The Interaction between Root Distribution and Pasture Growth During Water Deficit

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ABSTRACT

Quantification of water-limited pasture growth is of interest in agriculture since it allows prediction of impaired animal production during drought, and is the basis for scheduling irrigation. Experimental work on two dairy pastures 25 km south-west of Palmerston North, New Zealand found 50% of root mass was in the top 2.3 cm of soil. Soil moisture was, similarly, not uniformly distributed down the soil profile and dried most rapidly in the top 20†cm of soil. Leaf appearance rate was more strongly correlated with water status nearer the soil surface (r = 0.52 & 0.63 for 0-5 & 10-15 cm depth, respectively) than at depth (r = 0.13 for 20-70 cm depth). Water-limiting pasture growth models need to account for the distribution of roots and water in the soil to accurately predict growth of pastures subjected to, and recovering from, water deficit.

KEYWORDS

water deficit, drought, pasture growth, root distribution, leaf appearance rate

INTRODUCTION

Precise quantification of water-limited pasture growth is of interest in agriculture since it allows prediction of impaired animal production during drought, and is the basis for scheduling irrigation volume and time. Existing models relate pasture growth to average water content or total soil water storage (McAneney & Judd, 1983; Parfitt et al. 1985) and do not account for differences in the distribution of water in the soil. Such models might predict growth during development of a water deficit since the pattern of soil drying is from the top down, but might not predict growth responses to intermittent water deficit where preferential wetting of the top (rooting) zone occurs. The objective of this study was to measure the distribution of soil water and roots in the soil and relate this to pasture growth.

METHODS

Experimental work was conducted on two pastures of an irrigated dairy farm 25 km south-west of Palmerston North, New Zealand (175½ 19' E, 40½ 24' S). The soil for both pastures was a well fertilised Himatangi sand. The first pasture was irrigated to prevent severe water deficit during summer, with 40 mm of water being applied 11-13 December 1995. The composition (% by mass) of this pasture was 54% ryegrass, 26% other grass species, 16% white clover, and 4% other species. The second pasture was never irrigated, and comprised 24% cocksfoot, 3% C4 grasses, 71% other grass species, and 2% subterranean clover and other species.

Measurements were made 2-3 times per week during two regrowth periods (14 November-4 December and 4-21 December 1995) (early summer) at 5 sites in each of the two pastures. Pasture biomass was measured by cutting two 0.1 m^2 quadrats per site to ground level and growth rate calculated as the change in biomass over time. Lamina extension rate and leaf appearance rate were measured on 40 cocksfoot tillers marked along a 4 m transect at each site. Volumetric soil water content (VSWC) (m^3/m^3, %) was measured by time domain reflectometery (TDR) (Trase-1, Soil Moisture Equipment Corp.) for the horizons 0-5, 5-10, 10-15, 15-20 and 20-70 cm depth. Soil to 500 mm was sampled from two of the irrigated pasture sites, in ten 5 cm diameter cores, and divided into the same fractions as for the TDR. A sub-sample of soil was used to determine gravimetric water content, prior to roots being washed from soil using a metal screen (8 strands/cm) and subsequently dried.

RESULTS AND DISCUSSION

Weather was wetter than average with rainfall in November (117 mm) and December (89 mm) being 95 and 11%, respectively, greater than average. Water deficit was less extreme than expected. Air temperature at Palmerston North averaged 13.6½C and 17.6½C for November and December, respectively, compared to 30-year means of 14.3°C and 16.1°C, respectively.

Pasture biomass accumulated approximately linearly during both regrowth periods for both pastures. Growth rate for the dryland pasture in the second regrowth period (62 kg DM/ha/day) was 78% of the first regrowth period (80 kg DM/ha/day), and 76% of the growth rate of the irrigated pasture in the second regrowth period (82 kg DM/ha/day). Water deficit probably contributed to this depression in growth.

Mean total water storage to 700 mm depth of dryland pastures decreased from 233 mm to 161 mm, and including rainfall, mean water loss (principally evapotranspiration) averaged 4.3 mm/day. Mean total water storage to 700 mm depth of irrigated pastures decreased at similar rates as dryland pastures, excepting for a 28 mm increase in water storage resulting from the addition of 40 mm of irrigation water. Change in VSWC during the experiment was not uniformly distributed with depth, being greater nearer the surface for both pastures (Fig.1).

Total root mass (6.5 t DM/ha) was larger than for other rotationally grazed pastures (Denium, 1985; Matthew *et al*., 1991), however, this may have been because root dry mass was not adjusted for possible contamination by soil. Root mass varied with depth (Fig. 1) but was distributed relatively nearer the surface than lower fertility pastures (Barker *et al.*, 1988). Data were used to derive equation 1, which showed 50% of root mass occurred in the top 2.3 cm of soil.

