

RESEARCH ARTICLE



A review of grass species yields and growth rates in Northland, New Zealand

Carmen S. P. Teixeira , Sonya T. Olykan  and Derrick J. Moot 

Dryland Pastures Research Group, Field Research Centre, Faculty of Agriculture & Life Sciences, Lincoln University, Lincoln, New Zealand

ABSTRACT

Pastoral farming is a major land use in New Zealand's Northland region, with 3,171 farm holdings and a total area of 637,500 hectares in 2022. The region's pasture grasses include temperate (C3) and subtropical and tropical (C4) grasses which support dairy, and sheep and beef production from grazing. In lowland areas, C3 and some annual C4 grasses are prevalent where cultivation occurs, while perennial C4 grasses dominate areas with low soil fertility and summer dry conditions.

Grass-based pasture growth rates (kg dry matter/ha/day) from published and unpublished sources were assembled into the AgYields database. Among the resident and sown grasses tested in Kaitaia, Kaikohe, Whangarei and Dargaville, perennial ryegrass represented ~60% of the total data points. Dominant kikuyu pastures represented 23% and the remaining species represented 17%. Rates of growth ranged from 5 to 120 kg DM/ha/day, being lowest in late autumn-winter and highest in early summer. Data were compared and agronomic traits (i.e. drought tolerance, biomass production and tillering) are discussed to assess species suitability for the Northland environment. The medium-term prospect suggests an urgent need to improve research into management of cocksfoot and tall fescue-based pastures to provide viable alternatives to overcome the decreasing persistence of perennial ryegrass.

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Introduction

Pastoral farming in the Northland region of New Zealand is a major land use with 3171 farm holdings in 2022, and a total area of 637,500 hectares. These focused primarily on cattle grazing for dairy and beef production (Statistics New Zealand 2023). The pasture grasses in the Northland region are temperate (C3) and subtropical and tropical (C4). The C3 and some annual C4 grass species dominate the intensively cultivated lowland, while perennial C4 grasses prevail areas of low soil fertility and that experience prolonged periods of summer dry (Lambert 1967).

CONTACT Carmen S. P. Teixeira  carmen.teixeira@lincoln.ac.nz

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Northland's topography, soils, and climate are unique and can be challenging for the management of farming systems. The inland topography is typically low, rolling country. Of the 1.5 million hectares of mapped area in the province, 80% has the potential to be affected by erodibility, 12% by waterlogging and 8% by soil depth limitations (shallow). The maintenance of a vegetative cover is an essential tool for reducing erosion risk and top soil loss (Harmsworth 1996). The Northland climate is mild, humid, relatively windy, and has an annual rainfall ranging from ~1000 to 2000 mm (Chappell 2013). The rainfall tends to occur in large events so that up to 50% of the rainfall may be lost to drainage or run-off, resulting in an effective rainfall of 700–800 mm and frequent summer dry conditions (Teixeira et al. 2023).

Northland catchments (LAWA 2021; Min and Inglis 2021), where exotic grassland was the predominant land cover (i.e. > 50%) included Aharoa River, Awanui River, Hakaru River, Kerikeri River, Northern Wairoa River, Ruakaka River, Tauranga Stream, Waipapa Stream and Waitangi River (see map in Min and Inglis 2021). Northland pastoral systems are dependent on perennial ryegrass (*Lolium perenne* L.), Italian or annual ryegrass (*L. multiflorum* L.) and kikuyu (*Chenchrus clandestinum* Hochst. ex Chiov. Morrone) each with their own respective seasonal advantages and disadvantages (McCahon et al. 2021; Sierra et al. 2023). Ryegrasses (*Lolium* spp.) prefer cool-seasons with optimal temperatures between 10°C to 18°C (Wilson et al. 1991; Lonati et al. 2009). While perennial ryegrass flourish during spring the Italian ryegrass is commonly sown in autumn as a 6–8 month winter-spring forage crop. Kikuyu thrives in warm late spring and summer seasons when temperatures are above 23 °C. However, it becomes dormant during winter and early spring when temperatures decrease <12 °C (Herrero et al. 2000; Dodd et al. 2011).

Perennial ryegrass is the most widely sown species in Northland. However it reportedly lacks persistence (Ussher and Hume 2015) due to the combination of warm temperatures and summer dry conditions that lead to over grazing (Maxwell et al. 2018). Therefore, alternative temperate and tropical grass species have been investigated. Italian or annual ryegrasses can boost cool-season pasture productivity but are unlikely to last more than one to two years (Stewart et al. 2022).

Kikuyu is considered an invasive C4 grass species by some authors because it dominates Northland grasslands during summer and autumn but it is seldom sown (Piggot 1988). It is drought tolerant (Dodd et al. 2011) and creates a dense mat of stolons that out-competes other pasture species for sunlight (Garcia et al. 2008; Copland 2009; Ministry of Agriculture and Forestry 2010). However, kikuyu is sensitive to cold during winter and spring which restricts its growth. As a consequence, well managed pastures can have 5–10% of dry matter as kikuyu in late winter/spring, but as much as 90% in autumn (Copland 2009).

Lambert, as early as 1967 suggested other species may be better suited to the Northland environment than traditional perennial ryegrass. He noted that under critical summer conditions both grass and clover (*Trifolium* sp) in ryegrass plots were wilting due to dry weather. In contrast, the herbage in kikuyu and paspalum (*Paspalum dilatatum* Poir) plots was still green and growing.

An overview of the Northland pasture production indicated that pasture yields were low compared with other regions of New Zealand (Teixeira et al. 2023). These low yields and a lack of persistence (McCahon et al. 2021) may be compounded by a limitation of available

supplementary feed during summer dry or winter wet conditions. This raises the risk of overgrazing which reduces plant reserves and light capture by the canopy. Consequently, the physical damage to pasture plants lowers their potential yields (Teixeira et al. 2023).

A report by Ministry for the Environment (2018), based on climate change modelling simulations for New Zealand, noted that the Northland climate was predicted to become hotter and drier in the future. However climate variability, as a result of more frequent extreme climatic events between and within years, is likely to have a greater impact on agricultural systems than gradual climate change (Harrison et al. 2016). The heavy rainfall and storm events across upper Northland and the impact of Cyclone Gabrielle on Te Matau-a-Māui and Te Tairāwhitiare regions in the first half of 2023 (Harrington et al. 2023) are examples of extreme climatic events. Model studies have shown that there is a positive relationship between the intensity of a climate event and the corresponding best-estimate of change in the frequency of the event. For example, those models showed a 5–10% intensification of rainfall during an event like Cyclone Gabrielle. They also predicted between a 50% increase and doubling in the frequency of such extreme rainfall events (Reid et al. 2021; Harrington et al. 2023).

Looking forward, Northland farmers need resilient pastures that will improve dry matter yield, quality and/or timing of growth within a summer-dry environment. Resilient pastures are those that are able to withstand or recover from different abiotic and biotic pressure while maintaining their productivity and functionality (McCahon et al. 2021). Therefore it is timely to summarise the historical pasture grass growth rate data from Northland and use the results to consider future pasture options for the region. This review focuses on the main grass species currently managed in grazed pastures from the region that were included in formal experiments and used in on farm trials. Data were collated through the AgYields Database (Moot et al. 2021) and are used to quantify and compare yields and growth rates as the basis to assess pasture species suitability for the Northland region.

Material and methods

Northland pasture data

The pasture yields and growth rates (total yield and sown species yield) from published (peer reviewed journal articles) and unpublished (commercial trials, thesis) datasets were compiled and extracted using the methods described in Teixeira et al. (2023). In brief, this data assimilation grouped sites into four units: Kaitaia, Kaikohe, Whangarei and Dargaville based on physiographic criteria (Table 1) and the main climate records in Northland (Harmsworth 1996). After data compilation, measurement units were standardised as dry matter (DM) yields in kg DM/ha and monthly growth rates in kg DM/ha/d. The experiments were standardised according to the AgYields National database template (Moot et al. 2021). The complete list of compiled datasets for Northland, including their description and latitude was previously described (Teixeira et al. 2023). The total number of datapoints extracted was 6127. Of these 71% were from published datasets and 29% from unpublished sources (e.g. commercial company trials). From those, 4857 datapoints were from reported grass species and 3981 had the location assigned and these are summarised in Table 1.

