TECHNIQUES FOR MEASURING THE ROOT GROWTH OF A PERENNIAL RYEGRASS (*Lolium perenne* L.) DOMINANT PASTURE UNDER CONTRASTING SPRING MANAGEMENTS.

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ABSTRACT

Three techniques for measuring root growth were evaluated. Two were direct measurements (root lengths in intact soil cores, and root length in cores which had been bored out and refilled with sand or silt) and one was an indirect method using patterns of water extraction. Six cutting treatments which were intended to either, allow different degrees of reproductive growth, or stimulate vegetative growth of a perennial ryegrass (*Lolium perenne* L.) dominant pasture were imposed from 14 November 1985 (Day 0) until 2 February 1986 (Day 80). Measurement of root lengths under these contrasting sward managements formed the basis of an evaluation of the root sampling techniques.

Little or no change in root lengths was measured in intact cores in any of the six cutting treatments over the 80 days of the experiment. In contrast root growth into sand filled cores showed marked treatment differences at Days 56 and 80, and represented up to 47 percent of the root length measured in the upper 300 mm in intact cores at Day 80. Used in conjunction with intact cores, refilled cores give an estimate of root turnover. Patterns of water extraction were not a sensitive indicator of root growth.

Using the refilled core technique the rates of root growth measured for reproductive and vegetative ryegrass swards were significantly different. Root growth was reduced during reproductive development but swards in which reproductive growth was removed at head emergence or anthesis, subsequently showed greater root growth than swards which were vegetative throughout.

Additional Key Words: *root extraction, herbage mass, pasture growth rate.*

INTRODUCTION

The impact of grazing management on the root growth of pasture plants is not well understood. Immediately after defoliation, rapid and extensive root death can occur (Evans, 1971). This would reduce the ability of the plant to extract water and nutrients from the soil profile. If the density and distribution of the root system of a pasture is a function of the frequency and severity of grazing, then grazing management could provide a useful method for manipulating root growth. This would have some important implications when considering the uptake of water and nutrients and in pasture production.

The difficulty of extracting and recovering roots and the large number of samples required to overcome variation (Dienum, 1985) often deters workers from studying root growth in established pastures. It is also difficult to distinguish in the recovered sample those roots which are actively growing and involved in nutrient uptake, from those which are inactive or dead.

The first objective of this study was to evaluate two direct techniques (the use of intact or refilled cores) and an indirect technique (patterns of water extraction) for measuring root growth. A further objective was to investigate in a preliminary study the effect of manipulating reproductive stem development on the root growth of a perennial ryegrass (*Lolium perenne* L.) dominant pasture.

MATERIALS AND METHODS

Site description

The experiment was conducted at the Pasture and Crop Research Unit, Massey University, on a perennial ryegrass dominant pasture. This pasture was sown in March 1983 after approximately two years in crops. Seeding rates were: perennial ryegrass (*Lolium perenne* L. cv. 'Ellett') 18 kg/ha, white clover (*Trifolium repens* L. cv. 'Grasslands Pitau') 2 kg/ha and red clover (*Trifolium pratense* L. cv. 'Grasslands Pawera') 2 kg/ha. The soil at the site was a Tokomaru silt loam (Typic Fragiaqualf).

Sward manipulation and characterisation

Six cutting treatments were imposed from 14 November (Day 0). These and the cutting dates are summarised in Table 1. In three treatments the strategy was to allow reproductive growth to proceed to different stages by leaving plots uncut for varying periods and then resuming cutting. These three treatments were uncut to head emergence (RUHE), uncut to anthesis (RUAN), uncut to seed-set (RUSS), respectively. In the remaining three treatments, vegetative growth was stimulated by cutting on 14 November 1985 (Day 0), and periodically thereafter, to different heights and at different frequencies until the final harvest on 2 February 1986 (Day 80). The vegetative treatments included a hard frequent cutting regime (VEGH), a lax infrequent cutting regime (VEGL) and a

TABLE 1: The six cutting treatments and timing of cutting (Days from start of experiment).

