New Zealand dryland pastures: effects of sown pasture species diversity on the ingress of unsown species

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Summary Botanical composition was assessed in spring in 30 paddocks in each of four New Zealand regions: Northland (beef, sheep), Waikato (dairy), Taranaki (dairy) and North Canterbury (beef, sheep, deer). The hypothesis tested was that increasing functional diversity of sown species reduced ingress of unsown species as pastures age. Paddocks selected ranged in age and diversity of the sown mix (grasses + legumes, or grass + legumes + herbs). In all regions except for Taranaki, sown species declined and unsown species increased over time. This was mainly due to an increase in unsown grasses, although unsown herbs also increased. There was little unsown legume. In Northland, unsown herb ingress was less where herbs were sown, but only in older pastures. Percentage of unsown species in total dry matter in 4–6 year old pastures was: 35% (Waikato), 16% (Taranaki) and 15% (North Canterbury), while in 5–6 year old Northland pastures it was 30%. Most unsown species were undesirable. However, productive unsown species were also present (e.g. ryegrass, commercial plantain, white clover, subterranean clover).

Keywords Species diversity, functional diversity, pasture persistence, weed ingress.

INTRODUCTION

Pasture persistence has been identified as a key issue in dairy, beef and sheep industries. Lack of persistence of sown species and ingress of weedy species can lead to significant production loss (Bourdôt *et al.* 2007). In addition, renovation costs are high.

It has been demonstrated that increasing diversity of plant species in grassland communities can increase pasture resilience and resistance to invasion by exotic species (Sanderson *et al.* 2004). Often, it is the species identity that is most important, rather than the number of species *per se* (Crawley *et al.* 1999). This is related to their functional complementarity, or ability to respond to environmental factors in different ways to other species in the mix. Plants can therefore be classified according to their functional traits (e.g. perennial temperate grasses, perennial legumes, etc.). In a New Zealand North Island hill country field study, it was shown that increasing the number of sown functional groups reduced the number of unsown species (Dodd *et al.* 2004).

In New Zealand, given that most pastures comprise perennial grasses and perennial legumes, a key means of increasing functional diversity is through sowing the herbaceous species chicory (*Cichorium intybus* L.) and plantain (*Plantago lanceolata* L.), which are drought tolerant and provide useful summer feed.

The hypothesis tested was that increasing functional diversity of sown species reduces ingress of unsown species as pastures age. Controlled studies to test the hypothesis would limit the impacts of variation in management (e.g. beef and sheep versus dairy) and localised differences in climate that occur on different farms. Yet, we also needed to determine if there is evidence that this hypothesis is correct in real-life farming situations and if there are consistent, documentable benefits. An on-farm study was therefore undertaken in different regions throughout New Zealand to investigate the relationships between sown functional diversity, pasture age and ingress of unsown species.

MATERIALS AND METHODS

Sites Thirty paddocks were selected in Northland (sheep, beef), Waikato (dairy), Taranaki (dairy) and North Canterbury (sheep, beef, deer). These regions varied in climate, from Northland with mild winters and warm, subtropical summers that favour C4 summer-active species, to North Canterbury, which has a much harsher climate of hot dry summers and cold winters. Paddocks were selected such that they ranged in age since renovation and in functional diversity of the sown mix (grasses + legumes vs. grasses + legumes + herbs). In addition, paddocks were only selected if: (1) farmers possessed good paddock history records (i.e. pasture age, species and cultivars sown, sowing rates, seed coating, endophyte status and method); (2) they were not irrigated (other than effluent spreading on a small number of dairy paddocks); and (3) no under or oversowing had occurred since renovation. Paddock sizes varied considerably, although most dairy paddocks were approximately 1.5 ha and most beef and sheep paddocks were several hectares. Two to three paddocks were randomly selected on each farm, equating to 10–15 farms in each region.

Sampling Assessments took up to 1 week in each region and were undertaken during spring 2009. In each paddock, botanical assessments were undertaken in a 1 ha area. Percentage of total dry matter (DM content) was assessed in 20 0.1 m^2 quadrats in each paddock, using the BOTANAL method (Jones and Hargreaves 1979). This method visually ranks the three most dominant vegetation classes present in a quadrat, with respect to their dry matter contribution. Standard multipliers are then used to estimate the contribution of these vegetation classes to total pasture dry matter. Assessments were undertaken for sown and unsown grasses, legumes and herbs. Sown grasses included: ryegrass (*Lolium perenne* L.), tall fescue (*Festuca arundinacea* Schreb.), cocksfoot (*Dactylis glomerata* L.), prairie grass and grazing bromes (*Bromus* spp.), timothy (*Phleum pratense* L.) and phalaris (*Phalaris aquatica* L.). Sown legumes included white clover (*Trifolium repens* L.), red clover (*T. pratense* L.), subterranean clover (*T. subterraneum* L.), lucerne (*Medicago sativa* L.) and lotus (*Lotus* spp.), while sown herbs included chicory and plantain.

