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Theme 3. Sustainability of grasslands- social and policy issues
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Production and resource use of winter feed crops in New Zealand

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Introduction

In the South Island of New Zealand (NZ), dairy cow numbers have increased from 1.4 to 2.1 million since 2005 (Statistics, New Zealand, 2014). This has led to a strong demand for winter feed crops in place of pasture, and also for supplementing pasture during lactation. Yields of 19–35 t DM/ha are reported for fodder beet (*Beta vulgaris* L.) in NZ (Chakwizira *et al*., 2014) compared with 14–25 t DM/ha for forage kale (*Brassica oleracea* L.) (Chakwizira *et al*., 2009) and 18–25 t DM/ha for maize (*Zea mays* L.). Fodder beet has only recently been widely adopted for its ease of feeding and provision a high energy feed (Matthew *et al*., 2011). Choice of crop is based on yield potential, feed value and suitability for winter feed management. Nitrogen fertiliser and irrigation practices affect the productivity, profitability, and dynamics of resource use during crop growth; and losses of N during winter in situ feeding. Optimized systems with high water and N use efficiency are sought to reduce potential adverse environmental effects. The objectives were to compare efficiency of water and N use of fodder beet, kale and maize and assess their value to growers.

Materials and Methods

Data were derived from three experiments (A, B and C) in Canterbury, NZ. Experiments A and B, in seasons 2011–12 and 2012–13, respectively, were on the New Zealand Institute for Plant & Food Research Limited farm (43° 37.56' S, 172° 28.12' E) near Lincoln. Experiment C (2013–14) was on the Lincoln University dryland farm (43°38.90' S, 172°20.35' E). Experiments A and B were on a deep (>1.6 m), well drained Udic Ustochrept, with water capacity (WC) of 190 mm/m of depth. Experiment C was on a stony silt loam (Udic Haplustept), with a shallow top soil (0.25 m) and WC of 90 mm/m depth. All crops were sown between 21 October and 3 November, and final harvests taken between 15 April and 6 June. Mean long term (1961–2014) temperature for both sites was 14.4ºC during November to April. Annual rainfall of 650 mm is distributed evenly throughout the year.

Experiment A (fully irrigated): Separate blocks of maize, fodder beet and kale were grown in a randomized complete block design (RCBD, four reps). Treatments were five rates of nitrogen (N; kg/ha) for maize (0–400) and fodder beet (0–200) and seven rates for kale (0–500) applied as urea (46%) in 2–3 split applications.

Experiment B: Fodder beet and kale blocks arranged in a RCBD (four reps) and four water treatments: Rain-fed control; full potential evapotranspiration (ET) replaced weekly with surface lateral irrigation; 50% of ET replaced every 3 weeks; and 50% of ET replaced weekly, with maximum of 50, 25 and 25 mm/week for respective irrigation treatments.

Experiment C: Fodder beet and kale also in a RCBD (3 reps) with species in separate blocks. Within species, treatments were a factorial of irrigation (rain-fed control or full replacement of ET twice weekly (max. 50 mm/wk); and four rates of N (kg/ha) for each of fodder beet (0–200) and kale (0–300). Soil available N was determined as net mineral N (difference between pre- and post-season N+fertiliser N), sampled from 0–90 cm depth for Expts. A and B, and 0–30 cm for Expt.C. Water applied in Expts.1and 2 was calculated from daily ET records (NIWA, 2014) and adjusted for local rainfall. In Expt.3, water was applied to raise soil water to field capacity as measured by weekly TDR (0–20 cm depth). Irrigation was applied weekly, by surface drippers spaced at 15x20 cm grid except for designated treatments in Expt.B, and twice-weekly applications in Expt.C. Nitrogen use efficiency was calculated as dry matter (DM) yield/kg N fertiliser applied (NUEf) or DM/total available N (NUEt). Water use efficiency was determined as DM yield/irrigation applied (WUEi) or per total rain+irrigation (WUEt). Costs associated with crop husbandry were used in profit analysis using a standard value of $0.25/kg DM. Profit excluded costs associated with harvesting and/or storage. Profit was normalized against the crop with best return within each crop×season to demonstrate unbiased comparisons between crops and between efficiency indicators.

Results and Discussion

Productivity In all years, FB produced higher mean yield over all treatments of 21.9 t DM/ha (SEM 1.24) yields than kale (15.1 t DM/ha; SEM 1.60) but less than maize (24.4 t DM/ha, SEM 1.07). The range in fodder beet yield was 13.7–28.5 t

DM/ha, with variation attributed to N fertiliser rates, soil type and irrigation level. The range in kale yield was wider (4.9 –25.5 t DM/ha). NUE and WUE Patterns for NUEf and NUEt were similar as the net soil mineral N levels used for growth did not differ significantly among the treatments. All crops, except irrigated fodder beet in year 2, showed a three-fold increase in NUEf over the range of decreasing N fertiliser applications (data not shown). Treatments giving maximum yield had a base level of NUEf that differed among the species. NUEf at high N fertiliser rates was higher for fodder beet and maize than kale. Both irrigated fodder beet and kale showed elevated NUEf at the lower N fertiliser applications. WUEt varied widely over species from a low of 10 kg DM/mm for rain-fed kale under low fertiliser treatments to 75 kg DM/mm for irrigated-high N fodder beet (Figs. 1A and 1B). There was no clear overall relationship between NUEt and WUEt, (Fig.1A), however, when N rate and irrigation level were considered within crop there were systematic negative correlations between NUEt and WUEt (Fig.1A). Each crop responded differently to soil water and N availability and specific crops management was required to achieve optimized production systems.