Cutting Treatment	Abbreviation	Cutting Date 15 Nov.	26 Nov.	13 Dec.	20 Dec.	7 Jan.	20 Jan.
1. Vegetative: cut frequent hard	VEGH[1]	0	-	28	-	53	66
2. Vegetative: cut infrequent lax	VEGL	0	-	-	35	53	-
3. Reproductive: uncut to head emergence	RUHE	-	11	-	35	53	-
4. Reproductive: uncut to anthesis	RUAN	-	-	28	-	53	-
5. Reproductive: uncut to seed set	RUSS	-	-	-	-	53	-
6. Vegetative: uncut	VEGU	0	-	-	35	-	-

[1]Cutting height on 15 November was 15 mm and thereafter 40 mm. For all other treatments cutting height on 15 November was 40 mm and thereafter 160 mm.

regime intended to allow uncut vegetative growth (VEGU) by not cutting after 20 December. A randomised complete block design with four replicates was used and each plot measured 3 m x 5 m.

To characterise the sward, tiller counts using the method of Mitchell and Glenday (1958) were taken at Days 0 and 80, and herbage mass was measured for selected treatments and cutting dates before and after cutting.

Measurement of root lengths under these contrasting sward managements formed the basis of an evaluation of the root sampling techniques assessed in this experiment. Changes in root length over time were taken to measure root growth.

Root sampling procedures

Root sample cores were obtained by hand driving a steel tube of an internal diameter of 78 mm into the ground. Cores were taken from an undisturbed portion of a plot (intact cores) or from holes which had been drilled out and refilled with either sand or silt (sand filled and silt filled cores). This refilled core technique is an adaptation of the mesh bag technique (Bohm, 1979; Steen, 1984). The filled cores were all installed over a seven day period at the start of the experiment. A post-hole borer and 75 mm auger was used to drill the holes for refilling. Sieved sand or silt was packed wet, a layer at a time, to make the bulk density as uniform as possible.

Intact core samples were taken from all six cutting treatments on Days 26 and 80 and from the VEGL treatment on Days 32, 55, 62 and 68. Sand filled cores were harvested from all treatments at Days 56 and 80, and silt filled cores at Day 80. Sand and silt filled cores were also taken from the VEGL treatment on Days 32, 55, 62 and 68. Intact cores were divided at harvest into three segments (0 -70, 70 - 300 and 300 - 700 mm depth) and refilled cores into two segments (0 - 300 and 300 - 700 mm depth).

Change in gravimetric soil moisture over time was evaluated as an indirect measure of root growth. Five 15 mm cores taken on each plot from two depths (0 - 100 and 300 - 450 mm) on Days 79 and 86, were weighed moist and then oven dried at 105 °C for 24 h.

Extraction and recovery of roots from cores

Roots from refilled cores were recovered by placing the sample on a sieve and spraying with water (Bohm, 1979). A 4 mm mesh was used for sand filled cores and a 1 mm mesh for silt filled cores. By directing the hose into a drum below, the sieve washings could be collected. These washings were poured through a 0.2 mm sieve. If any fine root material was recovered the water pressure was reduced.

Intact cores were broken up and obvious roots picked out by hand. A subsample was then washed and remaining roots collected. These two fractions of roots from the one core were then measured separately and summed.

Measurement of root length

Root lengths were determined using the line intersect method described by Newman (1966), and refined by Tennant (1975). Root length measurements gave lower standard errors than measuring fresh weight, dry weight or ash free dry weight for the same samples. (The ratios of standard errors were 100:112:121:111, respectively; for sand filled core data, Day 56.) Root length data is presented as length per unit volume of soil (km/m^3). It should be noted that root lengths averaged in this way for a given soil depth are not additive nor comparable over different depths.

No attempt was made to distinguish between live and dead roots, or between grass and clover roots. It was therefore assumed that differences in total root lengths reflected differences in the length of ryegrass root, as ryegrass was the major component of the sward.

Statistical analysis

The data tended to show a non-normal distribution with a positive skew. Log transformation largely overcame this problem. In one case the most extreme data point (standardised residual = 3.87) was treated as a missing plot. Intact cores harvested on Days 26 and 80 were analysed as a split plot in time, as were sand filled cores harvested on Days 56 and 80. In a separate analysis, sand and silt filled cores harvested on Day 80 were also treated as split plot effects. This reduced coefficients of variation.

RESULTS AND DISCUSSION

Root density under a ryegrass dominant pasture

The root lengths measured in the upper 70 mm (400 to 600 km/m^3) were much greater than those reported by Mackay *et al.,* (1986) for a field crop such as corn (*Zea* *mays* L.), which were 20-40 km/m³ in the upper 75 mm of the profile. They were comparable with those reported (Evans, 1976) for perennial ryegrass swards (130 km/m³ in the upper 200 mm), but much lower than those reported (Barker *et al.,* 1986) for a low fertility, hill country sward (up to 1800 km/m³ in the upper 100 mm).