Statistical design There were two treatments: functional diversity and age. Of the 30 paddocks in each region, 15 paddocks were selected in which grasses and legumes had been sown (two functional groups), and 15 paddocks in which grasses, legumes and herbs had been sown (three functional groups). In each region, the 15 paddocks in each category were further subdivided into 'young' (renovated in the last 1–3 years), medium (4–6 years) and 'old' (7 years or more). However, in Northland, it was not possible to locate sufficient renovated paddocks with good paddock histories that were over 6 years old. Therefore, young was defined as 1–2 years, medium as 3–4 years and old as 5–6 years. This gave approximately five paddocks for each age and diversity category within each region.

REML was undertaken using GenStat 10.2 (VSN International Ltd., Oxford), with farm as a random effect, on the proportion of total dry matter of the different vegetation classes present, including total sown and unsown species, and sown and unsown grasses, legumes and herbs.

RESULTS

Northland sheep and beef Dry matter content of sown species (i.e. % of total DM) was greater in young than old pastures ($P < 0.05$, Table 1). Sown grass DM content was higher in young and medium aged pastures, when sown without herbs than with herbs, but was similar in old pastures (young pastures: 81% and 57% of total DM, medium pastures: 71% and 46%, old pastures: 53% and 57%, without and with sown herbs respectively, $P < 0.05$). This was due to a decline in sown grass DM content as pastures aged, when sown without herbs.

Dry matter content of unsown species was greater in old than in young pastures ($P < 0.05$, Table 2). This was primarily due to an increase in the DM content of unsown herbs ($P < 0.01$, Table 2). There was also a trend towards increasing unsown grass DM content as pastures aged, although this was not significant ($P > 0.05$). In addition, ingress of unsown herbs (e.g. buttercup (*Ranunculus* spp.), dock (*Rumex* spp.), pennyroyal (*Mentha pulegium* L.)) was less (5%) in pasture sown with than without (17%) herbs, but only in old pastures ($P < 0.05$, % of total DM). Unsown legumes contributed little dry matter (Table 2).

Waikato dairy Dry matter content of sown species was greater in young than old pastures ($P < 0.001$, Table 1). DM content of sown grasses was also higher when sown with (56%) than without (29%) herbs, but only in old pastures ($P < 0.05$).

Conversely, DM content of unsown species was higher in old and medium than in young pastures (Table 2, $P < 0.001$). This was due to the change in DM content of unsown grasses and unsown herbs, which were both higher in old than in young pastures ($P < 0.05$). There were negligible unsown legumes. Herb inclusion did not affect DM content of unsown species.

Taranaki dairy Dry matter content of sown species did not alter with pasture age (Table 1). There was also no change in DM content of unsown species as pastures aged (Table 2). Herb inclusion had no effect on DM content of sown or unsown species.

Table 1. Mean % of sown species in total dry matter in 'young', 'medium' and 'old' dryland pastures. Means followed by different letters are significantly different (P = 0.05).

Region	Young	Medium	Old	SED
Northland	90 b	77	69 a	7.3
Waikato	88 b	65 a	60 a	7.5
Taranaki	86	84	86	3.8
Canterbury	87 b	85 b	64 a	8.5

Table 2. Mean % of unsown species in total dry matter in 'young', 'medium' and 'old' dryland pastures. Means followed by different letters are significantly different (P = 0.05).

Vegetation	Young	Medium	Old	SED
Northland				
Grasses	7	17	18	6.4
Legumes	<1	<1	<1	1.0
Herbs	2 a	6	11 b	2.7
Total	10 a	23	30 b	7.2
Waikato				
Grasses	4 a	25 b	23 b	8.2
Legumes	0	0	0	
Herbs	8 a	11	15 b	2.9
Total	12 a	35 b	40 b	7.5
Taranaki				
Grasses	3	4	3	2.2
Legumes	0	0	0	
Herbs	11	13	11	3.4
Total	14	16	14	3.9
Canterbury				
Grasses	7 a	10 a	23 b	6.4
Legumes	6	5	6	4.5
Herbs	2 a	1 a	5 b	1.8
Total	13 a	15 a	36 b	8.5

North Canterbury sheep, beef and deer Dry matter content of sown species was greater in young and medium than in old pastures ($P < 0.05$, Table 1). Conversely, DM content of unsown species was greater in old than in medium and young pastures. This was due to an increase in DM content of unsown grasses and unsown herbs (Table 2, $P < 0.05$). Including herbs had no effect on DM content of sown or unsown species.

