Can pasture persistence be improved through the use of non-ryegrass species?

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Summary
Recent discussion about pasture persistence concentrates on pastures based on perennial ryegrass, the most commonly used grass species. This paper raises the question as to whether some of the causes of poor pasture persistence are due to perennial ryegrass being used in environments to which it is not suited. The adaptation to environmental stresses, particularly water, temperature and nutrient deficiencies, in different regions of New Zealand of tall fescue, cocksfoot, phalaris, and lucerne are discussed, and how this impacts on persistence advantages over perennial ryegrass.
Keywords: persistence, pasture, *Dactylis glomerata*, *Festuca arundinacea*, *Lolium perenne*, *Medicago sativa*, *Phalaris aquatica*

Introduction
Persistence of pasture has been an issue for many years. Often when this topic is discussed, emphasis is placed on the persistence of perennial ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*)-based pastures as these are the most commonly used species. It is important however to remember that there are other species that can be used instead of perennial ryegrass, and that these may offer solutions to pasture persistence in environments where our two main pasture species are currently failing to survive and produce.

Adaptation of grass species
Regional variation
One of the reasons for poor persistence of ryegrass pastures is that it is not adapted to some of the environmental conditions in which it is being used (Table 1). Perennial ryegrass is recognised as being a plant suited to climates with mild summer and winter temperatures, regular rainfall and few drought periods, good soil fertility, and low insect pressure. A good example of where these conditions exist is the Southland plains, with an average annual rainfall of 1037 mm, mean summer (Dec-Feb) temperature and monthly rainfall of 13.7°C and 85 mm, and rainfall/evaporation ratio (P/PE) of 1.69. Insect pressure is also lower than other regions, but porina (*Wiseana cervinata*) affects ryegrass persistence in some districts of Southland. In this region, perennial pastures can persist for more than 10 years without endophyte infection, when appropriate management practices are employed. Other regions where ryegrass has persisted well (excluding some micro-environments) include Taranaki, Wanganui, Manawatu, King Country, irrigated Canterbury plains, west coast of the South Island, and south Otago.

Regions which are not conducive for ryegrass to persist without seedling recruitment include; Northland, Waikato, Bay of Plenty, Gisborne, Hawkes Bay, Wairarapa, Marlborough, Nelson, dryland Canterbury, north and central Otago. The factors that affect ryegrass persistence vary between regions. In dryland Canterbury the main factor is the lack of rainfall (612 mm annual precipitation) relative to summer temperatures (17.3°C mean summer temperature) and evapotranspiration (P/PE of 0.92), combined with insect damage from Argentine stem weevil (*Listronotus bonariensis)* (ASW) and grass grub (*Costelytra zealandica*). The long-term climate data for the Waikato region (1214 mm annual rainfall, 18.6°C mean summer temperature, and P/PE of 1.76) would suggest ryegrass is suited, however in the period 2006 to 2010 many ryegrass pastures failed to persist due to drier-than-normal summers, greater insect pressure (e.g. from black beetle (*Heteronychus arator)*), and the previous use of novel endophytes which provided inadequate insect protection.

Where perennial ryegrass pastures have survived well in unsuited regions like Hawkes Bay, many of the plants may have been established from buried seed (volunteer ryegrass) rather than survived from sowing (Daly *et al.* 1999). This means that the persistence of sown ryegrass plants may be less than it appears, with pastures reverting to ryegrass plants with different characteristics and usually containing toxic standard endophyte.

Insects
Several insects affect perennial ryegrass (Table 2). Hardwick (2004) found that populations of these pests can build rapidly within 1 to 2 years after planting, and they are therefore considered to be a major reason for the decline in production and density of perennial ryegrass over several years.

Ryegrass endophyte can provide protection against some insects including ASW, pasture mealy bug (*Balanococcus poae*), black beetle, root aphid (*Aploneura lentisci*) and porina (Table 2), however, they often do not protect against all life stages, nor all insect species, meaning that endophyte-infected pastures can sometimes incur damage (e.g. NEA2 endophyte provides moderate control of ASW larvae, but not adults (Agricom 2011)). Additionally, there is no ryegrass endophyte currently available that provides protection from black beetle larvae, or grass grub.