Changes in root length under a lax infrequent cutting regime

Root lengths in intact cores from VEGL plots showed little or no difference over the 80 days of measurement (Figure 1a), whereas root growth in sand filled cores (Figure 1b) represented 36% of root length measured in intact cores at Day 58, and 47% at Day 80. Root growth into silt filled cores (Figure 1c) showed a pattern very similar to that found in sand filled cores (Figure 1c), although total root lengths were significantly less ($p<0.001$).

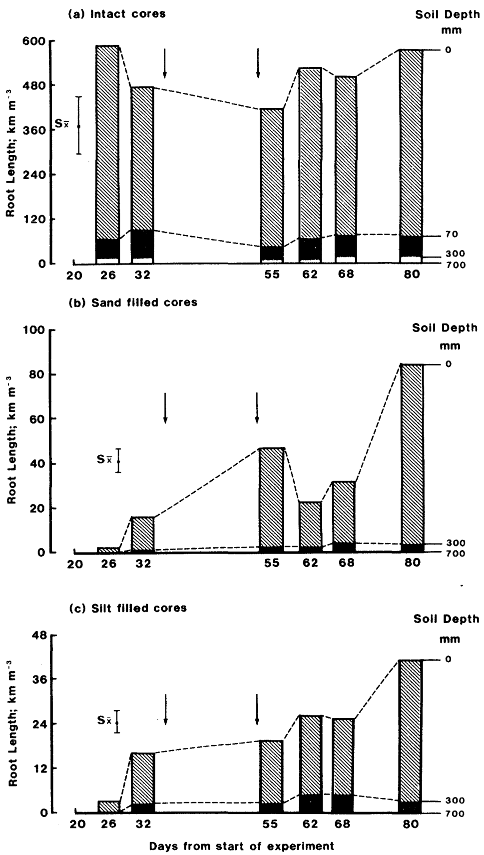

Figure 1: Root lengths in (a) intact cores in three soil depths, (b) sand and (c) silt filled cores in two depths in the lax infrequent cutting treatment at six sampling dates. Arrows indicate defoliation.

The explanation for the lower root lengths in silt filled cores is uncertain. It is not suggested that the growth into refilled cores is the same as that in undisturbed soil. The highly significant ($p<0.001$) difference between root lengths in sand and silt filled cores highlights this point. However root lengths in both sand and silt filled cores did show patterns of change which were consistent throughout the 80 days of measurement. Assuming root growth in the surrounding soil was at least of the same order as that in the refilled cores, comparison of the changes in root length in intact and refilled cores indicates that significant root growth did occur and implies substantial root turnover, even though total root length showed little change.

A high turnover rate of ryegrass roots at this time of year contrasts sharply with previous estimates (Jaques, 1956; Garwood, 1967). Both Jaques (1956) and Garwood (1967) suggested that in late spring and summer few adventitious roots are produced from the base of the plant. The high root turnover rate in this study suggests that new roots were continually initiated throughout the 80 days of measurement and may reflect, in part, the favourable soil moisture conditions which prevailed. Troughton (1981) noted that roots of perennial ryegrass have a short life, and Gibbs (1986) has also obtained data which indicate a high root turnover rate for ryegrass. These two observations support the view that regrowth into refilled cores represents turnover of roots rather than exploratory growth. Further, visual observations made during the experiment also indicated substantial tiller initiation, with associated nodal root production.

The measurements of root growth in intact cores at different times (Figure 1a) provided an estimate of net change in total root length, but no information on root growth rates, or the percentage of roots entering the decay cycle. Refilled cores (Figure 1b, 1c) provided a measure of root growth rates and of the timing of production of new roots. Used in conjunction, the intact and refilled core techniques appear to provide an estimate of root turnover.

Water extraction as an indicator of root growth

Water extraction patterns were not found to be a sensitive indicator of root growth. No significant differences between treatments for changes in gravimetric soil moisture were detected (Table 2) and differences in evaporation at the soil surface and in transpiration, due to differences in herbage mass, appear to have affected soil moisture as much as any changes in root growth or activity. Attempts to measure changes in soil moisture in the field over time would be confounded by rainfall events. Similar conclusions were reported by Bohm (1979).

