Persistence of a *Lolium perenne-Trifolium subterraneum* Pasture under Differing Defoliation Treatments

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Abstract

Effects of defoliation frequency and intensity on persistence of a perennial ryegrass *(Lolium perenne)*-subclover *(Trifolium subterraneum)* pasture were studied near Corvallis, Ore., during 1980 to 1983. While canopy cover of individual plant species did not differ between defoliation frequency or intensity treatments (P6.05) within years, all defoliated plots differed from the undefoliated control plots. Canopy cover of perennial ryegrass declined from its initial value of 43% in 1980 to an average of 30% and 1% in defoliated and undefoliated plots in 1983, respectively. Perennial ryegrass in defoliated plots was apparently replaced by subclover, whose canopy cover increased by 33% during the 3-year period. On undefoliated plots, however, both perennial ryegrass and subclover were replaced by annual grasses, whose canopy increased from approximately 2% in 1980 to 48% in 1983.

Density of perennial ryegrass plants at the end of the trial in 1983 was highest when plots were defoliated once every 21 or 35 days compared to those defoliated every 7 days, 49 days, or the undefoliated control plots. Root biomass per plant, however, increased linearly as defoliation interval increased from 7 to 49 days between defoliation events. Viewed together, these data suggest that underutilization of grass-clover pastures may be potentially as damaging to pasture persistance as overutilization.

Key Words: grazing intensity, clipping, pastures (cultivated), rotational grazing

Perennial ryegrass (*Lolium perenne* L.) and subclover (*Trifolium subterraneum* L.) are commonly seeded for pasture improvement on nonirrigated hill lands in the Pacific Northwest. Once established, grass-clover pastures require careful grazing management if a favorable ratio of grass to clover is to be maintained. Infrequent defoliation of the sward, while allowing high dry matter production (Wilman and Asiegbu 1982), favors erect-growing grasses over the more prostrate clovers (Brougham 1960). Conversely, frequent and/or intense defoliation may result in reduction of perennial grasses (Baker 1957) and a shift towards clover dominance of the sward (Cameron and Cannon 1970). These effects are well illustrated by a stocking rate study conducted by Sharrow et al. (1981) in western Oregon. They observed that perennial ryegrass-subclover pastures which were lightly stocked with sheep became grass dominant over a 6-year period. During this same period, perennial ryegrass was largely replaced by annual grasses and subclover in heavily stocked pastures. These shifts in species composition were reflected in substantially more herbage production being obtained from moderately stocked than from either lightly or heavily stocked pastures.

Although the general principles of grass-clover management are well understood (see Smetham 1977, Harris 1978), much of the past work was done using perennial ryegrass-white clover (*Trifolim repens* L.) pastures. The effect of concurrent changes in both defoliation interval and stubble height on the species composition of perennial ryegrass-subclover pastures are currently not well documented.

This study sought to gather information concerning the effects of interval and intensity of defoliation on species composition and the persistence of ryegrass in perennial ryegrass-subclover stands. Both defoliation interval and stubble height were simultaneously varied over a range of values likely to be encountered under short-duration grazing systems during the spring growing season. The purpose of this experiment was to generate information upon which hypotheses concerning the effects of short duration grazing systems on similar pastures could be formed. Such hypotheses would, of course, require further testing by an actual grazing trial.

Materials and Methods

The study area was located 1 km northwest of Corvallis, Ore. The soil is a Hazelair silt loam (fine, mixed, mesic Ultic Haploxeroll) with approximately 12% south slope (Soil Conservation Service 1975). The elevation is 100 m and the climate is maritime, with mild, wet winters and warm, dry summers. Average annual precipi-

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Table 1. Mean canopy cover[1] (%) estimated at the initiation of defoliation treatments in March 1980, 1981, and 1982.

Year	Canopy cover (%)						
	Perennial ryegrass	Subclover	Tall fescue	Other perennial grasses	Other forbs	Annual grasses	Total
1980	43.3c[1]	22.3a	17.0b	4.7b	2.0a	1.7a	91.0a
1981	34.0b	48.0b	5.0a	2.0a	2.4a	0.6a	92.0a
1982	30.0a	55.0c	4.7a	2.2a	1.9a	0.2a	94.0a

tation is approximately 990 mm (NOAA 1978). Mean average January and July temperatures are 6 and 17° C, respectively. The average yearly frost-free period is 189 days. Vegetation consisted of a perennial ryegrass (*Lolium perenne* L.)-subclover (*Trifolium subterraneum* L.) stand (Table 1), typical of nonirrigated, improved hill land pastures in the Willamette Valley.

