Plantain (*Plantago lanceolata*) – a potential pasture species

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Abstract

Plantago lanceolata L. is a herb species with a broad distribution in grasslands throughout the temperate world. The leaf is highly palatable to grazing animals, providing a mineral- rich forage. The species is rapid to establish, grows on a wide range of agricultural soils and is tolerant of drought and of many common diseases and pests. Two productive upright cultivars of plantain have been bred, Grasslands Lancelot and the more erect winter active Ceres Tonic. Plantain contains a range of biologically active compounds, often in large quantities. The antimicrobial compounds present can inhibit rumen fermentation and change the volatile fatty acid composition of the rumen. These changes have potential to affect bloat, animal performance and milk composition. The performance of animals grazing plantain has varied from excellent in mixed pastures to poor on nitrogen-fertilised pure swards. Animals grazing plantain have been observed to have a reduced incidence of scouring and dags in some trials, but despite a mild anthelmintic effect detected in the laboratory, field trials have failed to detect any significant reduction in worm burdens. The most likely use of plantain on farms is as a component of mixed pasture swards. Its contribution is likely to be greatest where grass growth is less vigorous and where there are gaps in the sward. These conditions are likely to be found in low fertility dryland pastures. It is unlikely to be the dominant species and could be expected to contribute less than 20% of the sward, except where the grass or legume growth is poor.

Keywords: perennial forage herbs, *Plantago lanceolata*, plantain

Introduction

Plantago lanceolata L., known as narrow leaf plantain or ribgrass, occurs naturally in many pastures and has had a long history of use as a minor forage plant in Europe (Foster 1988). However, modern agriculture has not valued the perennial herb component of pastures. In the last few years, however, the perennial herb chicory (*Cichorium intybus* L.) has been shown to be highly productive and capable of giving excellent animal performance. This has opened up the possibility that other perennial herbs could also be valuable as pasture components.

The ready acceptance of *Plantago lanceolata* by livestock and its widespread and successful adaptation to grassland communities throughout the temperate world makes it an obvious candidate for further study. The development of a productive cultivar of *Plantago lanceolata* was recognised by Dr W. Rumball (pers. comm.) as a prerequisite to using this species in New Zealand agriculture and Grasslands Lancelot was released. The release of a second cultivars, Ceres Tonic, now provides good opportunity to research this species and utilise any benefits it can provide.

The cultivars Grasslands Lancelot and Ceres Tonic

The cultivar Grasslands Lancelot was selected by AgResearch Grasslands from collections from productive North Island pastures. This cultivar was selected for bushy growth habit and the ability to tiller strongly under close sheep grazing (W. Rumball pers. comm.).

The cultivar Ceres Tonic was selected by the author from germplasm believed to have originated from northern Portugal, a region with warmer winters than most of New Zealand. This cultivar was selected for a very erect habit and very large leaves. Tonic remains erect under a wide range of conditions while Lancelot has the plasticity to become prostrate under close grazing.

The two cultivars are quite different in morphology and seasonal productivity, both from one another and from the common flatweed type as follows:

	Grasslands Lancelot	Ceres Tonic	Common flatweed type
growth habit	semi-erect	very-erect	prostrate
leaf size	med-large	very large	small-med
tiller number	high	medium	med-high
winter growth	low	high	very low
summer growth	high	high	low

Establishment of plantain

Plantain emergence is very rapid approaching that of perennial ryegrass (Blom 1978) and faster from autumn sowing than many common grasses (Table 1). Despite this however, the proportion establishing can be limited by strong competition from other species commencing some weeks after sowing (Hildebrandt & Schulz 1987). Successful establishment in mixtures is dependent on reducing competition and is more successful where slower establishing grasses are used (Sagar 1962; Tiley & France 1990).

Soil requirements

Plantain occurs naturally over a wide range of soil acidity (pH 4.2–7.8) (Troelstra & Brouwer 1992) and grows well in soils suited to ryegrass and white clover (Voisin 1960). It is found over a wide range of soil textures and organic matter levels, but not on extremely saline or swampy soils (Sawada *et al.* 1983; Mook *et al.* 1989; Troelstra & Brouwer 1992).