Other grass species are often tolerant (e.g. tall fescue) or resistant (e.g. phalaris) to a wider range of insects, and insect growth stages (Table 2). Phalaris has resistance to grass grub larvae (East *et al*. 1979) as measured by the effect of reducing grass grub populations relative to perennial ryegrass (Stevens *et al.* 1989). Tall fescue is tolerant of (but not resistant to) grass grub, with production not affected despite high grass grub larvae numbers (East *et al.* 1979).

Drought

As the duration and severity of a period of water stress develops, ryegrass growth slows, tiller density declines due to tiller formation stopping (Korte and Chu 1983), and plant growth eventually ceases and plants die. Even when plants are not killed directly by moisture stress, pastures often fail to recover due to a decreased ability to tolerate seasonal insect attack, or by weeds (e.g. *Poa annua*, annual thistles etc.) invading the bare ground created between surviving clumps of grass (Rumball and Grant 1972).

Species which have shown better survival after exposure to periodic drought conditions than perennial ryegrass and white clover include; cocksfoot (*Dactylis glomerata*), phalaris (*Phalaris aquatica*), tall fescue (*Festuca arundinacea* Schreb., *Lolium arundinacea*), brome species, lucerne (*Medicago sativa*), chicory (*Cichorium intybus*), plantain (*Plantago lancelota*), subterranean clover (*T. subterraneum*), and strawberry clover (*T. fragiferum*). This is apparently achieved using several mechanisms including; deeper roots (e.g. lucerne, chicory, tall fescue), increased root thickness and mass (e.g. tall fescue, cocksfoot), reduction in transpiration rate (e.g. tall fescue), annual re-seeding in spring (e.g. subterranean clover), and summer dormancy (e.g. Mediterranean tall fescue).

"Ryegrass pulling" in autumn can cause a decline in ryegrass content of pastures (Thom *et al.* 1996). The greater rate of root death relative to root growth over summer causes a net loss of functioning roots, resulting in a shallower and weaker root system (Garwood 1967). This can also be exacerbated by root-feeding insects (e.g. black beetle, root aphid, grass grub) and soil type. While there are some variations between cultivars of perennial ryegrass (Thom *et al.* 1996), plant pulling is less evident in other species like tall fescue, where the larger and deeper roots (Nie *et al.* 2008) present in autumn eliminate grass pulling.

Temperatures

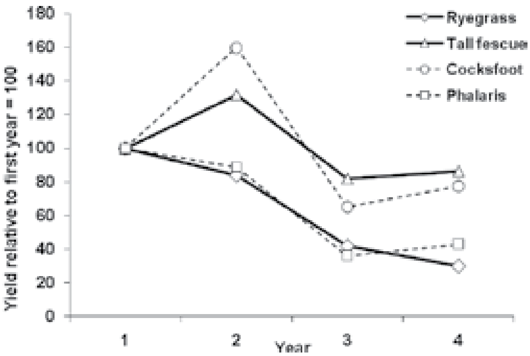
High summer and warm winter temperatures favour tropical (C4) grasses (e.g. kikuyu (*Pennisetum clandestinum*)) more than temperate (C3) grasses (e.g. perennial ryegrass). The optimum ambient air temperature for ryegrass is 18°C, with growth suffering when daytime temperatures exceed 31°C, and 25°C at night (Thorogood 2003), whereas other C3 grasses

Table 1. Reasons for poor adaptation of perennial ryegrass in regions of New Zealand (an interpretation by the author based on trial data and personal experience).

Region(s)	Reasons for poor adaptation of perennial ryegrass	Species that have better adaptation
Northland, Waikato and Bay of Plenty	High summer temperatures	TF, L
	Insects (BB, ASW, RA, PMB)	C, TFe+, P, L
	Occasional drought	C, TF, P, L
	Occasional wet winters/springs	TF
Gisborne, Hawkes Bay, Wairarapa	Frequent droughts	C, TF, P, L
	High summer temperatures	TF, L
	Insects (ASW, GG, RA, PMB, P)	C, TFe+, P, L
	Occasional wet winters/springs	TF
Nelson	Occasional drought	C, TF, P, L
	Insects (ASW, GG, RA, PMB)	C, TFe+, P, L
	Occasional wet winters/springs	TF
Marlborough, dryland Canterbury, north and central Otago	Frequent droughts	C, TF, P, L
	Low soil fertility	C
	Insects (ASW, GG, RA, PMB, P)	C, TFe+, P, L
	Cold winters	TF, L[1]

Tall fescue (TF), cocksfoot (C), tall fescue with endophyte (TFe+), phalaris (P), lucerne (L),
Argentine stem weevil (ASW), black beetle (BB), grass grub (GG), pasture mealy bug (PMB), porina (P), root aphid (RA).
[1] Depends of winter activity on different cultivars.