A 20 $\times$ 40 m exclosure was built in March 1980 to protect plots for sheep grazing. The pasture in the study area was established prior to 1970 and was moderately stocked with sheep in years prior to exclosure. The exclosed area was fertilized with 150 kg ha^{-1} of superphosphate (30 kg ha^{-1} P and 15 kg ha^{-1} S) in September each year. In addition, 0.8 kg ha^{-1} of molybdenum was applied as sodium molybdate in March 1980 to remove possible Mo deficiency. Thirty-nine 4.0-m^2 permanently marked plots were assigned randomly to defoliation treatments within blocks which were oriented across-slope on the hill within the exclosure.

Defoliation treatments included all possible combinations of 4 defoliation intervals (DI = 7, 21, 35, or 49 days between 2 consecutive defoliations), and 3 stubble heights (SH: High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation). In addition, 3 control plots remained undefoliated until final harvest each growing season. A 1-m wide buffer strip, which was defoliated as adjacent plots, was left around every plot to provide access and to reduce edge effects.

A rear-bagging rotary mower was used to defoliate the plots on assigned dates and at appropriate heights. Defoliation treatments commenced each spring when plant height reached 15 cm. Following this criterion, defoliation treatments began on 5 April, 24 March, and 7 April and continued through July in 1980, 1981 and 1982, respectively. Both perennial ryegrass and subclover were in an entirely vegetative growth stage at that time. All plots were defoliated at the same (40 mm) height at the beginning and at the end of the spring growing season each year.

Canopy cover of the study area was estimated by examination of 40 and 160 randomly placed ten-point frames (Sharrow and Tober 1979) prior to defoliation treatments in March 1980 and in spring 1981 and 1982, respectively.

Basal area, density, and average root weights of perennial ryegrass plants were estimated in July 1982, after 3 years of defoliation treatment. Perennial ryegrass plants within one randomly placed 1-m^2 quadrat per plot were counted. Basal area of each plant within the quadrat was then estimated from 2 diameter measurements, the largest diameter (d_1) and a second measurement taken perpendicular to the first (d_2), using the formula: plant basal area = $\pi d_1 d_2/4$.

Two plants per plot were chosen for root sampling using 2 criteria: (1) that the sample plant be at least 6 cm from its nearest neighbor and (2) that its basal area be near the population average of 14 cm^2. A 17-cm diameter loop was centered over each sample plant and all soil within the loop was excavated to a depth of 30 cm. Excavated soil was soaked for 24 hours, the roots washed free of soil and collected on a 1-mm^2 screen. Collected root material from each plant was oven-dried at 50° C for 48 h to determine total root dry matter. In order to check the distribution of root phytomass with soil depth, 6 additional ryegrass plants were randomly chosen for sampling. A core of 17-cm diameter by 60-cm depth was divided into 4 vertical segments of 15 cm each. Root phytomass of each soil segment was washed and dried separately for each plant.

Data were analyzed as a 3$\times$4 factorial arrangement of treatments in a randomized complete block design with 3 replications (Steel and Torrie 1980). Where appropriate, the means were separated by Student-Newman-Keuls' test (Steel and Torrie 1980). Significant treatment effects were separated into orthogonal polynomial components and response surfaces were fitted by least squares regression procedures (Neter and Wasserman 1974).

Results and Discussion

Average total canopy cover of the plots in March varied little between years (Table 1). Canopy cover of individual plant species, however, changed markedly during the course of the experiment. Canopy cover of perennial ryegrass declined steadily from its initial value of 43% in 1980 to 30% in 1982. Tall fescue and other perennial grasses also declined during this period. The resources which become available as the amount of perennial grasses

Table 2. Mean canopy cover (%) of perennial ryegrass (LOPE), tall fescue (FEAR), subclover (TRSU), and other plants measured in March 1981 and 1982 under 4 defoliation interval (DI) and 3 stubble height (SH) treatments.