Plantain will tolerate a moderate amount of treading and soil compaction but is considerably less tolerant than perennial ryegrass (Voisin 1960; Chappell *et al.* 1971; Blom 1976; Montacchini & Siniscalco 1979; Noee & Blom 1982) or broad leaf plantain (*Plantago major*).

Soil fertility

In natural grasslands plantain is a common constituent under conditions of low fertility (Klapp 1949; Olff & Bakker 1991) owing to its excellent adaptation to low-nutrient environments (Troelstra & Brouwer 1992). In particular plantain is very common on soils low in phosphorus or potassium (Watson & Nash 1960; Kruijne *et al.* 1967; Hoveland *et al.* 1976).

Plantain is responsive to nitrogen applications, promoting leaf number, shoot growth and total biomass but with a more limited effect on root growth (Lambers *et al.* 1981; Freijsen & Otten 1987; Blacquiere & Koetsier 1988; Hirose *et al.* 1988). However, nitrogen fertiliser applied to mixed grassland swards consistently increases the proportion of grasses and decreases the proportion of plantain and other herbs (Kasper 1976; Romero & Demanet 1989), and phosphorus or potassium fertiliser has little immediate direct effect on the proportion of plantain (Norman 1956; Voison 1960; Kasper 1976).

The competitive ability of plantain with grasses depends greatly on fertility. Where fertility is low plantain can have a competitive advantage over shallow-rooted grasses. Plantain is capable of utilising nutrients from deeper soil layers, and in mixtures plantain has been found to develop a greater proportion of roots at depth than in monocultures. This niche differentiation can provide a yield advantage to mixtures of up to 1.5 times that of the monocultures (Newbery & Newman 1978; Berendse 1981, 1982, 1983; Troelstra & Berendse 1982). Where there is competition for nutrients the surface application of fertiliser favours shallow-rooted grasses over the deeper rooted plantain (Berendse 1982).

However, under high fertility the ability to explore greater soil depth is of little competitive advantage to plantain (Berendse 1981). Under these conditions competition for light becomes of greater importance than nutrient uptake parameters in determining the competitiveness of the species. The leaf morphology of grasses then provides them with a competitive advantage for light over plantain (Stulen *et al.* 1992).

Drought tolerance

Plantain has drought tolerance more akin to cocksfoot than perennial ryegrass (Malden 1924; Ivins 1952; Mook *et al.* 1989) with the proportion increasing in mixed swards during drought (Lambert 1963). Plantain also has considerable summer heat tolerance, as indicated by its distribution in sub-tropical grasslands (Sagar & Harper 1964). The summer yields in Table 1 reflect the drought tolerance.

Pests and diseases

Of the many insects noted on plantain the most important leaf feeders are the weevils, the gallmidges and the flea beetles (Sagar & Harper 1964; de Nooij and Mook 1992). Plantain weevil (*Gymnetron pascuorum* Gyllenhall) has reached very high levels in local seed crops and may require controlling. Plantain has a low acceptability to many slugs and snails (de Nooij & Mook 1992; Hulme 1996), with chemical extracts deterring the slugs *Arion ater*, *Deroceras reticulatum* and *Cepaea nemoralis* but not *Arion rufus* or the snail *Helix pomatia* (Grime *et al.* 1968; Molgaard 1992). A range of nematodes has been recorded on plantain (de Nooij & Mook 1992). Plantain has good tolerance to New Zealand grass grub (*Costelytra zealandica*) and in pastures severely damaged by grass grub it often becomes an important component (Cockayne 1920).

Internationally a wide range of fungal and bacterial diseases has been recorded on plantain (Thornberry & Anderson 1937; de Nooij & Mook 1992). Locally the leaf diseases *Aschochyta* leaf spot, *Phoma* sp. and *Stemphylium* sp. have been noted on older leaves and *Rhizoctonia* sp. Root rot has also been noted on occasional plants in second year seed crops (M. Braithwaite pers. comm.).