Table 1. Details of the four Northland units used to group the grass datasets.

Unit name	Area in Northland *	Physiographic description #	Effective rainfall mm/year [®]	Data points
Kaitaia	Far north, Ahipara to Mangōnui	Undulating to steep terrain	806	435
Kaikohe	Kaikohe westward to Omapere	Undulating to steep terrain and uplifted greywacke	804	831
Whangarei	Upper east coast – Kerikeri to Maungawhai	Floodplains, old volcanic steepland, sand country and sedimentary terrain	752	1224
Dargaville	Lower Northland, west coast from Dargaville to Murawai	Uplifted greywacke, young basaltic volcanic	723	1491

* For more information see Teixeira et al. (2023), # Harmsworth (1996), ® Effective rainfall = annual rainfall – annual drainage/runoff.

Northland unit summary

Teixeira et al. (2023) provided further details for the four Northland areas (units) into which the data were aggregated for analysis (Table 1).

The mean dry season started in early November in Dargaville, Kaitaia, and Whangarei, and in late November in Kaikohe. The dry season finished earliest in Kaikohe (mid-March), then in early April in Kaitaia and Whangarei, and early May in Dargaville. Additional rainfall occurred when the soils were at field capacity, which is expected to have resulted in drainage and/or runoff and was therefore considered ineffective. Therefore the effective annual rainfall was calculated (Table 1). Further detailed information about the Northland climate were provided in Teixeira et al. (2023).

Grass species and cultivars

In Northland, both temperate (C3) and tropical (C4) grass species coexist in grazed pastures. The percentage of dominant grass species was estimated from the datasets. The species and cultivars reported are summarised in Table 2. The original datasets span the period from 1969 to 2021.

Analysis

Pasture yield (kg DM/ha) and growth rates (kg DM /ha/d)

The accumulated pasture dry matter (DM) yield was computed as described by Radcliffe (1974) and Baars et al. (1975). Monthly growth rates (kg DM/ha/d) of grass dominant pasture species at each site were estimated as growth rates (GR) with a 10–45-day growth period (Radcliffe 1974; Radcliffe and Cossens 1974; Mills et al. 2021; Teixeira et al. 2023):

Equation 1:

$$\text{GR}(\text{kg DM/ha/d}) = \text{DM yield (kg/ha)} \div \text{number of days,}$$

Figures of monthly GR data graphically ± 1 standard deviation are given to estimate variability and the expected range that growth rates would occur within ~66% of the time (Cumming et al. 2007, Mills et al. 2021). The average standard deviation for unequal sample size was determined and displayed due to the uneven number of records and data gaps (Dunnnett 1980) within datasets collated.

Table 2. Grass species, Northland unit (Kaitaia = 1; Kaikohe = 2; Whangarei = 3, Dargaville = 4), cultivars, and the reference details from the gathered datasets from Northland.

Species	Unit	Latin Name	Cultivar	Reference
Bermuda grass	1	<i>Cynodon dactylon</i> (L.) Pers.	Coastcross	(Rumball 1991)
Bermuda grass			Cy6 135	(Davies and Hunt 1983)
Cocksfoot	1,2,3,4	<i>Dactylis glomerata</i> L.	SF Greenly II	(McCahon et al. 2021)
Cocksfoot	2		Apanui	(Lambert et al. 1973)
Italian ryegrass	1,3,4	<i>Lolium multiflorum</i> Lam.	Tabu	(Wynn et al. 2011)
Annual ryegrass	2	<i>Lolium rigidum</i>	Tama	(Betteridge and Haynes 1986)
Kikuyu	1,2,3,4	(<i>Chenchrus clandestinum</i> Hochst. ex Chiov. Morrone)	local ecotype	(Davies and Hunt 1983)
Limpo grass	1, 2	<i>Hemarthria altissima</i> [Poir] Stapf	Bigalta	(Davies and Hunt 1983; Rumball 1989; Woods et al. 1995)
Limpo grass			Floralta	(Rumball 1989)
Nile grass	1,4	<i>Acroceras macrum</i> Stapf	Cedera	(Davies and Hunt 1983)
Pangola grass	1	<i>Digitaria eriantha</i> Steud.	Special	(Rumball 1991)
Pangola grass			CQ911	(Davies and Hunt 1983)
Paspalum	2,3	<i>Paspalum dilatatum</i> Poir	Slenderstem	(Piggot 1984)
Phalaris	2	<i>Phalaris aquatica</i> L.	G15	(Betteridge and Baker 1983)
Perennial ryegrass	1,2,3,4	<i>Lolium perenne</i> L.	Maru	(Keogh and Blackwell 2001)
Perennial ryegrass			AR1	(Lambert et al. 1969; Lambert et al. 1973; Lambert et al. 1974; Lambert et al. 1979)
Perennial ryegrass			Ariki	(Ussher and Hume 2015)
Perennial ryegrass			Base	(Ussher and Hume 2015)
Perennial ryegrass			Easton	(Ussher and Hume 2015)
Perennial ryegrass			Ellet	(Ritchie 1986)
Perennial ryegrass			Nui	(Percival 1980) (Steele and Dawson 1980) (Davies and Hunt 1983) (Easton and Couchman 1999) (Ritchie 1986) (Piggot 1984) (Betteridge and Baker 1983)
Perennial ryegrass			Ruanui	(Piggot 1984)
Perennial ryegrass			One50 AR37	Agricom (unpublished)
Perennial ryegrass			Prospect	(McCahon et al. 2021); Agricom (unpublished)
Perennial ryegrass			Request AR37	Agricom (unpublished)
Perennial ryegrass			Rohan Nea2/6	Agricom (unpublished)
Perennial ryegrass			Stellar AR1	Agricom (unpublished)
Perennial ryegrass			Trojan Nea 2/6	Agricom (unpublished)
Prairie grass	1	<i>Bromus willdenowii</i> Kunth	Matua	(Ussher 1986) (Betteridge and Baker 1983)
South African pigeon grass	1,2	<i>Setaria sphaeolata</i> L.	Narok	(Rumball 1991)
South African pigeon grass			du Toits Kraal	(Davies and Hunt 1983)
Tall fescue	1,2,3,4	<i>Festuca arundinacea</i> Schreber	Hummer	(McCahon et al. 2021)
Tall fescue			Quantum II	(Ussher and Hume 2015)
Tall fescue			Roa	(Ritchie 1986)
Weeping love grass	1	<i>Eragrostis curvula</i> [Schrad.] Nees	CPI 59808	(Davies and Hunt 1983)

Results and discussion

The following results are based on Northland grass datasets from 1969 to 2021 and include experiments and on-farm measurements that investigated the viability of a range of grass species.

Dominant grass species percentage

Perennial ryegrass (resident and sown cultivars) was in all four Northland units and represented ~60% of the total data points (Figure 1). Dominant kikuyu pastures represented 23% and the remaining grass species represented 17% (Figure 1).

Yield and growth rates of pasture species

Perennial ryegrass

The highest growth rates of 53.0 ± 8.44 kg DM/ha/d for perennial ryegrass dominant pastures were measured at Whangarei and Dargaville from October to December (Figure 2). Growth rates at Kaitaia from mid-October to mid-January were $\sim 39.48 \pm 3.13$ kg DM/ha/d. At this location these maximum growth rates started later and finished later than at Whangarei and Dargaville. From early December the growth rates declined at Kaikohe, Whangarei and Dargaville, in line with the expected decline in soil moisture. Growth rates at Kaikohe were highest from October to November (mean of 37.7 ± 0.45 kg DM/ha/d) and declined to $< 6.4 \pm 1.32$ kg DM/ha/d from March to July.