Cumulative root mass (%) = 98.71 - 98.61 $e^{(-0.31\ \mathrm{depth})}$
R^2=99.92 [Eq. 1]

Leaf appearance rate averaged 0.12 and 0.09 leaves/tiller/day over the experimental period for irrigated and dryland pastures, respectively. Specific observations of leaf appearance rate varied and these were moderately well correlated with VSWC (Fig. 2). The correlation was greatest for VSWC measured near the soil surface, than deeper in the profile (Fig. 2). Water-limited pasture growth models based on average VSWC over depth or total soil water storage are likely to be less accurate than models accounting for the distribution of water in the soil.

Lamina extension rate did not vary between pastures or with development of water deficit (average = 10.9 mm/leaf/day). In this study, leaf appearance was determined as a new leaf within the centre of a tiller. Since this appearance was 2-8 cm distant from the meristem it probably reflected early lamina extension rate, and could be distinguished from the latter phase of lamina extension. These data suggest the early phase of lamina extension was more sensitive to water deficit than subsequent lamina extension.

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Figure 1

Root mass (kg dry matter/ha) of an irrigated pasture and volumetric soil water content (m3/m3,†%) of dryland and irrigated pastures at the beginning and end of the measurement period (VSWC & root data are the mean of 5 & 2 sites, respectively)

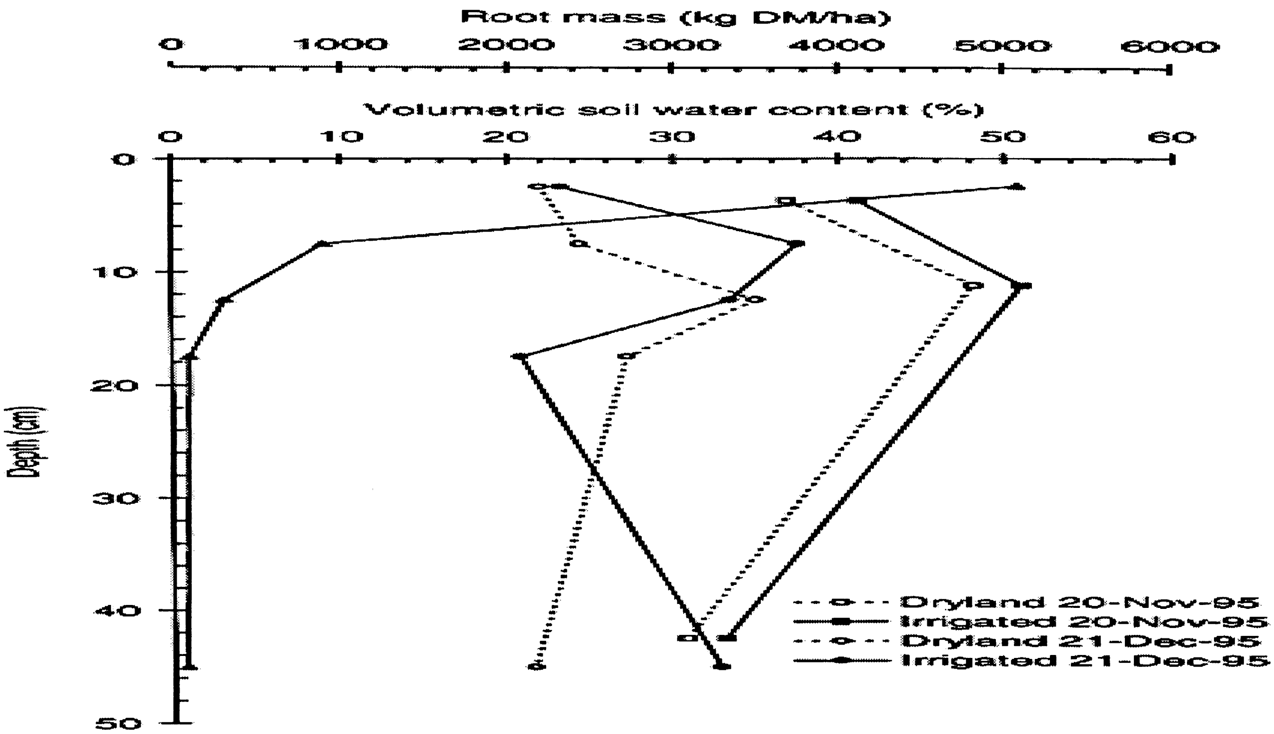

Figure 2

Relationships between cocksfoot leaf appearance rate (leaves/tiller/day) and volumetric soil water content (m3/m3, %) at three depths, for a dryland dairy pasture.