Forage productivity

A number of studies have compared the annual and seasonal yield of plantain with other forage species. The results show clearly that under certain conditions plantain can yield up to 20 000 kg/ha per year and is as productive as many of our common grasses or clovers (Milton 1938, 1943; Suckling 1960).

A replicated randomised block trial of Ceres Tonic and Grasslands Lancelot plantain was sown on 10 April 1992 at Ceres Research Station near Christchurch under dryland conditions. Plots were cut when the ryegrass reached approximately 2500–3000 kg/ha, followed by dressings of nitrogen fertiliser. The plantains were compared with a number of well known pasture grasses: Grasslands Nui perennial ryegrass, Grasslands Kara cocksfoot, Grasslands Roa tall fescue, Grasslands Maru phalaris and Grasslands Gala grazing brome.

Table 1 Yields of dryland pure species plots relative to perennial ryegrass (100) over 4 years.

	Establishment period (6 months)	Mean kg/ha		Autumn–Winter Proportion	Summer Yield
Perennial ryegrass (kg/ha)	100	9961		26	100
Yields relative to ryegrass					
Cocksfoot	53	9862	(99)	29	126
Tall Fescue	60	9327	(94)	25	92
Phalaris	46	9254	(93)	35	71
Grazing Brome	57	10759	(108)	36	128
Lancelot plantain	67	7582	(76)	10	105
Tonic plantain	80	8362	(84)	21	107
LSD 5%	18.9	961	(9.6)	4.6	30.1

Despite being pure swards under cutting, these trials provide a good indication of a number of features of plantain (Table 1). Firstly, it is rapid to establish, almost as fast as ryegrass, yielding better than most alternative grasses in the first year under dryland conditions. Second, Lancelot is winter dormant in this environment while Tonic remains active. The height of Tonic plantain was very similar to that of the perennial ryegrass at each cut but the plot density was lower.

Proportion of plantain in older swards

The contribution plantain will make to a sward in the longer term is determined by its ability to compete with the other species present. This depends on the specific conditions prevailing, such as fertility level, grazing management, companion pasture species, and many other factors. Higher proportions of plantain are usually found under low fertility (Klapp 1949; Olff & Bakker 1991); in swards subject to long grazing or cutting intervals rather than continuous grazing (Tamm 1956; Voisin 1960; Elsasser & Kunz 1988); under dryland conditions (Lambert 1963) and in swards containing "less aggressive" and slower-establishing companion species (Tiley & France 1990).

Grasses also have a competitive advantage over plantain owing to their more rapid response following disturbance or management change such as trampling, protection from grazing, fertiliser application and herbicides (Page *et al.* 1985).

The composition of plantain in mixed swards under sheep grazing was determined in a replicated randomised block trial sown in 15 November 1992 by AgResearch at Lincoln. In this trial Grasslands Lancelot was included in a number of mixtures with common grasses, all sown with Grasslands Prestige white clover. The grasses were Grasslands Roa tall fescue, Grasslands Kara cocksfoot, Grasslands Nui perennial ryegrass (endophyte infected), Grasslands Greenstone hybrid ryegrass (endophyte free) and Grasslands Gala grazing brome. In addition, a further four treatments were included, Gala grazing brome with red clover and white clover, Tonic plantain with white clover, Grasslands Puna chicory with Lancelot plantain and white clover and a herbal ley mix consisting of Lancelot plantain, Puna chicory, Gala grazing brome, Kara cocksfoot, Lotus corniculatus, sheeps burnet and red clover. The sward composition was monitored for over 3 years.

After 3 years plantain contributed between 5% and 15% of the sward in mixtures with persistent grasses (Table 2). However, in plots where Greenstone or red clover had failed to persist the plantain contributed over 30% to the sward. Perennial ryegrass was more competitive at establishment than other grasses.

Table 2 Composition of plantain mixtures at 3 months, 1 year and 3 years, under sheep grazing at a dryland site at Lincoln.