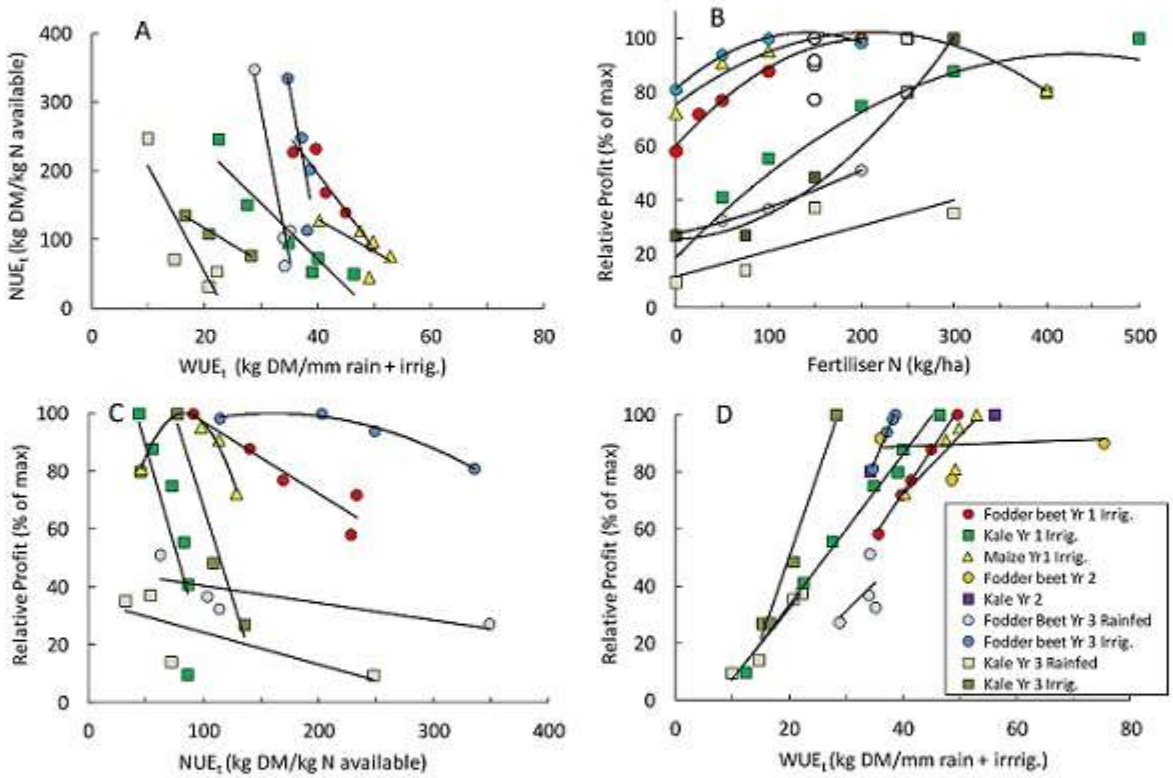

Fig 1. Relationships between NUE_t , WUE_t , normalized profit and level of N fertilizer applied in species × year treatments.

Profit: Cropping profit was strongly driven by yield (r=0.93). Irrigated crops grown on deep soils, fertilized with high rates of N gave highest returns. Profit in excess of 75% of maximum was achieved in irrigated treatments and for all N fertiliser rates when NUEf exceeded 140 kg DM/kg N fertiliser applied in maize and fodder beet. NUEf in excess of 100 kg DM/kg N was required for irrigated kale to achieve 75% of maximum profit. A decline in profit was observed in maize with high N inputs, however kale continued to show high yield and profit even at excessive N applications up to 500 kg N/ha. The patterns observed for actual $ profit/ha were not dissimilar to the normalized data. Irrigated crops were more profitable than corresponding rain-fed treatments over the range of N treatments (Fig.1B). In fodder beet, NUEt was higher than kale but the profit decline with lower N inputs was proportionally less (Fig.1C). Maize yield and profitability did not vary as much as kale over the range of N treatments tested and NUEt was intermediate between irrigated crops of kale and fodder beet (Fig.1C). In all crops, improved WUE meant improved profit, but this was dependent on the N fertilizer requirement to support yield gains (Fig.1D). The pattern was less consistent with fodder beet grown in year 2 on a deep soil with near-optimal N fertiliser management.

Conclusion

Restricting the total N available for growth resulted in improved N efficiency and lower total WUE. Therefore, efficient resource use requires a trade off between reduced N rates (and consequently lower yield) and improved water use as well as considerations for profitability. Each crop of maize, fodder beet and kale responded differently to soil water and N availability. Therefore, crop specific management is required to achieve optimized production systems with reduced potential for detrimental impacts to the environment caused by overuse of N fertiliser or potential drainage losses through excessive irrigation, especially on free draining soils.

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