Perennial and annual ryegrasses frequently co-exist, and were seen as complimentary companions for kikuyu, even though ‘they struggle to compete with kikuyu on north-sunny facing hillsides’ (Copland 2009). Northland’s Diversified Forages Group (2020) concluded that perennial ryegrass was ‘not best suited’ for many Northland localities and better adapted species, more permanent and productive grasses include tall fescue

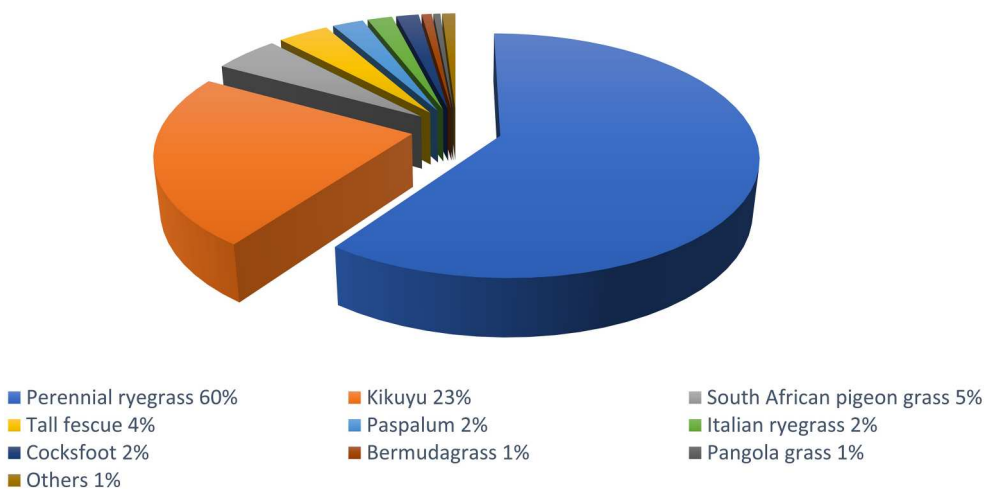


Figure 1. Percentage (%) of the total gathered datapoints from Northland grass species. ‘Others’ correspond to Limpo grass, Meadow fescue, Nile grass, Prairie grass and Weeping love grass.

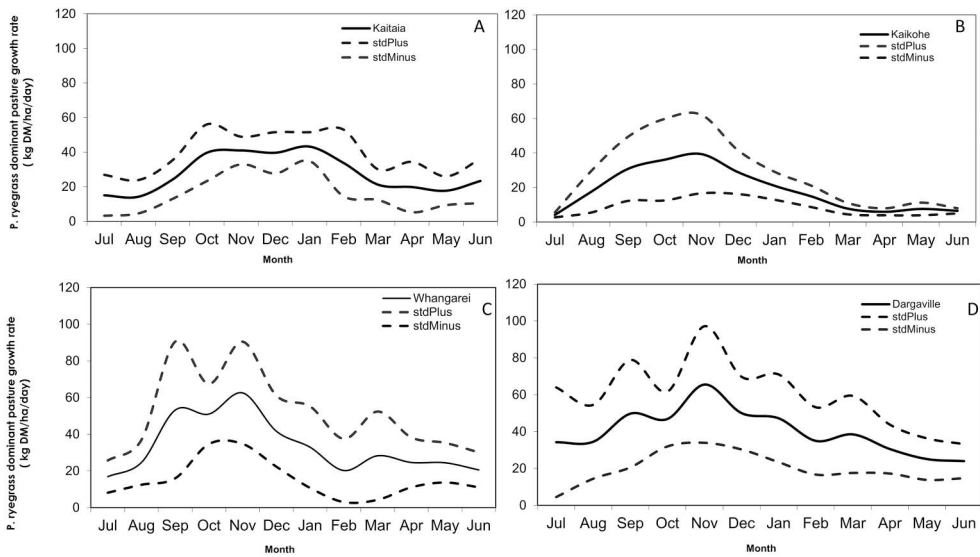


Figure 2. Mean monthly growth rate (kg DM/ha/d) of perennial ryegrass dominant pastures at sites near Kaitaia (A), Kaikohe (B), Whangarei (C), and Dargaville (D). The error bar represents the pooled mean standard deviation. This figure was generated from 14 published and 3 unpublished datasets (<https://www.agyields.co.nz>, see Supplement 1 for details) (Baars 1976; Steele 1976; Piggot et al. 1978; Goold 1980; Ledgard et al. 1982; Rumball 1983; Taylor and Hunt 1983).

or cocksfoot. The poor persistence of perennial ryegrass is consistent with the multiple pressures of temperatures above its optimum, coupled with periods of summer dry when the lack of supplementary feed may lead to overgrazing. This conclusion is consistent with that from Milne (2011) who stated that some pastures are not meeting the expectations of farmers for persistence in many parts of New Zealand due to the widespread use of perennial ryegrass, despite it not being well suited to some environments. In Northland, a range of investigations have examined perennial ryegrass and associated endophytes, grazing management, and its yield compared with other potential grass species. A farm pasture survey in the autumn of 2012 found that on ~6-year-old pastures, mostly dairy operations with high soil fertility (mean 43 ppm Olsen P), the perennial ryegrass pastures had a mean endophyte infection (mostly AR37) of 86% but the ryegrass only represented ~30% of the sward composition (Ussher and Hume 2015). They noted that most farmers felt that ryegrass with AR37 and NEA2 endophytes were persistent and essential for ryegrass persistence in Northland. However, they also commented that typical summer dry conditions and periodic drought were the greatest cause of poor persistence of perennial ryegrass. Hewitt et al. (2021) showed that drought coupled with insect attack threatens ryegrass survival and emphasised the benefits the *Epichloë* endophyte.

On a dairy monitor farm and a beef and sheep farm, endophyte-infected perennial grasses were established in autumn of 2011 and 2012 in the Aupouri Peninsula (Kaitaia unit, 1) of northern Northland (Ussher and Hume 2015). Three pasture mixes of certified seed were sown: (1) 'Base' tetraploid perennial ryegrass infected with AR37 endophyte, (2) 'Easton' or 'Quantum II' tall fescue infected with MaxP

(AR542) endophyte, and (3) 'Nui' perennial ryegrass without endophyte. All pastures were sown with white clover. These pastures were monitored for approximately 3.5 years, with a focus on pasture composition (persistence, endophyte presence and type), and soil fertility and moisture. In late spring 2011, they found that MaxP and AR37 pastures had > 70% endophyte-infected tillers and the endophyte presence lasted for more than three years. 'Nui' pastures however, had a mean of 8% infected tillers, assumed to be a standard endophyte. The 'Nui' ryegrass did not survive the first 12 months on either farm type. The 'Base' AR37 ryegrass percentage dropped from 55% (April 2012) to 10% (Oct-Nov 2014) on the beef and sheep farm and from 60 to 25% on the dairy unit. Ussher and Hume (2015) suggested this was due to a combination of pugging, low soil fertility and very dry summers. This led to low fertility weed species and summer-active grasses dominating the beef and sheep farm and kikuyu quickly reinvading the dairy farm and dominating summer-autumn pastures. The industry's Endophyte Technical Committee (ETC) ratings of endophyte AR37 in perennial ryegrasses indicates good to very good control for a number of insect pests that are present in Northland (Stewart et al. 2022).

Prolonged periods of moisture stress leads to reduced ryegrass tiller density and rate of leaf extension and appearance (Tozer et al. 2014). Keogh and Blackwell (2001) found that low endophyte (LE, 20% infection rate) perennial ryegrass pastures at Dargaville, over three seasons (spring 1997 to autumn 2000), became clover-dominant in the late-spring – summer period. This was achieved by implementing a longer rotation in October – November, which allowed higher pasture mass to accumulate, and laxer (stocked < 1270 kg liveweight/ha) grazing regime when compared with the high endophyte (HE, AR1 infected ryegrass). The advantages of LT pastures can only be sustained for as long as their low toxin status is maintained. This depends on keeping the rate of ingress of perennial ryegrass with wild-type endophytes (WT) to a low level, which requires reducing re-infestation. Removal of seed heads through cutting or grazing before seed-set is one strategy recommended to slow the rate of ingress of WT ryegrass (Thom et al. 2014).

Persistence of perennial ryegrass

McCahon et al. (2021) compared the relative performance of perennial ryegrass ('Prospect'+ AR37 endophyte), tall fescue ('Hummer'+ MaxP® endophyte) and cocksfoot ('SF Greenly II') at Awanui (north of Kaitaia) and Te Kopuru (south of Dargaville) in autumn of 2017. Grass treatments were sown with 'Mainstay' white clover. Low rates of N fertiliser were used: 30 and 60 kg N/ha during spring in Years 2 and 3, respectively, at Awanui, and 35 kg N/ha in Year 3 spring at Te Kopuru.