Dryland	Plantain	Grasses	Legume	Chicory	Other
Tonic	54, 67, 64		6, 26, 15		40, 7, 21
Lancelot	52, 56, 67		3, 34, 13		45, 10, 20
Roa-Lancelot	47, 37, 7	18, 18, 69	8, 32, 10		27, 13, 14
Kara-Lancelot	46, 34, 5	6, 9, 78	10, 40, 5		38, 17, 12
Gala-Lancelot	31, 23, 9	29, 19, 62	6, 32, 13		34, 26, 16
Gala-Lancelot-RC	28, 18, 36	20, 8, 23	25, 55, 13		27, 19, 18
Greenstone-L	23, 26, 34	46, 17, 26	4, 39, 7		27, 18, 33
Nui-Lancelot	12, 14, 11	51, 25, 65	4, 44, 10		33, 17, 29
Puna-Lancelot	22, 13, 13		10, 32, 13	16, 49, 61	52, 6, 13
Herbal ley	8, 5, 10	27, 12, 37	4, 37, 12	5, 35, 24	56, 11, 17

Similarly, in natural grasslands plantain usually makes up a lower proportion of the sward than the grasses and legumes. It seldom dominates, or contributes more than 20% to the sward except where the grass or legume is non-competitive.

Palatability

In mixed pastures plantain is highly palatable to cattle, sheep, deer and horses, and selectively grazed ahead of most legumes and grasses (Milton 1933, 1943; Ivins 1952; Sagar & Harper 1964; Archer 1971; Clark & Harris 1985; Bhadresa 1987). This can place plantain at risk of overgrazing, since the proportion of plantain leaf remaining in mixed swards after grazing has been found to be extremely low compared with a range of other species (Derrick *et al.* 1993).

Reproductive stems of plantain and older mature leaves, however, are much less palatable than fresh leaf material (Ivins 1952) and, as a result, plantain is often able to reseed in pasture (Derrick *et al.* 1993). Quality can be maintained by grazing before flowering while the stems are still soft and palatable.

Mineral composition

Many reports have compared the mineral composition of plantain with commonly used grasses and clovers. These show that plantain contains high levels of calcium, magnesium, sodium, phosphorus, zinc, copper and cobalt, at least as high as perennial ryegrass–white clover based pastures and usually higher (Fagan & Watkins 1932; Thomas & Thompson 1948; Thomas *et al.* 1952; Armstrong 1953; Adams & Elphick 1956; Wohlbier & Kirchgessner 1957; Bruggemann *et al.* 1960; Boberfeld & Buyukburc 1974; Forbes & Gelman 1981; Holubek & Jancovic 1989; Tiley & France 1990; Spatz & Baumgartner 1990; Wilman & Riley 1993). The retention of calcium, magnesium and sodium by grazing animals was higher from plantain than from perennial ryegrass, for calcium four times higher (Wilman & Derrick 1994). This suggests that a small proportion of plantain in the sward could significantly increase calcium retention by animals.

Nutritional value

Compared with perennial ryegrass, leafy plantain had similar physical breakdown characteristics, a lower proportion of cell wall, less cellulose, less neutral and acid detergent fibre but less crude protein, less water soluble carbohydrate and more lignin. Stems of plantain have more cellulose, more lignin, higher neutral and acid detergent fibre contents and less crude protein than perennial ryegrass stems (Derrick *et al.* 1993; Isselstein 1993a; Wilman & Riley 1993; Wilman & Derrick 1994; Deaker *et al.* 1994b).

Derrick *et al.* (1993) reported that with sheep fed ad lib., the daily intake of plantain herbage was slightly higher than that of endophyte-free perennial ryegrass. However, plantain required a greater amount of chewing and rumination activity than perennial ryegrass.

Plantain is considered to make good quality hay but is slower than perennial ryegrass or white clover to dry (Thomas *et al.* 1952; Turner 1955; Isselstein & Ridder 1993).

