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Theme 5. Environmental issues related to grassland
Sub-theme 5.1. Climate change and grassland management

Comparison of two different pasture species compositions for recovery of deep soil nitrogen during winter

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Introduction

Surplus nitrate (NO_3^-) beneath animal urine patches is highly vulnerable to leaching, particularly during winter when soil drainage is often highest. Most common pastures in New Zealand (*i.e. Lolium perenne*) have relatively shallow root systems and produce low dry matter (DM) yields during winter months. Recent investigations suggest that alternative pasture species may be able to recover more soil nitrogen (N) during winter and consequently reduce NO_3^- leaching losses (Moir *et al*., 2013; Malcolm *et al*., 2014; 2015). However, further work is required to better understand the importance of root system architecture and plant growth of these alternative species during this cool period.

The objective was to determine the ability of *L. multiflorum* (Italian ryegrass) and *F. arundinacea* (tall fescue)-based pastures to recover mineral-N from different soil depths under simulated winter conditions and determine the relative importance of plant growth/metabolic activity and root system architecture.

Materials and Methods

Trial preparation and treatments: The trial was carried out in a climate-controlled growth chamber (Conviron BDW120) at The New Zealand Biotron facility at Lincoln University, Canterbury (latitude 43°39'south, longitude 172°28'east); air temperature and day length simulated an average Canterbury late autumn-early spring climate (May–October).

Twenty-four intact soil monolith lysimeters (18 cm diameter x 70 cm depth) were collected from a pre-established pasture site of Templeton fine sandy loam soil (Immature Pallic) at the Lincoln University Research Dairy Farm, Canterbury, following well-established protocols and procedures outlined in Cameron *et al*. (1992), and installed into the Biotron research facility. Half the lysimeters contained *Lolium multiflorum* 'Tabu' (Italian ryegrass) with *Trifolium repens* (white clover; It. ryegrass WC), while the remaining were *Festuca arundinacea* 'Advance' (tall fescue) also with WC (T. fescue WC). Both grass species were sown at 25 kg ha^{-1} with 3 kg ha^{-1} of WC, 18 months before lysimeters were collected. Basal fertilizer (0-10-6-16) at 50 kg P ha^{-1} was applied before the trial began to ensure optimum nutrients.

Soil moisture and temperature were recorded using Campbell Scientific probes/sensors. Average weekly volumetric water content ranged from 30 to 34 g cm^{-3} from early June until the end of the trial in early October. Average weekly soil temperature was lowest in late June, at 5.7°C, and steadily rose to 14.1°C by October.

The trial was arranged as a completely randomized 2 (pasture species) x 3 (depth to N treatments) factorial design with four replicates of each treatment. The three ^{15}N injection depth treatments (equivalent to 300 kg N ha^{-1}) were either 5, 25 or 45 cm below the soil surface and uniformly administered as a dissolved ^{15}N-enriched urea (10 atom %) solution in a grid pattern, using specially designed needles for each of seven injection points around the lysimeter casing. All lysimeters were irrigated with deionised water 2–3 times per week to near-field capacity. Over-watering was avoided to prevent leaching and to ensure plants had optimal opportunity to draw on the available N.

Measurements: Pasture within the lysimeters was periodically harvested to simulate animal grazing. Herbage wet and dry weights were obtained for each lysimeter sample to calculate DM production. Finely ground sub-samples were analyzed for total N/^{15}N content by a stable isotope ratio mass spectrometer, following combustion at 1000°C in an automated Dumas style elemental analyzer. ^{15}Nitrogen recovered was calculated using the formula:

$$^{15}N\ recovered\ (\%) = 100p(c-b)/f(a-b) \qquad (1)$$

where p = moles of N in plant material, f = moles of N in the injected urea solution, c = atom % ^{15}N abundance in the plant, a = atom % ^{15}N in the urea solution, and b = atom % ^{15}N abundance of plants grown in unfertilized soil (Cabrera and Kissel, 1989).

At the end of the trial all the 45-cm injection depth treatment lysimeters were destructively sampled for root analysis. Soil samples of 10 x 10 cm width x 20 cm depth were taken from each monolith between the depths of 5–25, 25–45 and 45–65 cm. Pure root samples were obtained by carefully washing soil away with water. Roots were then analyzed for root length density (cm root cm^{-3} soil) by the computer scanner and software package WinRHIZO, derived from digitized grey-scale images (EPSON EXPRESSION 10000XL 3.49).

