Best-practice pasture renewal for forage production and sustainability: description of a farmer-led study and initial findings

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Abstract

Constraints to pasture renewal success have been identified by many farmers so this multi-disciplinary study was initiated to trial and monitor the establishment, persistence and production of key forage species. Eight farms in the Bay of Plenty are being monitored. On each farm, paddocks have been selected so that a wide range of contrasting previous management and current pasture performance is covered. Initial measures of pasture production, composition, insect populations, nematodes, earthworms and interactions amongst these variables were made in February 2009. Pasture renewal significantly increased white clover yield ($P<0.01$). Black beetle (*Heteronychus arator*) was the major pest insect at almost all sites and populations were significantly decreased by renewal ($P<0.01$). The root-knot (*Meloidogyne*) and cyst (*Heterodera*) clover-feeding nematodes were increased in renewed paddocks, probably in response to increased clover content. Earthworm populations were significantly reduced by renewal ($P<0.05$). The relationship between pasture performance and invertebrate populations is complex but critical to pasture establishment.

Keywords: clover, grass, dry matter, black beetle, clover root weevil, grass grub, white fringed weevil, cyst nematode, root-knot nematode, earthworm, soil moisture

Introduction

The concept of changing an existing pasture to one with more desirable plant species ("pasture renewal") to gain greater plant and therefore animal productivity is not new and detailed methods to achieve this have been available for some time (e.g. Anonymous 1993; Baker 1977; Beggs 1975). Despite this, farmers are still raising questions as to the financial benefit of the renewal process with particular concern about the longer-term persistence of the new pasture.

The term "pasture renewal" is used here to denote any change from an existing pasture to one where seeds of desirable pasture plants are added to the pasture. This includes all practices from oversowing (i.e. spreading seed on the soil surface) of existing pasture to full cultivation and succession through a cropping sequence to a new pasture. For this study, the majority of pasture renewal involved herbicide spraying of existing pasture with or without full cultivation and with or without a cropping phase.

One of the factors that is likely to limit the success of pasture renewal is that much of the readily-available information is largely out of date (e.g. Anonymous 1993). With the advent of novel grass/endophyte combinations (Bluett *et al.* 2003; Bluett *et al.* 2005; Hume *et al.* 2007), new pests (Barratt *et al.* 1996), recognition of new pest species (Mercer *et al.* 1997) and new weeds (Tozer *et al.* 2008), new strategies need to be developed and communicated to farmers and contractors.

The opportunity to suppress weed and pest populations through herbicide treatment, physical disruption or host plant removal (Barker 1990; Bell *et al.* 2004; Bell *et al.* 2006; Davison *et al.* 1979) is one of the driving forces behind pasture renewal. Another major driver is incorporation of new germplasm to the pasture, in particular new grass/endophyte combinations (Bluett *et al.* 2004). The potential production and persistence of these new technologies is considerably higher than from older cultivars (Hume *et al.* 2007; Thom *et al.* 2008).

A project is now underway to investigate factors that affect pasture establishment after renewal so that recommendations can be given to farmers which will help ensure the renewal process is successful. This paper examines the pest and beneficial soil-dwelling invertebrate populations present in recently renewed and non-renewed pastures in the Bay of Plenty, as an initial step towards forming integrated pest management recommendations for pasture renewal.

Materials and Methods

Two to four paddocks on each of eight dairy farms in the Bay of Plenty were selected which had been either renewed within the previous 12 months (n=11) or not (n=12). Factors other than recent renewal such as renewal method, cultivation and sown germplasm, were ignored for the purposes of this paper. The farms were, with one exception, within the low summer rainfall/ high summer temperature region of the Edgecumbe plain.