Figure 1. Pasture production of four grass species over 4 years, relative to the yield in the first year of each species (Johnson *et al.* 1994).



actively grow at higher temperatures (e.g. the optimum temperature for tall fescue is 25°C (Robson 1973)), allowing them to dominate multi-species swards over time.

Soil fertility

Pasture persistence can be affected by the availability of soil nutrients. Perennial ryegrass has a requirement for high soil fertility relative to some weedy and naturalised grass species (e.g. browntop), so when nutrients are limiting, these weeds have a competitive advantage. Over time, this leads to a dominance of weeds, and this can be an indicator of poor pasture persistence. Other grass species like cocksfoot have a reputation of being more tolerant of lower soil fertility, and being able to compete better with weeds, resulting in better persistence (Smith *et al.* 1998). Production of cocksfoot however, is still responsive to increasing soil fertility (Smith *et al.* 1998).

Some alternative grasses to ryegrass have a similar or higher requirement for soil fertility (e.g. tall fescue and prairie grass), so in low fertility soils these may offer no advantage in persistence associated with soil fertility. Keys *et al.* (1996) found the persistence of tall fescue during droughts was greater with higher superphosphate fertiliser applications.

In low rainfall climates (450-600 mm/yr) it has been observed that drought-tolerant grasses with a requirement for high soil fertility, such as tall fescue, have persisted well (> 10 years), but farmers have reported that production and palatability often declines after 2-4 years. It is hypothesised that this may be due to the decline in white clover growth and content after the first 2-3 years, causing a deficiency in N for the grass. Without the use of N fertiliser, the best solutions to this may be to use companion legumes at planting that are more persistent in dryland climates (e.g. lucerne), or to introduce annual legumes (e.g. subterranean clover) (Ates *et al.* 2010) to swards that have little clover content.

Summary of major alternative species

Some alternative pasture species have roles on New Zealand farms, but have not been discussed in this paper as they do not offer persistence advantages over perennial ryegrass, and these include; chicory, plantain, prairie grass (*Bromus willdenowii*), and other brome species.

Tall fescue

Tall fescue (endophyte-free) had superior persistence relative to perennial ryegrass (with endophyte) in a grazed trial (Figure 1) (Johnson *et al.* 1994; Judd *et al.* 1990; Hainsworth *et al.* 1991; Fraser 1994). By the fourth year, tall fescue yield was 86% of its first year

Table 2. Insect tolerance of commonly used grass species. Ryegrass information sourced from the endophyte insect control tables compiled by AgResearch, Agricom, Grasslanz and PGG Wrightson (Agricom 2011), ratings for other species compiled by the author based on several papers and reviewed by Alison Popay, AgResearch.

Species	Endophyte	Argentine stem weevil	Pasture mealy bug	Black beetle (larvae)	Black beetle (adults)	Root aphid	Grass grub	Porina
Perennial ryegrass	Nil	-	-	-	-	-	-	-
Perennial ryegrass	AR1	◆◆◆◆	◆◆◆◆	-	◆	-	-	-
Perennial ryegrass	AR37	◆◆◆◆	◆◆◆◆	-	◆◆◆	◆◆◆◆	-	(◆◆◆)
Perennial ryegrass (tetraploid)	Endo 5	◆◆	◆◆◆◆	-	◆◆◆	(◆)	-	(◆)
Perennial ryegrass (tetraploid)	NEA2	◆◆	(◆◆◆◆)	-	◆◆◆	(◆)	-	NT
Tall fescue	Nil	◆◆		◆◆	-	-	◆◆◆	◆◆◆
Tall fescue	MaxP	◆◆◆◆	◆◆◆◆	◆◆◆	◆◆◆◆	◆◆◆◆	◆◆◆	◆◆◆
Phalaris		◆◆◆◆	NT	◆◆◆	◆◆◆◆	NT	◆◆◆◆	◆◆◆
Cocksfoot		◆◆◆◆	NT	◆◆	-	NT	◆◆	◆◆

- No control; ◆ Low level control; ◆◆ Moderate control; ◆◆◆ Good control; ◆◆◆◆ Better than good control; ( ) Provisional result.

whereas perennial ryegrass was 30%. In Canterbury under irrigation, perennial ryegrass is considered a persistent species, yet unpublished data indicated tall fescue had improved persistence (T. Knight, pers. comm.), yield and water use efficiency.