Year	Plant species	Defoliation regimes						
		DI (days)				SH (mm)		
		7	21	35	49	70	55	40
1981	LOPE	32.3[1]	32.7	34.9	36.1	33.9	34.7	33.4
	FEAR	4.5	4.9	4.9	5.7	5.1	5.2	4.7
	TRSU	46.2	50.1	47.3	48.4	48.0	47.3	48.7
	Others[2]	4.1	4.9	5.3	5.7	4.8	5.0	5.2
1982	LOPE	30.0	29.7	31.2	29.1	31.9	29.7	28.4
	FEAR	4.5	4.0	4.9	5.4	4.6	4.3	5.2
	TRSU	57.2	50.9	56.3	55.6	54.2	55.0	55.8
	Others[2]	4.1	4.9	4.3	3.9	4.0	4.1	4.5

[1]Means in each row and within DI or SH categories do not differ ($P<.05$).
[2]Mainly consisted of annual grasses.

declined were apparently used by subclover, which increased from its initial value of 22% in 1980 to a value of 55% in 1982. Weather data from a station approximately 16 kilometers northeast of the study area (NOAA 1980, 1981, 1982) indicated no noteworthy differences between years in soil temperatures, air temperatures, or precipitation. Therefore, relative differences in canopy cover between individual plant species between years are believed to reflect treatment, rather than climatic effects over time.

Canopy cover of individual species did not vary among defoliation treatments ($P>.05$) within years (Table 2). However, differences were apparent ($P>.01$) between all defoliated plots and the undefoliated control plots (Table 3). Control plots became dominated by annual grasses. They contained only about half as much perennial ryegrass and subclover as did the defoliated plots ($P>.05$) in both 1981 and 1982. Similar effects have been reported for underutilized pastures (Sharrow et al. 1981). All defoliation treatments were apparently equally effective in maintaining subclover and in preventing annual grass dominance of the sward. Low amounts of annual grasses and other weeds on defoliated plots likely resulted from competition by the vigorous stand of subclover on these plots (Evers 1983). Loss of subclover from underutilized stands such as our control plots is often attributed to the presence of an overburden of unharvested forage which hampers germination and establishment of subclover in the fall (Hedrick 1964). Both control and defoliated plots were mowed to a 40-mm stubble height and harvested material removed at the end of the spring growing season each year. It is unlikely, therefore, that differences in species composition between the control and defoliation treatments reflect differences in fall seedbed conditions. It is more likely that reduced shading (Collins et al. 1978) and/or stimulation of flower production as a result of defoliation (Collins 1978) allowed production of a larger subclover seed crop on defoliated plots. Such an effect would be especially significant for annual clovers such as subclover which must be reestablished from seed each year.

Table 3. Mean canopy cover (%) of perennial ryegrass (LOPE), tall fescue (FEAR), subclover (TRSU) and other plants in defoliated and nondefoliated control plots in March 1981 and 1982.

Year	Plant species	Canopy cover (%) Defoliated[2]	Nondefoliated
1981	LOPE	34.0b[3]	6.7a
	FEAR	5.0a	3.6a
	TRSU	48.0b	15.0a
	Others[1]	5.0a	43.6b
1982	LOPE	29.8b	1.0a
	FEAR	4.7a	5.0a
	TRSU	55.0b	4.5a
	Others[1]	4.3a	47.5b

[1]Mainly consisted of annual grass.
[2]Data are averaged over all defoliation intervals and stubble heights.
[3]Means within a species and year not sharing a common letter differ $P<.05$.

Similar reductions in the canopy cover of perennial ryegrass among all defoliation treatments during the 1980 to 1982 period suggested that this phenomenon was not related to severity of defoliation. The average life expectancy of individual perennial ryegrass plants is approximately 5 years (Calmin and Stewart 1976). Thus, in the absence of reproduction, one would expect a 20% reduction in perennial ryegrass each year due to natural mortality events. This is approximately what we observed. Seed production was largely prevented by harvesting of plots prior to seed formation on all defoliation treatments. While perennial ryegrass plants on control plots produced seed, few seedlings became established. A general chlorotic appearance of the grass seedlings in the control, as compared to those on the defoliated plots in early spring was investigated by microKjeldal analysis (AOAC 1970) for comparison of tissue nitrogen content of these seedlings. The average nitrogen concentration of ryegrass plants inside the treated plots was 4.2%. This was substantially higher ($P<0.01$) than the 2.8% nitrogen content of ryegrass seedlings in control plots. Nitrogen deficiency is believed to have contributed to mortality of perennial ryegrass in control plots.