At Awanui, the average three-year (2017/18–2019/20) yields of cocksfoot (10900 kg DM/ha) and tall fescue (10300 kg DM/ha) were higher than the perennial ryegrass (8600 kg DM/ha). In contrast, at Te Kopuru there was no difference among the grass species with a three-year average of ~11300 kg DM/ha. However mean pasture yield declined from 12700 kg DM/ha/yr in 2018/19 (Year 2) to 6600 kg DM in 2019/20 (Te Kopuru, Dargaville). The authors noted cocksfoot became a dominant volunteer grass in the perennial ryegrass treatment after the second summer. This is a biological indicator that it was more suited to the environment than perennial ryegrass. The

contribution of the sown endophyte infected perennial ryegrass declined to 25% and <10% of herbage yield at Awanui and Te Kopuru after three years. These results are consistent with other summer dry regions of New Zealand, where perennial ryegrass fails to survive. When soils are dry the surface temperature can rise to in excess of 40°C (White et al. 2000; Mills et al. 2008) which can cause tiller death in perennial ryegrass and stolon death in white clover.

In Northland, Waikato and an irrigated site in Canterbury, perennial ryegrass tiller numbers were expected to peak in late spring, decline rapidly through summer to a minimum in autumn and then gradually recover through winter and spring (Woodward et al. 2020). Analysis of modelling simulations suggested that increased tiller mortality associated with moisture stress was the main cause of perennial ryegrass persistence failure at the dryland sites. Therefore, decreasing grazing pressure or breeding for tolerance to higher temperatures may not be successful in preventing this. Seasonal tiller data were not available to validate this prediction, but these patterns generally match those reported by Matthew et al. (2000) and Matthew and Sackville Hamilton (2021), who noted high perennial ryegrass tiller turnover in summer, followed by increasing numbers in autumn to reach peak density in winter.

Ussher (2021) presented data from three sites (Awanui near Kaitaia, Northland Agricultural Research Farm (NARF) and Te Kopuru near Dargaville) sown in 2018. Compared with perennial ryegrass, the advantage of growing cocksfoot and tall fescue was evident in the 2020/21 season, the third year after sowing. Averaging the three sites, perennial ryegrass produced 4600 kg DM/ha (and was 57% of total yield), compared with tall fescue at 7570 kg DM/ha (83%) and cocksfoot at 7840 kg DM/ha (84%).

Italian ryegrass

Italian ryegrass growth rates were recorded from July to November over six years at Kaitaia, Whangarei and Dargaville. Growth rates of Italian ryegrass dominant pastures peaked at 93.1 ± 2.54 kg DM/ha/d, in August at Dargaville (Figure 3). At Kaitaia and Whangarei growth rates ranged from 45.0 ± 5.50 kg DM/ha/d in August to 42.3 ± 10.62 kg DM/ha/d in November.

Italian ryegrass research in Northland has focused on its introduction into existing kikuyu pastures to improve the seasonal pattern of production by providing more DM during the winter period.

Wynn et al. (2011) evaluated direct-drilling Italian ryegrass (sowing rates of 0, 10, 15, 20 or 30 kg seed/ha) into kikuyu pasture, following mulching, at Kaitaia, Whangarei and Dargaville. Dry matter production was measured with a plate meter five times during winter-spring. At Kaitaia sowing Italian ryegrass at 30 kg seed/ha increased total pasture DM yield from June to December from 2870 to 5480 kg DM/ha (+89%). At Whangarei, yield increased from 3900 to 5760 kg DM/ha (+48%) because of the increased growth rates. At Dargaville the overall increase in yield was negligible but plots sown with Italian ryegrass had significantly higher growth rates than the straight kikuyu control plots (34 versus 22 kg DM/ha/d) during July. Wynn et al. (2011) concluded the optimum sowing rate of Italian ryegrass was between 20 and 30 kg seed/ha. The increased yield meant higher stocking rates and reduced bought in feed, which is important in a region where supplementary feed can be scarce.

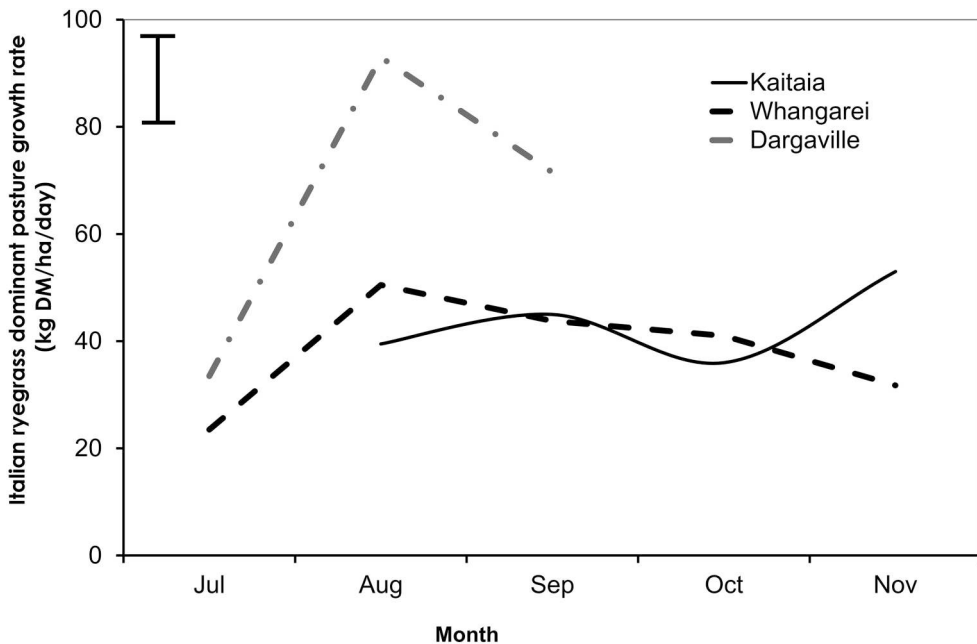


Figure 3. Mean monthly growth rate (kg DM/ha/d) of Italian ryegrass dominant pastures in Kaitaia, Whangarei and Dargaville. The error bar represents the pooled (sites x year) mean standard deviation. Figure generated from 1 published dataset (Wynn et al., 2011, <https://www.agyields.co.nz/dataset/215>) and 1 unpublished dataset (Ussher, G., <https://www.agyields.co.nz/dataset/449>).

A study that compared annual ryegrass, sown into sprayed out pasture, with an existing kikuyu pasture found that the annual ryegrass system provided 1700kg DM/ha more harvested pasture (61%) than kikuyu alone and 52% more liveweight gain per hectare. At the time the additional revenue was \$347/ha (49% more) and after deducting costs of \$290/ha the effective return was \$57/ha or 8% higher than the existing kikuyu pasture (Beef Profit from Pasture Group 2017a).

At Whangarei the work from the Beef Profit from Pasture Group (2017b) compared the performance of annual ryegrass ('Bullet' at 20 kg seed/ha), drilled late March into the existing kikuyu dominant pasture, with the existing pasture (control). Neither area was mulched. The introduction of annual ryegrass increased pasture eaten by 300 kg DM/ha (+5%) and lifted liveweight gain per hectare by 10% (53 kg LWG/ha). At the time the annual ryegrass added extra revenue of \$145/ha (or 15% more). After deducting costs of \$200/ha there was a loss of ~\$55/ha. Through late winter and spring, the annual ryegrass treatment increased pasture cover.

Because beef farms usually operate on slimmer margins than their dairy counterparts it is important that the cost:benefit analysis of a new technology shows significant profitability. The introduction of annual ryegrass into existing kikuyu pastures has shown potential to increase pasture growth and liveweight gain, but additional profit was not guaranteed. This means its use should be assessed based on current prices. The inconsistent financial returns may be one reason it is not widely used in this region. The research group concluded that annual ryegrass may be an appropriate option for farmers who

have already optimised grazing management and are looking to fine tune their production systems (Beef Profit from Pasture Group 2017b).