Root ^{15}N uptake efficiency (mg ^{15}N m^{-1} of root) is reported and defined as the total amount of ^{15}N recovered in the herbage of all pasture cuts per unit of root length measured between the N injection depth and the base of the lysimeter.

Data were analyzed using ANOVA in GenStat (14th Edition, Lawes Agricultural Trust).

Results and Discussion

Pasture species had a highly significant (P<0.001) main effect on DM yield (Fig. 1). Italian ryegrass WC yielded between 8.2 and 9.2 t DM ha^{-1}, 39–75% higher than T. fescue WC. Higher winter yields of Italian ryegrass pastures were also reported by Malcolm *et al*. (2014; 2015). There was no difference in total yield between injection-depth treatments as yields from lysimeters where ^{15}N was injected lower in the profile sequentially increased.

Similarly, ^{15}N recovery was overall significantly (P<0.01) higher (~15%) in the It. ryegrass WC pasture treatment than T. fescue WC, in line with findings by Moir *et al*. (2013). Again, N injection depth had no significant effect on ^{15}N recovery, indicating that both pastures were capable of drawing on freely available N reserves at depths of ≥45 cm, without compromising DM yield. However, Malcolm *et al*. (2015) unsurprisingly reported that both pastures declined in yield and recovered lower amounts of N from the deepest injection depth (45 cm) when drainage was imposed, as a result of leached N.

Total herbage N uptake (data not shown) showed similar trends to ^{15}N recovery and ranged from 137 kg N ha^{-1} (T. fescue WC) to 186 kg N ha^{-1} (It. ryegrass WC).

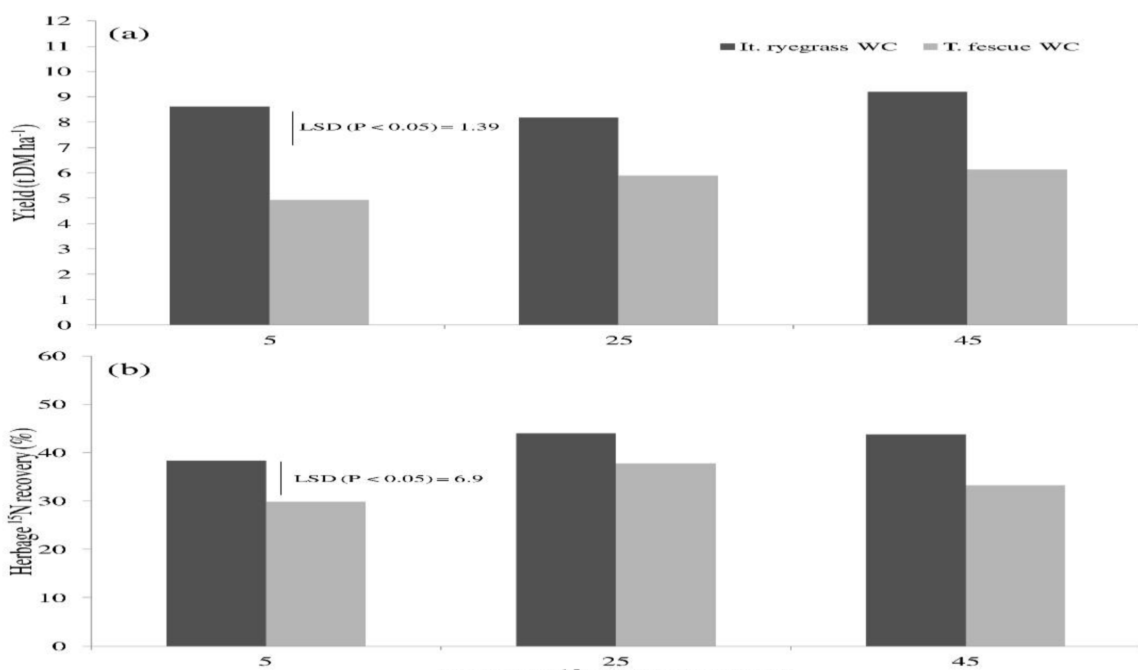

Fig. 1: (a) Total pasture dry matter production (t DM ha^{-1}), and **(b)** herbage ^{15}N recovery (%) following ^{15}N injections at 5, 25 or 45 cm depths. WC = white clover; It. = Italian; T. = tall.