Lower density of perennial ryegrass plants at the end of the experiment on control plots compared to all defoliation treatments (Table 4) suggests that a higher rate of mortality occurred for undefoliated than for defoliated plants. The extent to which increased mortality of undefoliated plants may be attributed to lower soil nitrogen on control plots and/or to shading effects within undefoliated swards is unclear. Average basal areas of perennial ryegrass plants from defoliated plots were consistently greater ($P<05$) than those from control plots. Survival and basal area expansion of existing perennial ryegrass plants may have been reduced on control plots by lack of sufficient light at the plant bases to stimulate production of new tillers. Lack of adequate light at the base of perennial ryegrass plants has been reported to hasten tiller death and to prevent the initiation of new tillers (Wilman et al. 1976, Ong 1978, Ong et al. 1978).

In contrast to canopy cover which did not differ between defoliation treatments, differences in plant density were evident between DI treatments (Table 4). The relationship between plant density and DI was parabolic (Fig. 1) with maximum density occurring at a DI of 29 days. Similar to control plots, reduction in perennial ryegrass density as DI increased beyond 29 days may reflect inhibition of tillering due to low light levels under the dense canopy present on these plots. Reduced perennial ryegrass density as DI was reduced below 29 days is believed to result from an inability of frequently defoliated plants to maintain adequate leaf area to accumulate necessary carbohydrate reserves and to support a strong root system (El Hassan 1977). Stubble height had no ($P>.05$) apparent effect on the persistence of perennial ryegrass. In addition, no DI × SH interaction was evident.

Average basal area per perennial ryegrass plant did not differ ($P>.05$) among DI or SH treatments. Total basal area of perennial ryegrass plants per m^2, however, was greater ($P<.05$) for DI21 and

Table 4. Mean density, basal area/plant, basal area/m^2, and root weight of perennial ryegrass plants in plots under 4 defoliation intervals (DI), 3 stubble heights (SH) and in undefoliated control plots measured in July 1982.

	Category							
	DI Treatments (days)					SH Treatments (mm)		
Source	7	21	35	49	Control	70	55	40
Density (plants/m^2)	29.8b[1]	42.1c	42.0c	30.0b	9.0a	39.3a	35.0a	33.7a
Basal area (cm^2/plant)	14.0b	14.0b	15.9b	13.5b	9.6a	13.6a	16.6a	12.9a
Basal area (cm^2/m^2)	417.2b	584.4c	667.8c	405.0b	86.4a	534.5b	581.0b	434.7a
Root weight (g/plant)	2.3a	4.2b	6.7c	6.9c	11.5d	5.5a	5.2a	4.5a

[1]Means in each row and within each treatment category not sharing a common letter differ ($P<.05$).

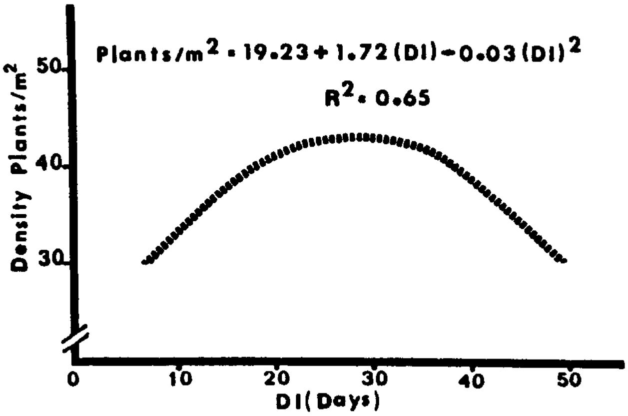

Fig. 1. *Relationship between perennial ryegrass plant density and Defoliation Interval (DI) in July 1982 after 3 years of defoliation treatment.*

DI35 than for DI17 or DI49 treatments. This difference reflected the greater plant density for DI21 and DI35 plots. Total basal area per m^2 was less (P<.05) under low than under Medium or High SH treatments. Treatment differences in plant density and total basal area per m^2 were not reflected in percent canopy cover. This suggests that lower total basal areas of DI17 and DI49 treatments were compensated for by the display of more canopy cover per unit of basal area.