Cocksfoot

Growth rates of ‘Apanui’ cocksfoot as a dominant pasture grass species were reported from trials at Kaikohe (Lambert et al. 1973). Growth rates increased in late spring and peaked at $\sim 31.3 \pm 8.93$ kg DM/ha/d in December after which they declined (Figure 4). Currently, there are no other Northland growth rate datasets for cocksfoot cultivars in the AgYields database.

The growth rates of cocksfoot ‘Apanui’ dominant pastures in Figure 4 are low compared with other temperate perennial grasses in Northland, e.g. tall fescue (Figure 5) but higher than perennial ryegrass or Italian ryegrass (Supplement 2). Recent studies have shown cocksfoot to be a productive grass in Northland. At Awanui McCahon et al. (2021) found that the average three year (2017/18–2019/20) yield of cocksfoot ‘SF Greenly II’ was 10900 kg DM/ha and at Te Kopuru it was 11800kg DM/ha. Ussher (2021) reported that a third year cocksfoot pasture produced 7840 kg DM/ha and cocksfoot represented 84% of the pasture (average of three sites).

Research in other regions of New Zealand has found cocksfoot to be a more persistent grass than perennial ryegrass in summer dry and lower soil fertility environments (Mills and Moot 2010). In field trials (60 farms) on the east coast of the North Island, ‘Wana’ cocksfoot became the dominant grass (33% of pasture content) except in areas of paddocks with poor drainage (Smith et al. 1993). Cocksfoot had some tolerance to grass grub (*Costelytra zealandica*), although less than tall fescue, phalaris (*Phalaris aquatica*) and lucerne (*Medicago sativa*) (Milne 2011).

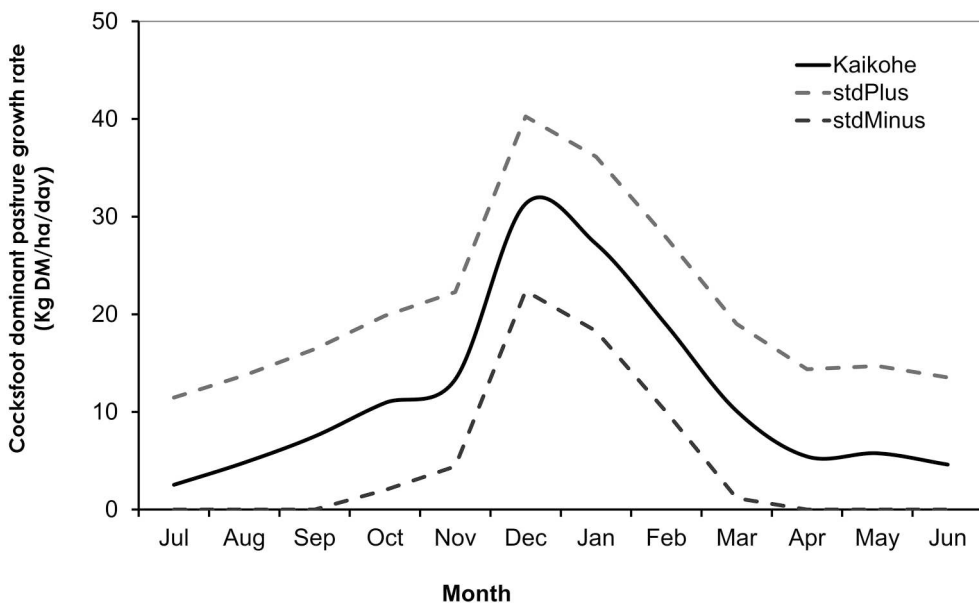


Figure 4. Mean monthly growth rate (kg DM/ha/d) of cocksfoot dominant pastures at Kaikohe. Average ± 1 standard deviation lines (StdPlus, StdMinus) are shown. Figure generated from 1 published dataset (Lambert et al. 1973, <https://www.agyields.co.nz/dataset/248>).

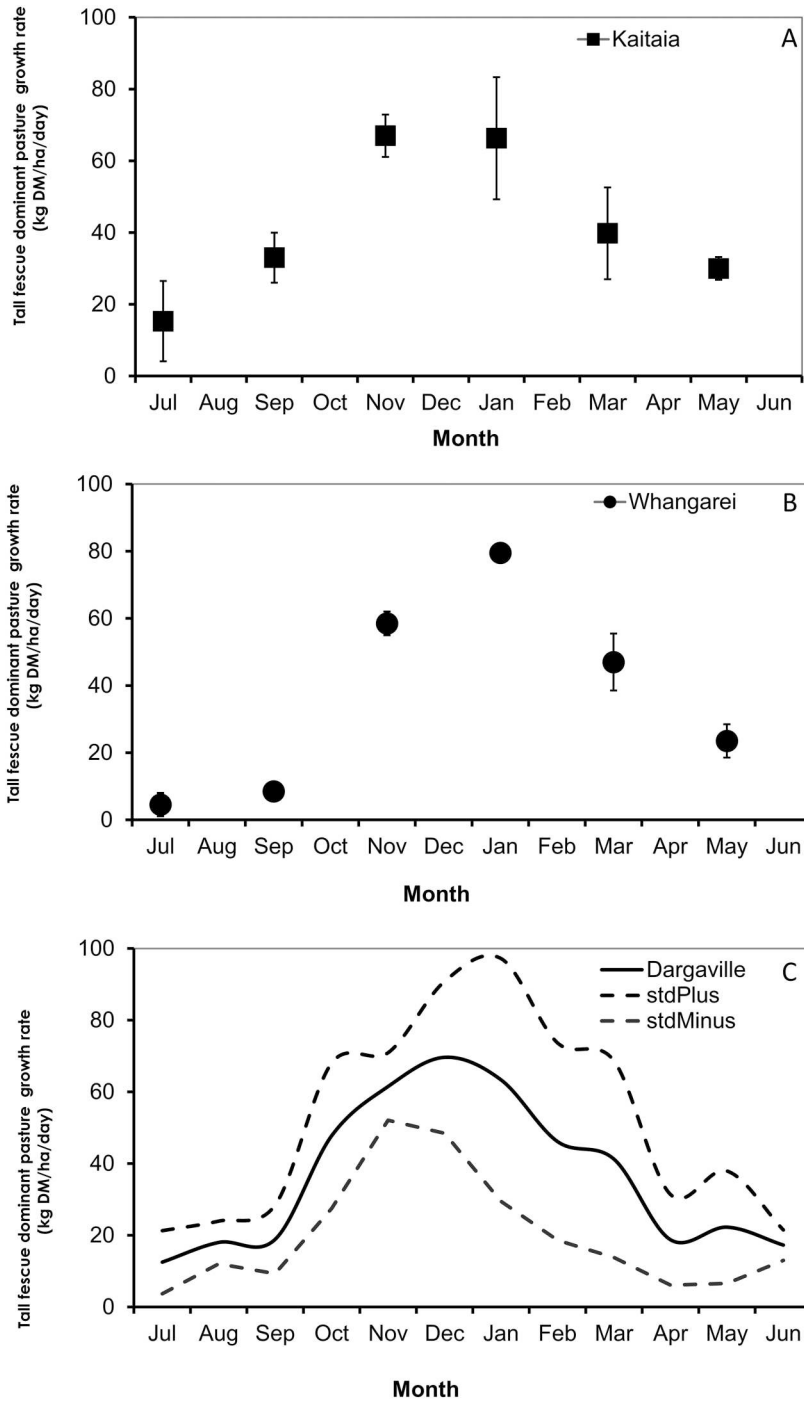


Figure 5. Mean monthly growth rate (kg DM/ha/d) of tall fescue dominant pastures at Kaitaia (A), Whangarei (B), and Dargaville (C). The error bar represents the pooled (sites x year) standard deviation. Kaitaia and Whangarei data for July, September, November, January, March, May months. Figure generated from 1 published dataset (McCahon et al. 2021; <https://www.agyields.co.nz/dataset/154>) and 1 unpublished dataset (Ussher G; <https://www.agyields.co.nz/dataset/377>).