Effects of sward manipulation on sward characteristics

Uncut swards at the start of the experiment contained a large proportion of reproductive tillers. Mean live ryegrass tiller density on Day 0 was 5041 (S.E. ±382)/m², of which 998 (S.E. ±45)/m² had seedheads emerged. The density of emerged seedheads had increased on uncut plots to 1690 (S.E. ±170)/m² by Day 28, but was reduced to 216 (S.E. ±43)/m² on VEGL plots. This difference in the number of emerged seedheads, along with differences in the growth rate of the swards between Days 0 and 28 (Table 3)

TABLE 2: Gravimetric soil moisture contents (%) in two soil depths for the six cutting treatments at Days 76 and 83.

Cutting Treatments	0-100 mm Day 76	0-100 mm Day 83	Δ[1]	300-450 mm Day 76	300-450 mm Day 83	Δ[1]
1. VEGH	28.6	19.4	9.2	21.4	21.0	0.4
2. VEGL	28.2	20.6	7.6	21.0	19.8	1.2
3. RUHE	28.1	20.2	7.9	21.3	20.1	1.2
4. RUAN	28.2	20.0	8.2	21.4	19.7	1.7
5. RUSS	28.2	19.5	8.7	21.4	19.8	1.6
6. VEGU	29.1	19.5	9.6	21.8	20.9	0.9
MEAN	28.4	19.9	8.5	21.4	20.2	1.2
S.E.D.	0.7	0.8	1.0	0.6	0.6	0.5

[1]Difference between Days 76 and 83.

TABLE 3: Herbage mass and pasture growth rates under different cutting treatments between Days 0 and 28.

Cutting Treatment	Grass Leaf	Grass Stem	Grass Total	Clover	Weed	Dead	Total
Herbage Mass (kg DM/ha)							
Day 0							
VEGH	25	467	492	32	0	233	757 (113)[1]
VEGL	291	771	1062	116	23	580	1781 (184)
RUSS	1122	1701	2823	186	4	711	3724 (377)
Day 28							
VEGH	933	332	1262	387	173	125	1950 (154)
VEGH	976	681	1657	544	310	141	2652 (122)
RUSS	843	4355	5198	340	82	597	6217 (802)
Pasture growth rate, (kg DM/ha/day) Days 0 to 28							
VEGH	32.4	-4.8	27.6	12.7	6.2	-3.9	43.0 (5.3)
VEGL	24.5	-3.2	21.3	15.3	10.2	15.6	31.1 (3.9)
RUSS	-10.0	94.8	84.8	5.5	2.8	-4.1	89.0 (18.8)

[1]Standard error to total values.

illustrates that the vegetative and reproductive treatments were indeed different. The cut (vegetative) swards showed increases in the production of grass leaf and clover but marked decreases in total production, as compared to the uncut (reproductive) treatments. These differences are consistent with those reported by Butler (1986).

By day 80 tiller density had declined on all but the VEGH plots (Table 4) and in the VEGL and VEGU swards the number of tillers was roughly half that measured at the start of the experiment. The RUHE and RUAN swards showed tiller numbers intermediate between those of VEGH and VEGL. This may reflect increased tillering after interruption of reproductive growth (Korte *et al.,* 1984). No attempt was made to establish if there were differences between swards in the average age of the tillers.

Effects of sward manipulation on root growth

Root lengths (km/m^3) measured in intact cores at Days 26 and 80 are presented in Figure 2, and those in sand filled cores at Days 56 and 80 and in silt filled cores at Day 80 in Figure 3. No statistically significant treatment differences in root lengths in intact cores were found at either sampling date (Figure 2). In contrast sand filled cores showed significant treatment differences ($p < 0.05$) at both Days 56 and 80 and a significant treatment x time interaction ($p < 0.01$) when data from the two harvests were analysed as a split plot in time (Figure 3). Treatments subjected to

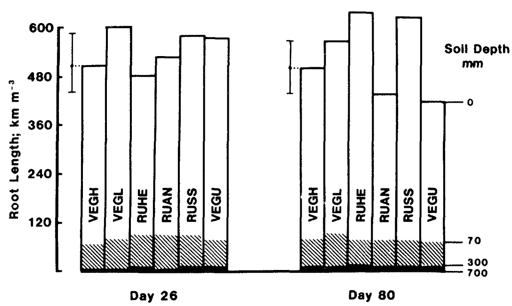

Figure 2: Root lengths in intact cores in three soil depths at Days 26 and 80 for the six cutting treatments. Vertical bars indicate standard error of means.