Root length density following 15N injection at the 45 cm depth was highly significantly (P<0.001) affected by pasture species, with 76% (25–45 cm depth horizon) to over 4-fold (45–65 cm depth horizon) higher densities of T. fescue WC roots than It. ryegrass WC roots at all three sampled horizons (Fig. 2). Similar trends have also been reported by Malcolm *et al*. (2014; 2015). The total amount of 15N recovered and the total root length below the point of injection (45 cm depth) indicate an uptake efficiency of 1.19 and 0.18 mg 15N m-1 root material for the It. ryegrass WC and T. fescue WC pasture treatments, respectively (P<0.001) (data not shown). Malcolm *et al*. (2015) reported lower uptake efficiencies at this 45-cm injection depth, because of imposed leaching; however, differences between pastures were highly significant as were calculated in our study, with uptake efficiencies of T. fescue WC c. 73% less than those of It. ryegrass WC.

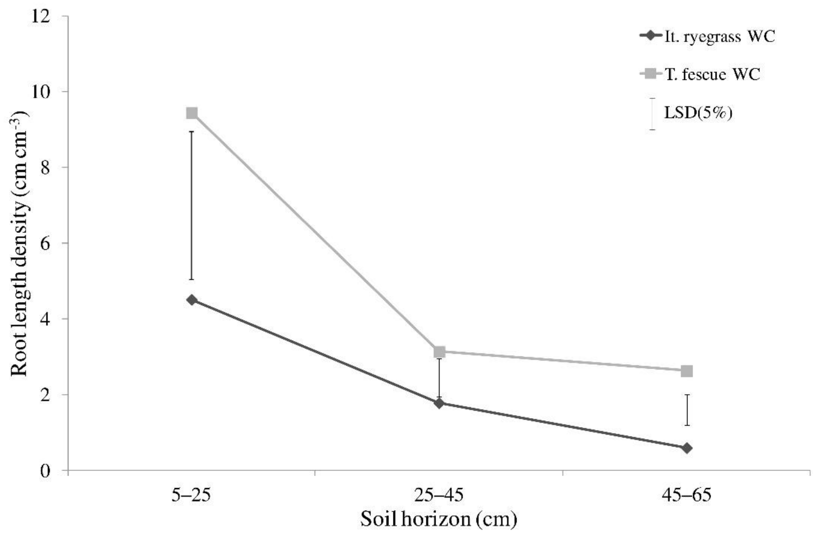

Fig. 2: Pasture root length density (cm root cm^{-3} soil) at three soil horizons (5–25, 25–45 and 45–65 cm depth) following administered ^{15}N at the 45 cm injection depth. LSD (P<0.05) calculated for two treatment means at each depth separately. WC = white clover; It. = Italian; T. = tall.

Conclusion

Italian ryegrass WC pasture yielded higher and was more effective at recovering N from all soil depths than T. fescue WC, despite containing notably lower root densities at all measured soil horizons (5–65 cm depth). This provides evidence that N capture/NO_3^- leaching losses can be more strongly mitigated by pasture species with greater winter growth/N uptakes than by deep roots alone.

References

Cabrera, M. L. and D. E. Kissel. 1989. Review and simplification of calculations in ^{15}N tracer studies. *Fertilizer Research* 20(1): 11-15.

Cameronm, K. C., N. P. Smith, C. D. A. McLay, P. M. Fraser, R. J. McPherson, D. F. Harrison and P. Harbottle. 1992. Lysimeters without edge flow: an improved design and sampling procedure. *Soil Science Society of America Journal* 56(5): 1625-1628.

Malcolm, B. J., K. C. Cameron, G. R. Edwards, H. J. Di and J. Moir. 2014. The effect of four different pasture species compositions on nitrate leaching losses under high N loading. *Soil Use and Management* 30(1): 58-68

Malcolm, B. J., J. L. Moir, K. C. Cameron, H. J. Di and G. R. Edwards. 2015. Influence of plant growth and root architecture of Italian ryegrass (*Lolium multiflorum*) and tall fescue (Festuca arundinacea) on N recovery during winter. *Grass and Forage Science* DOI: 10.1111/gfs.12157.

Moir, J. L, G. R. Edwards and L. N. Berry. 2013. Nitrogen uptake and leaching loss of thirteen temperate grass species under high N loading. *Grass and Forage Science* 68(2): 313-325.

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