Moot et al. (2008) reported spring (Sept-Nov) WUE (water use efficiency) for a range of dryland monoculture and mixed species pastures in Canterbury. During this period cocksfoot pastures out-performed ryegrass pastures. They concluded that a combination of subterranean and white clovers in cocksfoot based pastures, without perennial ryegrass, was a suitable pasture capable of responding to the environmental variability in summer dry conditions.

McCahon et al. (2021) advocated for the use of a modern cocksfoot as the basis of 'longer-term' Northland pastures in summer-dry areas, supported by small-seed species such as chicory, plantain (*Plantago lanceolata*), Persian (*T. resupinatum*), red (*T. pratense*) and white clovers. These results suggested there is a need for targeted research to refine the most appropriate combinations of grasses and legumes for this unique environment. Over time cocksfoot swards can become grass dominant, which may reduce nitrogen cycling and palatability. Therefore, assessment of its yield response to N fertiliser is also recommended in this environment.

Tall fescue

Tall fescue dominant pasture data were available from Kaitaia, Whangarei and Dargaville but not Kaikohe. Tall fescue dominant pasture growth rates increased from early spring at Kaitaia and from late spring at Dargaville and Whangarei. Overall mean growth rates were 55 ± 23.9 kg DM/ha/d from November to March and 15.0 ± 7.64 kg DM/ha/d during the three months of winter.

The average three year (2017/18 to 2019/20) yield of 'Hummer' tall fescue-'Mainstay' white clover pastures at Awanui was 10300 kg DM/ha and at Te Kopuru was 11000 kg DM/ha (McCahon et al. 2021). Across three sites, McCahon et al. (2021) reported that tall fescue yield averaged 7600 kg DM/ha in its third year after sowing and represented 83% of the pasture. Under climatic and insect pressure, tall fescue is known for its resilience and advantages over perennial ryegrass (Popay and Thom 2009; Thom et al. 2014). In the 2011 survey of farms in Northland (from Dargaville to Kaitaia), pastures averaged six years of age and were predominately dairy operations with high soil fertility (e.g. Olsen P of 43). These showed 84% of endophyte-infected tall fescue tillers and all the tillers typed for endophyte strain confirmed the presence of the sown MaxP strain (Ussher and Hume 2015). None of the tillers had the wild-type strain of tall fescue endophyte which can be toxic to livestock. These pastures also had low levels of weed species. These results contrast to the poor persistence of tall fescue (Hume et al. 2009) reported at Omapere Station, Kaikohe (Usher 2021), where it lacked endophyte and was grown in a paddock with declining soil fertility. In the environments covered by these localities, and given equivalent soil types and fertility, the presence of ryegrass is less than 50% of pasture composition 5–8 years after sowing. This makes tall fescue with a selected endophyte a preferred species to sow (Ussher and Hume 2015). Persistence of tall fescue in New Zealand is usually a function of fertility and grazing management. Easton et al. (1994) noted that established tall fescue needed careful grazing management to avoid it becoming rank and losing quality. It requires more frequent grazing than perennial ryegrass which means as short as a 15-day rotation in spring to maintain quality. They noted that early-heading cultivars needed hard grazing in early-mid spring when farmers were reluctant to 'push their animals hard'.

There were no reports of the use of Mediterranean type tall fescues which reportedly have more tolerance to moisture stress. Summer dormancy in Mediterranean tall fescue lines is controlled by high temperatures and long days (Easton et al. 1994) and may become more appropriate if extended periods of summer dry continue to occur in Northland. The dormancy is an evolutionary mechanism that some tall fescue plants developed to avoid heat and dry periods in summertime (Missaoui et al. 2017). It may be an asset for this region in the future, given that winter growth can be expected to be higher than measured in the rest of New Zealand, due to warmer winter temperatures. Mediterranean type tall fescues however, are not easily used with a novel endophyte due to unclear toxicity issues with horses (Munday et al. 2017).

Kikuyu

There were no growth rate records for kikuyu as a dominant pasture in the Kaikohe datasets (Figure 6). At Kaitaia, kikuyu mean growth rate was 34.3 ± 3.50 kg DM/ha/d in late spring-summer (from October to February) and peaked at 45.9 ± 15.3 kg DM/ha/d in April. At Whangarei growth rates peaked in November at 62.0 ± 20.43 kg DM/ha/d and dropped to 27.2 ± 9.32 kg DM/ha/d during the winter months. Seasonal kikuyu growth rates from August to April averaged 32.1 ± 5.37 kg DM/ha/d in Dargaville. Across the sites, the growth rate data indicates higher spring/summer/autumn growth of kikuyu compared with the winter months, as expected from a C4 grass species.

Goold (1979) measured the effect of cutting intervals (2, 4, or 6 weeks) and rates of N (rates 0–480 kg N/ha/year) on kikuyu-dominant pastures in Kaitaia and Dargaville, and quantified the effect of temperature on seasonal DM production. The results showed that from April to July monthly pasture growth rates over all sites were positively correlated ($P < 0.001$) with temperature. For every 1°C decline in daily grass minimum temperature pasture production decreased by 3.4 ± 0.4 kg DM/ha/d. Pasture cuts every 6 weeks, compared with 2 weeks, were higher yielding by 50–70% (no N and N applied, respectively).

Piggot (1988) found that the growth-rates of a kikuyu-based pasture in Dargaville peaked at ~ 120 kg DM/ha/d in the late spring-summer period and declined to 30.4 ± 11.1 kg DM/ha/d from late autumn to early spring. The botanical composition of the pastures changed seasonally with the percentage DM of ryegrass and other grasses being highest during the winter and spring while kikuyu dominated in the summer and autumn (Figure 7). Kikuyu dominates because it is drought tolerant and creates a dense mat of stolons that out-competes other pasture species for sunlight (Ministry of Agriculture and Forestry 2010). Well managed kikuyu pastures can have 5–10% of dry matter as kikuyu in late winter/spring, but as much as 90% in autumn (Copland 2009). Application of gibberellic acid and fertiliser can be used to promote the growth of kikuyu in late winter and spring (Percival 1980). This is reflected in the peaks in Figure 6 which are not present in Figure 7 (no N or plant hormone treatments).

Historically there has been a strong emphasis on the management of kikuyu by groups such as the Northland Kikuyu Action Group. They produced newsletters in the 2000s for the farming community. Kikuyu management treatments (control, mowing, mulching, or hard grazing) were applied to farmlets on a property in Taipa (Far North) from mid-April (Beef Profit from Pasture Group 2017c). Once the bulls started grazing (12th May), all systems received the same management (i.e. the same initial stocking