DISCUSSION

A reduction in sown species and increase in unsown species was evident in all regions as pastures aged, except in Taranaki. Most pastures assessed in this study were less than 10 years old, and in Northland, all were less than 6 years old. Yet in Waikato, unsown species content had reached 35% within 4 years of sowing.

There was evidence that increasing species diversity improved persistence of sown species in Northland and Waikato, thus reducing the ingress of unsown species. This concurs with other studies, in which increasing functional diversity increases resilience (Dodd *et al.* 2004). This also concurs with anecdotal evidence provided by farmers interviewed for this project. A number of the farmers observed that sowing a combination of species that were adapted to a range of environmental conditions (e.g. winter-active species such as ryegrass or bromes and summer-active or more drought tolerant species such as lucerne or cocksfoot) improved pasture persistence and lessened the ingress of undesirable species, (e.g. Californian thistle *Cirsium arvense* (L.) Scop.; barley grass *Hordeum murinum* L.). Overall, however, we only detected weak relationships between sown functional diversity and unsown species ingress. It may be that the functional diversity was insufficient for effects to be detectable, especially as sown herbs comprised a small amount of the dry matter content. Further, the classification we chose (grass + legumes vs. grasses + legumes + herbs) may be too simplistic to detect benefits of functional diversity. Further analyses are in progress.

While sown species composition can affect weed abundance, maintaining an even distribution of forage species is also important. In an American grazed field study, species evenness was negatively correlated to weed abundance over two consecutive years (Tracy *et al.* 2004).

The identity of unsown species in this study varied between regions, although winter grass (*Poa annua* L.) was prevalent in all regions. C4 grasses, such as kikuyu (*Pennisetum clandestinum* Hochst. ex Chiov.) were detected in Northland, while temperate species such as browntop (*Agrostis capillaris* L.), barley grass and vulpia (*Vulpia* spp.) were more prevalent in Canterbury. Unsown species were often undesirable, as farmers viewed them as less productive, less palatable and of poorer forage quality, especially during seed maturation. Furthermore, seeds of some of the species observed can damage hides or carcasses of grazing livestock (e.g. vulpia, barley grass, storksbill (*Erodium* spp.) (Dowling *et al.* 2000).

In addition to weedy undesirable species, some unsown species were productive, such as ryegrass, subterranean clover or commercial cultivars of plantain. Ryegrass was documented in many pastures where it was not sown, in varying amounts. For example, ryegrass was the dominant species present (>50% of total dry matter) in one 4 year old Waikato paddock, which was sown with tall fescue and established well in its first year. Therefore, it is also likely that old varieties of ryegrass were present in pastures where newer cultivars of ryegrass were sown (Burggraaf and Thom 2000). Ingress of older ryegrass cultivars would result in an overestimation of sown grasses and underestimation of unsown grasses, as it was not possible in the field to identify different ryegrass cultivars. Further work is underway to test for endophyte identity of the ryegrass present, which will enable us to determine how well the sown ryegrass cultivars are persisting.

Commercial cultivars of plantain were likewise found in small quantities where it had not been sown. This occurred in all regions assessed. Farmers observed that plantain appeared to self-seed readily and to establish in stock dung. Plantain was usually present in 'old' pastures in which it was sown, in contrast to chicory, which appeared to be less persistent. Plantain may show more promise than chicory in preventing the ingress of unsown species.

Ingress of unsown species and persistence of sown species varied between regions; further analyses are underway to quantify these differences. Variation may reflect differences in climate, as well as in enterprise (e.g. sheep vs. dairy). For example, Taranaki tended to have the highest proportion of sown species in the pastures, while Waikato, Northland and North Canterbury had greater ingress of unsown species. In Taranaki, average maximum temperature (17°C) and rainfall (1604 mm) in years in which pastures were sown would favour establishment of ryegrass, the dominant sown grass. In comparison, mean Canterbury rainfall in the years in which pastures were sown was much lower (789 mm). Also, there were numerous summer droughts over the last decade in Canterbury, which would reduce vigour of sown species and favour winter-active annual grasses, such as vulpia, winter grass and barley grass, which avoid the summer drought. These differences between regions give insights into how pastures may perform as regional climates change.

While there is only limited evidence for the hypothesis that increasing functional diversity (by including herbs) reduces ingress of unsown species, results from this study give us valuable insight into persistence of sown species and ingress of unsown species. Currently, a study is underway to further test this hypothesis relating to functional diversity, under controlled conditions, in replicated field plots. In combination with results from the present study, we can better ascertain the role and potential benefits of functional diversity on pasture persistence and weed ingress in New Zealand pastures.

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