Tall fescue had good tolerance to grass grub (production unaffected despite high grass grub numbers), with good persistence even when they were present (Kain 1979; Fraser 1994; McCullum *et al*. 1990). The novel endophyte (MaxP) improved the persistence of tall fescue (Hume *et al*. 2009). This endophyte provided the plant with greater tolerance to ASW, black beetle, and root aphid (*Aploneura lentisci*) than endophyte-free tall fescue (Popay *et al*. 2005).

A mechanism tall fescue has for persistence is the development of rhizomes to allow the plant to expand in a sward (Brock *et al*. 1997). This occurs from the third autumn/winter after an autumn establishment, and can be enhanced with less frequent rotational grazing (grazing at the four-leaf stage rather than two-leaf) and N application in autumn.

Tall fescue has greater annual water use efficiency than ryegrass (Smeal *et al*. 2005), and minimises water stress through leaf rolling, stomatal closure, and a reduction in transpiration rate (Renard & Francois 1985).

Tall fescue also has greater heat tolerance than perennial ryegrass, able to grow at temperatures up to 35°C and with an optimum of 25°C, and has proven to be the best temperate grass to compete with C4 grasses (Callow *et al.* 2003).

Mediterranean tall fescue cultivars have proven to be persistent in summer-dry climates (J Moir, pers. comm.), and may be more persistent than the standard continental cultivars where soil moisture is severely limiting over summer (e.g. in light soils in Canterbury).

Cocksfoot

Cocksfoot is a more persistent grass than perennial ryegrass in dryland (Mills & Moot 2010) and lower soil fertility (Smith *et al.* 1998) environments. Earlier survey results (Korte *et al.* 1991) indicated that in ryegrass/cocksfoot mixtures, high rates of cocksfoot (>3 kg/ha) in the seed mix had a negative long-term effect on the ryegrass and white clover presence. Cocksfoot had some tolerance to grass grub, although less than tall fescue, phalaris and lucerne, with good persistence even when grubs were present (Kain 1979; Fraser 1994; McCullum *et al*. 1990).

Phalaris

Phalaris has good drought tolerance compared with perennial ryegrass, through its ability to store energy in basal buds during spring, summer dormancy (varies depending on soil moisture), and deep root system (Nie *et al.* 2008). Stevens *et al.* (1989) found it to have greater production than perennial ryegrass in dry hill country sites. It has good insect tolerance, and is the only grass available that has resistance to grass grub. It has not been recommended as the only grass in a sward, as it can have some toxic effects on animals. It has been used successfully with other persistent dryland grasses such as tall fescue and cocksfoot.

Phalaris has been proven to be persistent in most trials which were monitored for 5 years (Stevens *et al.* 1989), even under drought (Robinson 1952) and hard grazing (Hutchinson 1970). Persistence has been less than tall fescue in some trials in south Taranaki (Hainsworth *et al.* 1991), but this may have been due to the trial being conducted in a high summer rainfall climate (1218 mm annual rainfall, 16.7°C mean summer temperature and 1.83 P/PE ratio), which favours summer-active species.

Phalaris has resistance to grass grub, reducing grass grub populations relative to perennial ryegrass (Fraser 1994; McCullum *et al*. 1990; Stevens *et al.* 1989).

Lucerne

Lucerne may not be a species that comes to mind when discussing pasture persistence as it has a limited lifespan. In dryland climates however it often outlasts perennial ryegrass pastures when managed correctly, as well as yielding more and producing more liveweight gain in sheep (Mills & Moot 2010), so deserves consideration.

Lucerne is resistant to grass grub (Kain 1979) and other insects that affect perennial ryegrass, but is affected by different pests and diseases, so cultivar selection needs to be based on the required tolerances. Drought stress is unlikely to affect the persistence on soils where roots have access to subsoil moisture due to its deep root system, provided grazing management is appropriate to the species. Well managed dryland lucerne stands typically persist for 7-10 years, with some surviving longer than this.

Conclusions

Some pastures are not meeting the expectations farmers have for their persistence in many parts of New Zealand. This is partly due to the widespread use of perennial ryegrass, despite this species not being very well suited to some environments. Some other species have better tolerance to these environments and display better persistence. If pasture persistence is required, farmers are wise to firstly consider the species most tolerant of their environment.

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