The results of digestibility measurements of plantain herbage vary depending on the method of determination. When measured using the *in-vitro* cellulose/pepsin method the digestibility has been similar to perennial ryegrass and white clover. However, when the *in-vitro* rumen-fluid/pepsin method is used the apparent digestibility can be 10–20% lower (Derrick *et al.* 1993; Deaker *et al.* 1994b), although Wilman & Riley (1993) found that allowing additional time for digestion reduced this effect. Further experiments using rumen fluid from animals previously grazing a range of pasture species led Deaker *et al.* (1994b) to conclude that plantain herbage slows down the action of rumen microflora but does not permanently impair rumen function. This effect was attributed to the presence of biologically active compounds.

Unique chemical properties

Plantain contains a number of unique properties for which it has been widely used in traditional medicine around the world. These properties became apparent when Freerksen (1950) and Freerksen & Boniche (1951) reported antimicrobial properties. Although antimicrobial properties are not unique among plants, it was the only species from 550 surveyed in which the antimicrobial properties were still detectable in rabbit urine samples 8 to 16 hours after feeding.

Further studies have identified the iridoid glucoside aucubin and its derivatives as important biologically active compounds. These have a number of effects, including antimicrobial (Rombouts & Links 1956; Ishiguro *et al.* 1982), laxative (Wagner & Wolff 1976); tissue growth promoters and non-steroidal anti-inflammatory (Salas-Auvert *et al.* 1985); providing liver protection effects (Yang *et al.* 1983; Chang *et al.* 1984); weak anti-oxidant (Toda *et al.* 1985); and stimulation of uric acid excretion (Kato 1946).

Aucubin occurs in plantain at very high levels, up to 3% of dry matter, depending on the genotype, soil fertility and other factors (Puffe & Zerr 1989; Fajer *et al.* 1992; Adler *et al.* 1995). The levels increase with increasing leaf age and during dry summer conditions; even after cutting the levels in detached leaves can increase significantly (Bowers & Stamp 1992; Stamp & Bowers 1994, 1996).

The genus *Plantago* is widely known and used as a source of mucilage, or polysaccharide hydrocolloids (Morton 1977; Franz 1989). Plantain leaves contain approximately 0.8% of mucilage (Brautigam & Franz 1985). Mucilage hydrates slowly with water to form a viscous gel regulating movement through the digestive system with its laxative and purgative effects (Duke 1992). *Plantago* mucilage is used in commercial preparations to control diarrhoea in calves (Verschoor 1987).

P. lanceolata also contains the phenylpropanoid glycoside verbascoside (syn: acteoside) at levels up to 9% of dry matter (Fajer *et al.* 1992). This compound is also biologically active, having antimicrobial effects (Andary *et al.* 1982,); antifungal effects (Shoyama *et al.* 1986); *in-vitro* antitumour activity (Pettit *et al.* 1990; Herbert *et al.* 1991); acting as a strong superoxide anion scavenger and antioxidant (Zhou & Zheng 1991); and having anti-hypertensive and anti-tremor activity (Andary *et al.* 1982).

The sugar alcohols sorbitol (syn: *D*-glucitol), and to a lesser extent mannitol, act as the major osmotic regulators in *Plantago* in contrast to grasses where the amino acid proline performs this role. Sorbitol is commonly present in plantain at 2% and can accumulate when plants are in drought or saline conditions (Lewis 1984).

Sorbitol has 60–70% the sweetness of sucrose (Oku 1992) and at the high levels present in plantain has the potential to enhance palatability.

There has been considerable interest in forage plants containing tannins owing to their value in protecting protein in the rumen and to their anthelmintic effects. Plantain contains tannins (Dorfer & Roselt 1989; Launert 1984). Plantain responds to the vanillin/HCl test but gives an unusual slow response, while the butanol–HCl test (Terrell *et al.* 1992) indicates that levels of condensed tannins are between 0.4 and 1%. However, in both tests the resultant extracts are of a different colour to that normally obtained and further studies demonstrating that plantain extracts can either precipitate protein or animal studies with PEG (polyethylene glycol) would be required to confirm the presence of condensed tannins (R. Keogh pers. comm.).