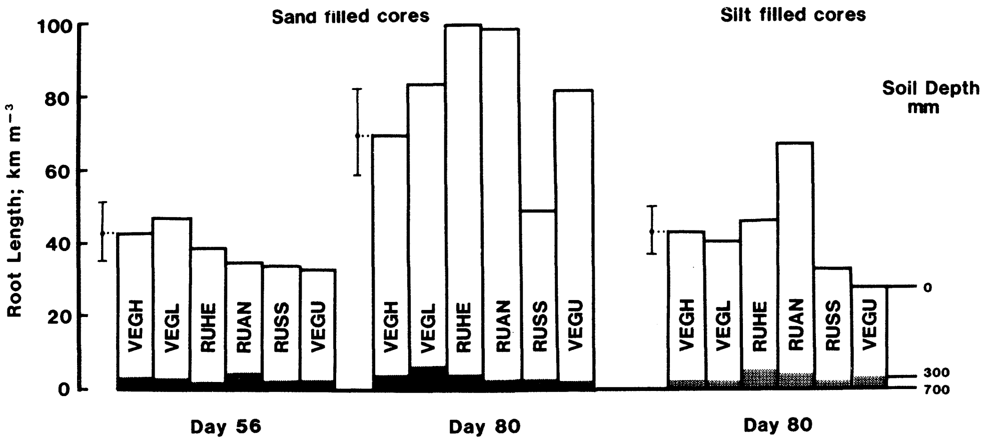

Figure 3: Root lengths in sand filled cores in two depths at Days 56 and 80 and silt filled cores in two depths at Day 80 for the six cutting treatments. Vertical bars indicate standard error of means.

longer periods of reproductive growth (RUAN and RUSS) had significantly lower root lengths ($p<0.05$) than VEGH plots at Day 56. Troughton (1978) has also observed a reduction in root growth in reproductive perennial ryegrass plants in a greenhouse pot trial. If new root growth is assumed to arise from newly initiated tillers, such a reduction is consistent with reduced tiller initiation rates in a reproductive sward (Korte *et al.,* 1984).

By Day 80 root lengths in refilled cores were greatest on RUHE and RUAN plots (Figure 3), treatments that had been defoliated for the first time at head emergence and anthesis, respectively, while RUSS plots showed significantly less root growth. The VEGL plots were intermediate. The VEGU plots had high root growth in sand filled cores, but low root growth in silt filled cores. The high root growth on RUHE and RUAN plots between Days 56 and 80 could represent roots produced by tillers initiated after the removal of reproductive growth (Table 4; Korte *et al.,* 1984). Parsons *et al.,* (1981) have shown that the total quantity of carbohydrate partitioned to roots in ryegrass during early reproductive growth is greater than for vegetative growth, even though the proportion of photosynthate partitioned to roots is decreased. To what extent increases in carbohydrate supply to the roots during reproductive growth contribute to increases in tillering and to new root growth occurring after removal of reproductive growth has not been established.

Intense or frequent defoliation is often cited as a factor resulting in reductions in root growth or in root death (Evans, 1971). In this experiment VEGH plots generally showed lower root lengths than VEGL plots in intact (Figure 2) and refilled cores (Figure 3), but the differences were relatively small, and never statistically significant.

CONCLUSIONS

The refilled core technique provided information on the relativity of the rates of root growth in different plots. Used in conjunction with measurements of total root length from intact cores the refilled core technique yields an estimate of the rate of turnover of roots.

Reproductive development of the sward reduced root growth, but in swards where the reproductive growth was removed by cutting (e.g. at head emergence of flowering) root growth was subsequently greater than in swards which were vegetative throughout the trial period.

TABLE 4: Herbage mass, ryegrass tiller numbers and clover stolon densities at Day 80.

Cutting Treatment	Herbage mass (kg DM/ha) Grass	Clover	Total	Ryegrass tiller numbers (tillers/m²)	Clover Stolon density (m/m²)
VEGH	2330	28	2930	4774	32.6
VEGL	5250	840	7030	2327	53.6
RUHE	6180	1510	8230	3052	54.4
RUAN	6250	1130	8120	3233	45.6
RUSS	6560	1380	8260	2372	47.7
VEGU	7050	1040	8720	2455	63.8
MEAN	5600	1030	7220	3036	49.6
S.E.D.	972	485	1010	496	11.0

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