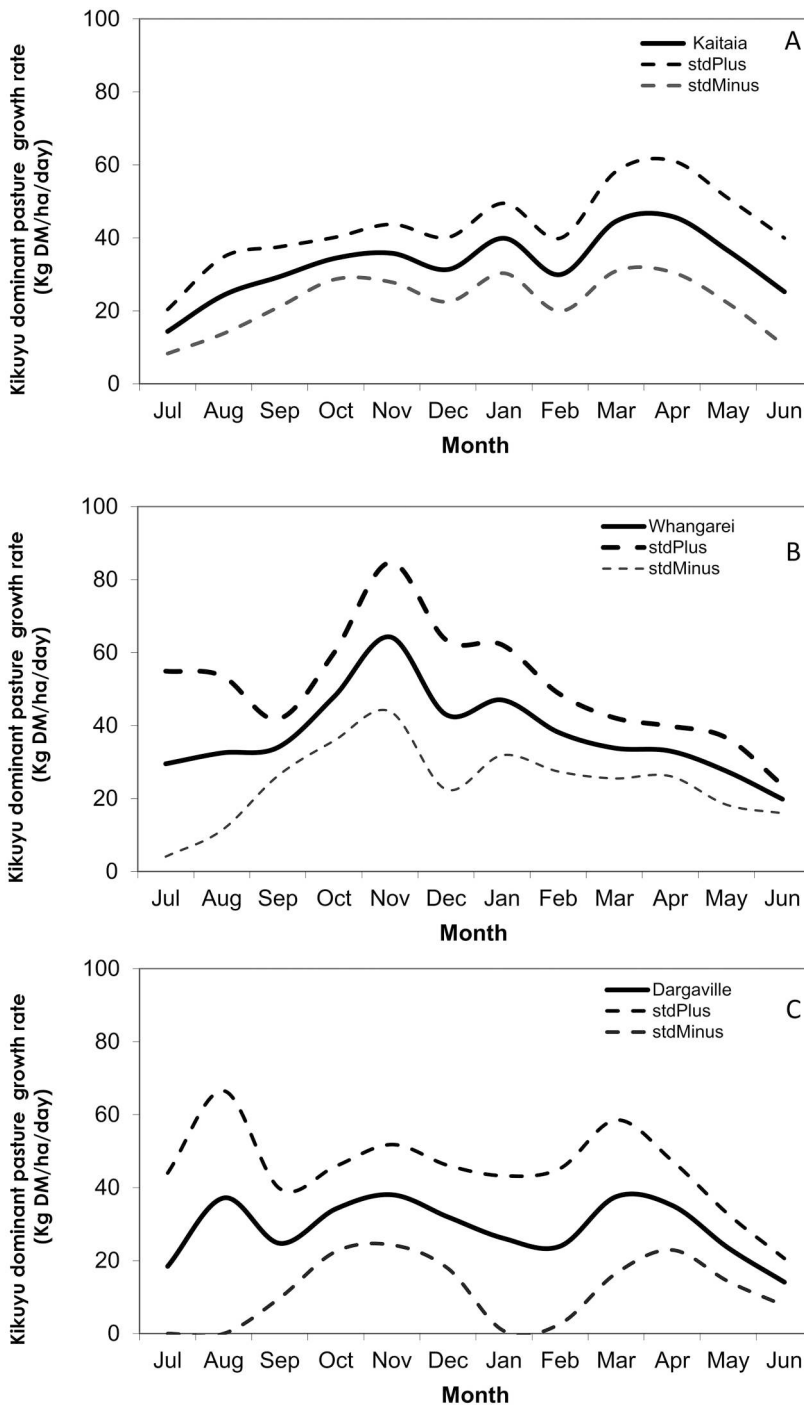


Figure 6. Mean monthly growth rate (kg DM/ha/d) of kikuyu dominant pastures at Kaitaia (A), Whangarei (B), and Dargaville (C). The error bar represents the pooled (sites x year) mean standard deviation. Figure generated from 6 published datasets including Piggot and Morgan (1987) and 4 unpublished datasets (<https://www.agyields.co.nz>, see Supplement 1 for details).

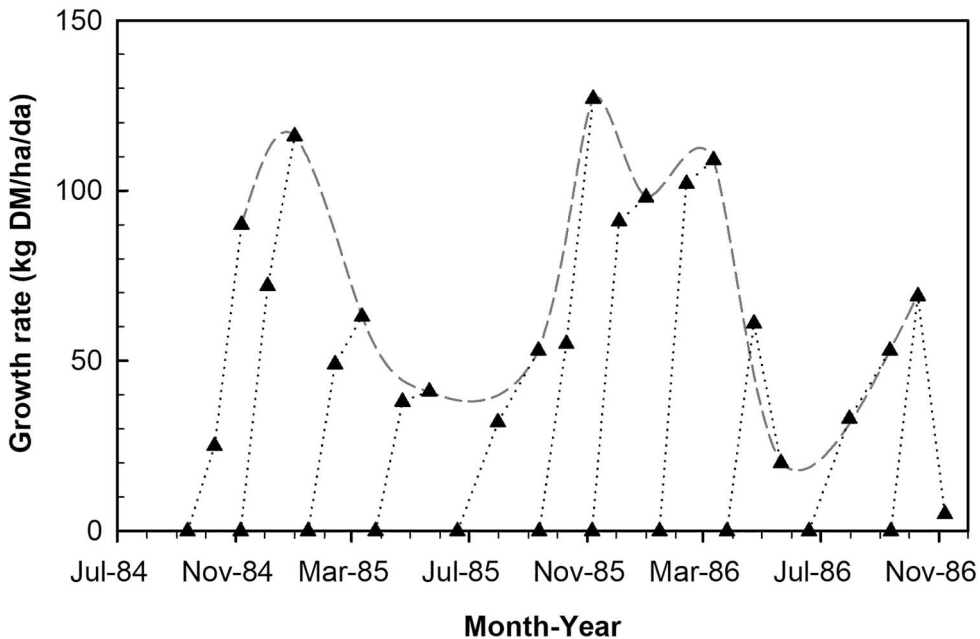


Figure 7. Growth rates of a kikuyu based pasture at Dargaville (no nitrogen treatments). Data digitised from Figure 2 in Piggot (1988). Cages placed 5 times per year and herbage cut twice afterwards. Spline curve based on Cut 2 data to highlight the seasonal growth pattern.

rate, rotation length, shift frequency and nitrogen). At the time, after deducting practice costs, the hard grazing practice and mulching provided a similar net benefit of ~\$160/ha (40% more) and the mown treatment ~\$240/ha (60% more) compared with the control. This demonstration indicated that, for many beef farmers, mowing could be a practical and cost-effective option that compares well with mulching. Hard grazing with breeding cows made around half the production benefit of a mechanical control. However the lower cost makes it an effective control option for areas where mechanical control is impractical because of topography or soil type. The hard grazing is most effective alongside other options (such as mechanical control) on areas where winter and spring pasture growth and quality will be most beneficial (Beef Profit from Pasture Group 2017c).

Copland (2009) reported that on a north-east (NE) facing aspect of a hill paddock kikuyu had been growing vigorously for 30 years but was not present on the south-easterly (SE) aspect of the same paddock. The implication is that the colder SE aspect restricted kikuyu growth in winter.

Yield improvement from kikuyu based pastures

According to Betteridge and Haynes (1986), established temperate grass species can markedly improve both annual and seasonal yields from kikuyu-based pastures. This can be accomplished by:

- i removing the dense kikuyu mat prior to sowing and in each autumn by mob stocking or mechanical means to allow temperate species room to express their winter growth potential;

- ii further suppressing kikuyu with herbicide especially if seed is oversown or if drilled in early autumn, and;
- iii introducing vigorous, temperate, perennial grasses such as ‘Matua’ Prairie grass or ‘Nui’ perennial ryegrass.

Paspalum

Paspalum is a perennial tropical C4 grass. Whangarei was the only location for which data were available for paspalum as a dominant pasture grass species. There, growth rates increased from 14.8 ± 7.70 kg DM/ha/d to 85.6 ± 3.54 kg DM/ha/d from September to December (Figure 8). Growth rates then declined steadily to 14.1 ± 1.70 kg DM/ha/d in March.

A farm survey by Percival (1977) showed that the ability for paspalum to produce herbage during summer was the characteristic considered most desirable. The exclusion of other pasture components by becoming sod-bound was the most undesirable feature. Reports indicated that sod-bound paspalum pastures have been a problem since the 1930s because of inadequate plant nutrition and low pasture use during its growing season. As a constituent of mixed pastures, optimising the use of paspalum requires skilled management to control its vigorous summer growth (Allo 1953). Paspalum has been ‘knocked around’ by black beetle which was the main reason to cease paspalum breeding programme. It has not returned to the dominant levels seen in the 1960s (Copland 2009).

Lambert et al. (1979) suggested that intensive grazing by sheep may have been a factor contributing to the poor paspalum performance in their research. This was based on earlier research that found paspalum production under sheep grazing was much less than under mowing (Lambert 1967).