Performance of animals grazing plantain

Liveweight gain trials carried out with plantain have given variable results depending on whether the comparison was pure swards or mixed plantain swards. In pure swards plantain has generally given liveweight gains equal to or less than endophyte free perennial ryegrass (Derrick *et al.* 1993; Fraser & Rowarth 1996), with losses in weight on rank and stemmy swards (Robertson *et al.* 1995).

In contrast, animal liveweight gains have been improved by the inclusion of plantain in mixed pastures (Thomas *et al.* 1956). In mixtures with red and white clover the liveweight gain of lambs on a plantain–clover sward was superior to that on a ryegrass–clover, tall fescue–clover and cocksfoot–clover swards but slightly lower than a chicory–clover sward (R. Keogh pers. comm.). In Australia a plantain sward with 10% clover achieved a liveweight gain of 41% greater than achieved on a good perennial ryegrass–clover pasture (J. Chin 1996). Unlike the trials with pure swards, this trial was carried out in winter on a leafy plantain sward which had not received nitrogen fertiliser.

The carcass composition of lambs was not affected by grazing plantain. However, they were found to have significantly heavier kidneys with no apparent impairment of renal function (Deaker *et al.* 1994a), a result attributed to greater water intakes. Greater urine flows are recorded by animals grazing plantain (Wilman & Derrick 1994), consistent with the diuretic effects of iridoid compounds.

The meat flavour of lambs grown on plantain was no different to those grazing on ryegrass (Fraser *et al.* 1996).

In some grazing trials of lambs grazing plantain dags and scouring has been less than that in perennial ryegrass, white clover or chicory (J. Deaker pers. comm.).

There has been much interest in anthelmintic properties of plantain. In the laboratory an extract with mild anthelmintic properties has been detected (G. Lane pers. comm.). However, field trials to date have failed to detect any reduction (Robertson *et al.* 1995; Fraser & Rowarth 1996, Knight *et al.* 1996; J. Chin 1996).

Interaction of biologically active chemicals with animal performance

The antimicrobial compounds in plantain appear capable of interacting with the fermentation process. Deaker (1994b) observed an inhibition of rumen fermentation during herbage digestibility experiments and attributed this to the presence of such compounds.

Similarly, the silage fermentation process is believed to be retarded by antimicrobial compounds. Isselstein (1993a, 1993b) reported that silage pH values remained over 5, protein degradation to ammonia was insignificant and there was little lactic or acetic acid produced. However, plantain silage has an agreeable aroma and even after 180 days had not started to deteriorate.

The ability of some synthetic antibiotics to change microbial activity and protozoal numbers is well known, as is their ability to lower the rate of gas production in the rumen, leading to a reduction in the severity of bloat (Katz *et al.* 1986) and their effect on mineral metabolism (Chirase *et al.* 1988). They can promote propionic-producing bacteria, leading to altered volatile fatty acid composition of the rumen with higher propionic to acetic acid ratios (Mir 1989), resulting in improvements to animal productivity and milk composition (Davey 1965). Similar effects have also been reported with some herbal remedies (Randhawa & Randhawa 1996) and on high starch diets (Forbes & France 1993).

The supplementation of ruminant diets with *Plantago* seed husks has been shown to increase the ratio of propionic acid to acetic acid (Mir & Mir 1994) and initial studies suggest that plantain herbage may have a similar effect (P. Mir pers. comm.).

The presence of antimicrobial compounds capable of affecting the rumen fermentation process is likely to have important implications for rumen efficiency, mineral nutrition of ruminants, animal performance, milk composition, bloat and animal health. Further research will be required to determine their full significance.

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Plantain (Plantago lanceolata L.), a forage used in grazed pastures, contains active secondary metabolites that could potentially inhibit nitrification, a key step in nitrous oxide (N2O) production from grazing ruminant livestock urine patches. A field study was performed to determine the effects of aucubin, a secondary metabolite in plantain, on nitrification and soil N2O emissions under a ruminant urine patch.Â Aucubin, a potential nitrification inhibitor found in plantain (Plantago lanceolata) was assessed in two field trials for its efficacy in reducing urine patch nitrate (NO3â») accumulation and N2O emissions.