Root weights of perennial ryegrass plants at the end of the trial in July 1982 are presented in Table 4. Perennial ryegrass appears to be a relatively shallow-rooted species. Our preliminary survey of root distribution indicated that 95% of the plant's root biomass occurred in the surface 15 cm of soil. Only 4.5% and 0.5% of the total root biomass harvested were contained in the 15 to 30 and 30 to 45 cm soil depths, respectively. Therefore, our 30 cm deep soil cores should have been adequate to capture almost all of the root system.

Varying SH from 40 to 70 mm of stubble remaining after defoliation had no effect (P>.05) on root biomass. Root biomass was sensitive to DI, however, increasing linearly by 0.11 gram per day as days between defoliation events increased from 7 to 49 (g of root/plant = 1.85 + 0.11 DI, r^2 = 0.84). Such sensitivity is not surprising as defoliation may temporarily stop root growth (Crider 1955). Reduction in root growth would be especially detrimental to a plant such as perennial ryegrass, whose roots live only a few months to a year (Stucky 1941, Garwood 1967, Troughton 1981) before they must be replaced. The greatest root biomass occurred on control plots. Although data from control plots were not used in the regression analysis, extrapolation from the equation relating root biomass to DI predicts a root biomass of 11.1 grams per plant for control plots. This is reasonably close to the actual value obtained from these plots. Many authors have attributed observed reductions in the size and longevity of grass root systems to severe defoliation treatments (Crider 1955, Baker 1957, Hodgkinson and Baas Becking 1977). Brougham (1970) stressed the importance of defoliation-induced reductions in perennial ryegrass root systems as a factor contributing to plant mortality during the summer period. Presumably, increased mortality due to a reduction of root biomass as DI decreased contributed to the observed decline in plant density as DI was reduced below 29 days between defoliation events in our study. It is interesting to note that increased root biomass as DI increased beyond 29 days was not associated with increased plant persistence. As mentioned earlier, the parabolic relationship between plant persistence and DI may be explained by persistence operating on a whole organism basis (both roots and tillers) with DI impacting roots and tillers differently.

Management Implications

Percent canopy of perennial ryegrass decreased, while that of subclover increased steadily over the 3 years of this trial on all defoliation treatments. Decline of perennial ryegrass and its replacement by subclover, to a certain extent, is desirable as it tends to improve forage quality. A ratio of 60–70% grass and 30–40% clover is generally considered to be optimum for production of both quantity and quality of forage in livestock production systems (Harris and Thomas, Curll 1981). By the second year of our study, perennial ryegrass was already well below optimum levels on all defoliation treatments. If the observed rate of decline continued, perennial ryegrass would be practically eliminated from the plots within 5 years. Clearly, if a favorable grass-clover balance is to be achieved and maintained, factors affecting plant natality and mortality must be considered in designing production systems.

The data presented here suggest the following points which may be useful in designing pasture management systems:

(1) Some defoliation during the growing season is necessary to maintain subclover in high-producing swards. The exact timing and intensity of defoliation over the range of values tested was not particularly important in this regard. However, simply removing the overburden of old unharvested forage prior to the advent of fall rains was not sufficient to perpetuate the clover stand.

(2) Perennial ryegrass is a short-lived perennial which appears to be highly dependent upon seed production for perpetuation of the stand over time. In the absence of seed production, it will probably disappear from the stand within 5 to 6 years.

(3) Mortality of perennial ryegrass plants is affected by defoliation regime. Density of perennial ryegrass plants at the end of the experiment was not affected by SH regimes. Defoliation interval, however, did affect plant density. Decreased plant density, presumably reflecting increased mortality of perennial ryegrass plants under frequent defoliation, was associated with reduced root biomass. Mortality was also high on plots which were defoliated infrequently, presumably due to lack of new tiller formation as evidenced by low plant basal areas. Evidently, defoliation plays a role in maintaining adequate root/top ratios of perennial ryegrass plants. Deviation from the optimum DI of 29 days resulted in decreased plant density. The actual effects of DI on the proportion of perennial ryegrass in the stand over time, however, are believed to be small compared to changes induced by lack of seed production.

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