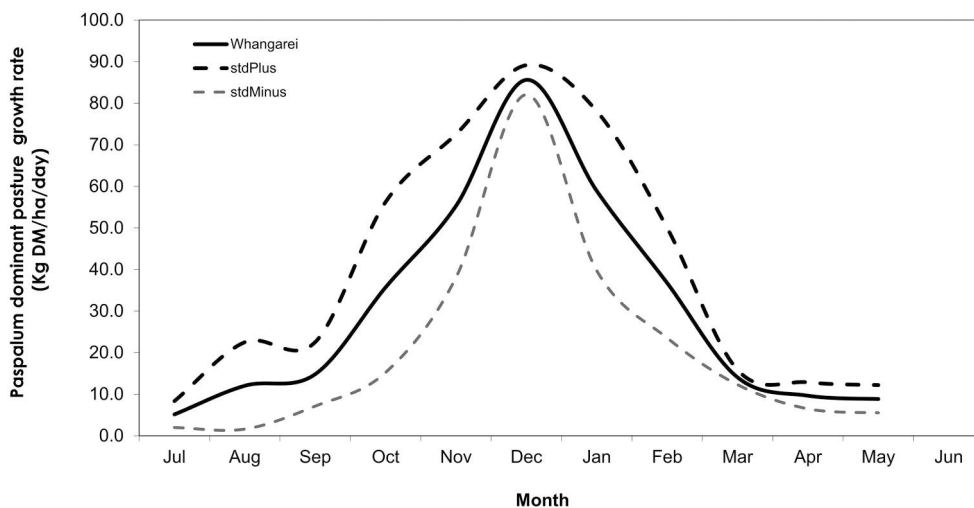


Figure 8. Mean monthly growth rate (kg DM/ha/d) of paspalum dominant pastures at Whangarei. Average ± 1 standard deviation lines (StdPlus, StdMinus) are shown Figure generated from Piggot (1984), <https://www.agyields.co.nz/dataset/223>.

Prairie grass

Betteridge and Haynes (1986) suggested that 'Matua' Prairie grass was a vigorous, temperate, perennial grass that could be established in kikuyu-based pastures to improve both annual and seasonal production. In their 'Annual vs Perennial grasses' trial, 'Tama' annual ryegrass, 'Nui' perennial ryegrass, and 'Matua' prairie grass were direct drilled or oversown (rates of 22, 15 or 40 kg seed/ha respectively) in April into resident kikuyu dominant (95%) pastures on three dairy farms near Kaikohe. Prior to establishment, the resident pasture had been hard grazed, or forage harvested. The 'Matua' pasture grew at 59.6 ± 6.02 kg DM/ha/d from spring to autumn and peaked at 65 kg DM/ha/d in summer. Winter growth rates were 16 kg DM/ha/d and higher ($P < 0.05$) than the 9 kg DM/ha/d of the resident pasture. The authors concluded that the sown grasses moved the pasture production pattern closer to the feed requirements of spring-calving cows. They noted that the mowing regime used kept the kikuyu under control so that it did not smother the sown grasses, which may not happen in a warm wet autumn under grazing.

Ussher (1986) reported that a 'Pawera' red clover – 'Matua' prairie grass pasture sown in the autumn of 1984, yielded 14,000 kg DM/ha during its first summer (November 1984 to March 1985), with 80% being red clover, and this exceeded the 12-month production of 12,000 kg/ha from the kikuyu based pastures. The extra 132 kg milkfat/ha from the 'Pawera' – 'Matua' pasture easily covered the costs of its establishment.

Other tropical grasses

Data for the tropical perennial Bermuda grass, South African pigeon grass and Limpo grass have also been included in the AgYields database.

Bermuda grass

The only data for Bermuda grass dominant pastures was from Kaitaia. Davies and Hunt (1983) found that the growth rates of a Bermuda grass-pasture mixture in the second year at Kaitaia increased from 15.6 ± 0.80 kg DM/ha/d in late winter and peaked in early January at 54.5 ± 1.51 kg DM/ha/d. Of this, Bermuda grass was 24.0 ± 4.50 kg DM/ha/d of the growth from summer to autumn but was not present during the winter/early spring when pasture growth was reliant on the ryegrass/clover components. Bermuda grass did not persist past the second year.

South African pigeon grass

Lambert et al. (1973) studied four lines of South African pigeon grass with cocksfoot and ryegrass between 1967 and 1969 at two sites in Kaikohe – one with mild frosts and the other heavy frosts. The highest growth rates were recorded during summer months: an average of 15 ± 7.9 kg DM/ha/d and the maximum recorded value of 50.1 ± 4.21 kg DM/ha/d. Growth was negligible, < 1 kg DM/ha/d, during winter and early spring. In Year 2, average South African pigeon grass yield at the mild frost site was twice that of the heavy frost site (3700 vs. 1685 kg DM/ha from June 1968 to August 1969). At the mild site, the highest yielding South African pigeon grass line 'CPI 32930' produced ~7400 kg DM/ha. During this same period cocksfoot yielded ~5950 kg and ryegrass ~4850 kg DM/ha across the two sites. Compared with other grasses, South African pigeon grass had relatively low growth rates.

Davies and Hunt (1983) reported that South African pigeon grass cultivar 'du Toits Kraal' (Table 2) growing in a mown mixed sward with ryegrass and clover at Kaitaia, produced ~8000 kg DM/ha in the first year, 2800 kg in Year 2, but was not present in the mixed pasture in Year 3. The total mixed pasture production for those years was ~14000 kg DM/ha.

Limpo grass

The tropical perennial limpo grass was identified by Davies and Hunt (1983) as a persistent grass that grew well in a mixed pasture with ryegrass and clover in Kaitaia. In the second year, growth rates of 'Bigalta' limpo grass were highest between December and February (43 ± 11.51 kg DM/ha/d) and represented 55–75% of the pasture growth during this period. However, limpo grass growth rates in winter were negligible. Across the three years of their study, limpo grass yield declined from ~11000 to ~5500 kg DM/ha/yr while pasture total yield went from 17000 to 12000 kg DM/ha/yr. Of interest, clover content in Year 3 was ~2500 kg DM/ha and ryegrass ~1700 kg DM/ha.

Woods et al. (1996) revisited historic plantings of 'Bigalta' limpo grass and found that it had not persisted under normal pasture management practices except at one frost-free site. After their own investigations of eight limpo grass accessions at four sites (Kaitaia, Dargaville, Hamilton and Te Puke) they concluded that when in a mixed pasture it was best when grown as standing feed banks for *in situ* feeding of cattle during summer or for hay. They recommended further work be carried out on the 'Floralta' cultivar and the management techniques required to optimise production.

Rumball (1989) grew three lines of limpo grass in a mix with ryegrass and white clover (*Trifolium repens*) at Kaikohe. He found that 'Floralta' had similar yield (12500 kg DM/ha) yield as Bigalta (12800 kg DM/ha) but 'Floralta' was more persistent and had a 13% warm season advantage over 'Bigalta' where no N fertiliser was applied, and soil water was limited. The yield of both cultivars was very responsive to N addition (300 kg/ha/yr). The establishment of limpo grass in the experiments was by transplanting stolons (Rumball 1989) or glasshouse-raised plants which is impractical commercially. Therefore authors (Davies and Hunt 1983; Woods et al. 1996) reported the need to identify methods of vegetative establishment for limpo grass and, presumably, other potential tropical grasses.

Practical insights and future research

A summary of the results of experiments performed within the main pasture grasses in Northland is presented in Supplement 2. The dominant grass studied in Northland has been perennial ryegrass. It is the least resilient of the common temperate species to summer dry conditions and overgrazing. It seems likely that a long duration of summer dry leads to early grazing before plant reserves have been restored (Davies and Thomas 1983; Mills et al. 2008; Moot 2023). The impact of this on perennial ryegrass may not be apparent after a single event but over grazing will lead to greater vulnerability to pests (Popay and Thom 2009; Donaghy et al. 2021). Lower pasture production leads to less stock production that reduces farm income that may restrict fertiliser applications which, over time, further reduces pasture production. The result is an ongoing cycle of decline that becomes insidious.

The medium-term prospect suggests a necessity to evaluate more cocksfoot and tall fescue-based pastures to replace perennial ryegrass. In addition, improved grazing management practices, such as increasing the spelling period under drier conditions and keeping the grazing residual above 1500 kg DM/ha, need to be considered. This may require the strategic use of conserved feed and require farmers to adjust the grazing management to accommodate cocksfoot and tall fescue without compromising pasture quality. In a follow up article, the role of legumes and herbs on pasture production in Northland will be explored because legumes can fix the N required to maximise grass growth and palatability.

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ORCID

Carmen S. P. Teixeira  <http://orcid.org/0000-0003-0606-8666>
Sonya T. Olykan  <http://orcid.org/0000-0002-7482-8455>
Derrick J. Moot  <http://orcid.org/0000-0002-5691-4915>

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