exclosure.

	Sampling Dates							
Treatment	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	5.08	4.68	-	-	4.01			
G_1	(5.08)	5.03	5.21	-	-	5.05		
G_2	(5.08)	(5.03)	4.56	-	-	-	4.86	
G_3	(5.08)	(5.03)	(4.56)	4.78	-	-	-	5.88

Table 8. Computed F values from the randomized block analysis of variance for number of tillers per plant on the last sampling date in 1979.

SOC	DF	MS	F
Reps	3	0.3599	0.7679 (NS)
Treatments	3	2.3574	5.0291 *
Error	9	0.4687	
Total	15		

APPENDIX 1 (continued)

Table 9. Mean diameter of tiller stem bases at indicated sampling dates for each treatment in 1978, expressed as cm. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

	Sampling Dates				
Treatment	2/21	3/9	3/20	4/4	5/9
G_0	2.44	2.67	2.59	-	2.55
G_1	(2.44)	2.74	2.45	-	2.41
G_2	(2.44)	(2.74)	-	2.23	2.20
G_3	(2.44)	(2.74)	-	-	2.17

Table 10. Computed F values from the randomized block analysis of variance for diameter of tiller stem bases on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	0.0005	0.1898 (NS)
Treatments	3	0.1281	41.7541 **
Error	9	0.0030	
Total	15		

APPENDIX 1 *(continued)*

Table 11. Mean diameter of tiller stem bases at indicated sampling dates for each treatment in 1979, expressed as cm. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

	Sampling Dates							
Treatment	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	2.45	2.60	-	-	2.60			
G_1	(2.45)	2.57	2.61	-	-	2.68		
G_2	(2.45)	(2.57)	2.62	-	-	-	2.38	
G_3	(2.45)	(2.57)	(2.62)	2.56	-	-	-	2.36

Table 12. Computed F values from the randomized block analysis of variance for diameter of tiller stem bases on the last sampling date in 1979.

SOV	DF	MS	F
Reps	3	0.0089	1.1723 (NS)
Treatments	3	0.1023	13.4003 **
Error	3	0.0076	
Total	15		

APPENDIX 1 (continued)

Table 13. Mean leaf area per 500 cm^2 at indicated sampling dates for each treatment in 1978, expressed as cm^2. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

Treatment	Sampling Dates				
	2/21	3/9	3/20	4/4	5/9
G_0	954	1130	1095	-	1732
G_1	(954)	281	344	-	1240
G_2	(954)	(281)	-	151	1152
G_3	(954)	(281)	-	-	864

Table 14. Computed F values from the randomized block analysis of variance for leaf area per 500 cm^2 on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	142,143	18.1551 **
Treatments	3	520,118	66.4314 **
Error	9	7,829	
Total	15		

APPENDIX 1 (continued)

Table 15. Mean leaf area per 500 cm^2 at indicated sampling dates for each treatment in 1979, expressed as cm^2. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

Treatment	Sampling Dates							
	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	1220	1354	-	-	1950			
G_1	(1220)	589	1020	-	-	1534		
G_2	(1220)	(589)	521	-	-	-	997	
G_3	(1220)	(589)	(521)	442	-	-	-	1128

Table 16. Computed F values from the randomized block analysis of variance for leaf area per 500 cm^2 on the last sampling date in 1979.

SOV	DF	MS	F
Reps	3	142,143	18.1551 **
Treatments	3	520,118	66.4314 **
Error	9	7,829	
Total	15		

APPENDIX 1 (continued)

Table 17. Mean specific leaf weight at indicatd sampling dates for each treatment in 1978, expressed as mg/cm^2. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

Treatment	Sampling Dates				
	2/21	3/9	3/20	4/4	5/9
G_0	7.17	9.13	11.15	-	16.70
G_1	(7.17)	9.63	9.18	-	14.07
G_2	(7.17)	(9.63)	-	10.22	9.10
G_3	(7.17)	(9.63)	-	-	8.50

Table 18. Computed F values from the randomized block analysis of variance for specific leaf weight on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	0.000001	0.8128 (NS)
Treatments	3	0.00006	49.3626 **
Error	9	0.000001	
Total	15		

APPENDIX 1 (continued)

Table 19. Mean specific leaf weight at indicated sampling dates for each treatment in 1979, expressed as mg/cm^2. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

	Sampling Dates							
Treatment	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	6.5	9.9	-	-	10.19			
G_1	(6.5)	11.4	9.3	-	-	12.8		
G_2	(6.5)	(11.4)	8.9	-	-	-	11.8	
G_3	(6.5)	(11.4)	(8.9)	11.0	-	-	-	10.3

Table 20. Computed F values from the randomized block analysis of variance for specific leaf weight on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	0.000002	6.7741 *
Treatments	3	0.000004	10.9045 **
Error	9	0.0000004	
Total	15		

APPENDIX 1 (continued)

Table 21. Mean percent of water soluble carbohydrate in stem bases at indicated sampling dates for each treatment in 1978, expressed as percent. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

Treatment	Sampling Dates				
	2/21	3/9	3/20	4/4	5/9
G_0	35.98	40.47	41.09	-	35.63
G_1	(35.98)	18.31	19.93	-	28.28
G_2	(35.98)	(18.31)	-	7.52	18.25
G_3	(35.98)	(18.31)	-	-	16.53

Table 22. Computed F values from the randomized block analysis of variance for percent of water soluble carbohydrate in stem bases on the last sampling date in 1978.

SOV	DF	MS	F
Reps	3	5.4125	0.9484 (NS)
Treatments	3	320.9575	56.2405 **
Error	9	5.7068	
Total	15		

APPENDIX 1 (continued)

Table 23. Mean percent of water soluble carbohydrate in stem bases at indicated sampling dates for each treatment in 1979, expressed as percent. Numbers shown in parentheses were not physically sampled, but logically express values appropriate to that treatment exclosure.

	Sampling Dates							
Treatment	3/5	3/26	4/9	4/18	4/23	4/30	5/7	5/14
G_0	31.35	41.62	-	-	60.06			
G_1	(31.35)	35.48	49.27	-	-	53.63		
G_2	(31.35)	(35.48)	40.24	-	-	-	55.40	
G_3	(31.35)	(35.48)	(40.24)	47.08	-	-	-	38.26

Table 24. Computed F values from the randomized block analysis of variance for percent of water soluble carbohydrate in stem bases on the last sampling date in 1979.

SOV	DF	MS	F
Reps	3	21.4340	2.2325 (NS)
Treatments	3	356.9008	37.1741 **
Error	9	9.6007	
Total	15		

APPENDIX 1 (continued)

Table 25. Computed F values from the randomized block analysis of variance for total number of vegetative tillers on last spring tiller sampling date in two years.

SOV	DF	1978 MS	1978 F	1979 MS	1979 F
Reps	3	5,238.79	3.82 (NS)	1,691.97	0.88 (NS)
Treatments	3	79,750.21	58.09 **	18,980.05	9.92 **
Error	9	1,372.99		1,913.86	
Total	15				

Table 26. Computed F values from the randomized block analysis of variance for number of fertile tillers at harvest in two years.

SOV	DF	1978 MS	1978 F	1979 MS	1979 F
Reps	3	233.89	1.84 (NS)	289.45	0.81 (NS)
Treatments	3	1,052.37	8.28 **	1,197.20	3.35 (NS)
Error	9	127.04		357.76	
Total	15				

APPENDIX 1 (continued)

Table 27. Computed F values from the randomized block analysis of variance for percent of vegetative tillers which became reproductive as influenced by grazing duration treatments in two years.

		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	0.0182	4.0730 *	0.0055	1,2165 (NS)
Treatments	3	0.0962	21.4834 **	0.0212	4.6249 *
Error	9	0.0403		0.0045	
Total					

APPENDIX 1 (continued)

Table 28. Computed F values from the randomized block analysis of variance for dry matter distribution at harvest as influenced by grazing duration treatments in two years.

		Seed Yield			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	1.13	0.16 (NS)	7.56	0.2937 (NS)
Treatments	3	26.59	3.84 (NS)	25.23	0.9804 (NS)
Error	9	6.92		25.73	
Total	15				

		Straw Weight			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	239.91	7.43 **	26.44	0.1558 (NS)
Treatments	3	103.02	3.19 (NS)	51.70	0.3046 (NS)
Error	9	32.30		169.70	
Total	15				

		Total Dry Matter			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	267.86	4.72 *	53.79	0.1751 (NS)
Treatments	3	180.48	3.18 (NS)	141.05	0.4593 (NS)
Error	9	56.70		307.04	
Total	15				

APPENDIX 1 (continued)

Table 29. Computed F values from the randomized block analysis of variance for seed yield components as influenced by grazing duration treatments in two years.

		Spikelets/Spike			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	1.3460	0.9592 (NS)	1.8240	3.2688 (NS)
Treatments	3	3.0978	2.2074 (NS)	7.3589	13.1878 **
Error	9	1.4033		0.5580	
Total	15				

		Fertile Florets/Spikelet			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	0.1198	1.7667 (NS)	0.0637	1.0214 (NS)
Treatments	3	0.1791	2.6417 (NS)	0.3793	6.0804 *
Error	9	0.0678		0.0623	
Total	15				

		Seed Weight/400 Seeds			
		1978		1979	
SOV	DF	MS	F	MS	F
Reps	3	0.0086	6.7575 *	0.0003	0.1596 (NS)
Treatments	3	0.0182	14.2893 **	0.0021	1.0395 (NS)
Error	9	0.0012		0.0020	
Total	15				

APPENDIX 1 (continued)

Table 30. Computed F values from the randomized block analysis of variance for germination of harvested seed as influenced by grazing duartion in two years.

SOV	DF	1978		1979	
		MS	F	MS	F
Reps	3	29.94	2.0960 (NS)	2.4425	3.4659 (NS)
Treatments	3	33.06	2.3945 (NS)	3.3625	4.7713 *
Error	9	13.80		0.7047	
Total	15				

Table 31. Computed F values from the randomized block analysis of variance for seedling vigor of harvested seed as influenced by grazing duration treatments in two years.

SOV	DF	1978		1979	
		MS	F	MS	F
Reps	3	1.1936	10.3712 **	0.0123	0.2131 (NS)
Treatments	3	0.0486	0.4229 (NS)	0.2047	3.5389 (NS)
Error	9	0.1150		0.0578	
Total	15				

APPENDIX 1 (continued)

Table 32. Average monthly minimum temperature and precipitation from September-August, 1977-78 and 1978-79, recorded at Salem, Oregon.

	Average Temperature °C		Precipitation, cm.	
	77 - 78	78 - 79	77 - 78	78 - 79
Sept	8.61	10.61	5.99	6.71
Oct	4.89	4.61	6.02	.94
Nov	2.61	-1.00	15.72	11.43
Dec	3.06	-2.44	22.17	6.25
Jan	2.44	-4.22	14.40	7.21
Feb	3.78	2.44	8.99	18.26
Mar	2.83	3.22	3.12	5.51
Apr	4.11	4.50	8.89	7.16
May	6.11	6.61	7.54	5.59
June	11.28	8.33	1.22	1.65
July	12.33	10.83	2.72	.76
Aug	12.83	11.28	6.50	1.78