Herbage was harvested monthly for January and February 2009 from three pasture exclusion cages (quadrat size 0.25 × 0.5 m) per paddock using an electric shearing handpiece to 'grazing height' (ca 2.5 cm). Proportional composition of plant components (grasses, clover and other plants) was determined by visual assessments in the field, and verified through lab dissection of a third of all samples. Cut herbage was weighed, dried (>48 h at 65°C) and re-weighed. Total herbage dry matter (DM) was calculated on a per hectare basis and the proportional composition was converted to DM/ ha. The herbage data considered here are from the growth period 8/9 January to 4/5 February 2009. Temperature and rainfall estimates are for the same period from Edgecumbe (NIWA virtual climate station, see Cichota *et al.* 2008).

Over 4–5 February 2009, 10 spade-squares were dug from each paddock along a transect bisecting the placement of the pasture cages, following the long axis of the paddock. Soil from each spade-square was hand-crumbled and all insects and earthworms encountered were placed into a labelled plastic specimen container (75 ml) which was then filled with 70% ethanol to preserve the specimens. They were identified and recorded to family, genus or species level as appropriate.

One soil core (2.5 cm diameter × 10 cm depth) was taken adjacent to each spade- square for nematode determination, with the ten cores per paddock being bulked in a single labelled plastic bag. Soil from each paddock was transported to a laboratory where it was hand-crumbled, and a 100 g subsample used to extract nematodes over 3 days using the modified Whitehead & Hemming tray method described by Bell & Watson (2001). The total number of nematodes were counted and plant feeding forms identified to genus in a Doncaster counting dish (Doncaster 1962). A further ca. 100 g subsample of this hand-crumbled soil was weighed into labelled paper bags, dried for 48 h at 80°C then re-weighed to determine soil moisture content.

Data were analysed by REML using Genstat on untransformed or natural log (n + constant) transformed data as appropriate. The constant added was the smallest non-zero value in the data range.

Results and Discussion

Overall, pasture production was low during the sampling period, with an average of less than 40 kg DM/ha/day. Soil moisture levels were low in almost all the paddocks at sampling (Table 1) which would have had a negative impact on pasture production, especially with the warm temperatures at this time of the year (mean daily maximum air temperature 25.9°C, total rainfall 9.5 mm and mean daily potential evapotranspiration 5.3 mm for the month preceding sampling). There was no significant effect of pasture renewal on total dry matter accumulation but clover production was significantly increased in renewed paddocks at the February sampling (Table 1).

Pasture renewal significantly decreased populations of the pest insects black beetle (*Heteronychus arator*), grass grub (*Costelytra zealandica*) and white-fringed weevil (*Naupactus leucoloma*), but also significantly reduced beneficial earthworm populations (Table 2). The reduction in black beetle numbers is likely to be of benefit to the new pastures because of the high numbers that would otherwise be present. Black beetle can cause damage to pastures at populations of 40/m^2 or greater (Watson *et al.* 1980) and for the pastures that had not been renewed this threshold was reached by 10 of the 12 paddocks sampled (with a maximum of 95/m^2 being observed in one paddock). For the renewed pastures the threshold was reached in only 2 of the 11 paddocks sampled (maximum 98/m^2). At the sampling time used here the black beetle population consisted of 26% adults, 39% pupae and 35% larvae.

Table 1 Raw mean plant production over 27 days (kg DM/ha) and soil moisture (% by weight) (means of natural log transformed data in parentheses). Note *** = P<0.001.

	Not renewed	Renewed	SED
Total DM	918	1325	267.3
Grass DM	551 (6.3)	677 (6.2)	(0.29)
Clover DM	107 (3.3)	334 (5.4)	(0.36)***
Other DM	230	282	102.8
Soil moisture	21.0 (3.0)	19.6 (2.8)	(0.12)

At least seven of the 11 paddocks which were renewed employed soil cultivation at some point in the renewal process, including rotation through a summer crop in some cases, and this has likely had a large negative impact on invertebrate populations (Table 2). Grass-to-grass renewal without cultivation can be successful in black beetle areas but requires: good control of weed grasses that may host black beetle; sowing of grass/endophyte combinations that are resistant to adult black beetle feeding; and sowing of insecticide-treated seed to reduce resident black beetle populations and protect emerging seedlings. Although some grass/endophyte combinations provide resistance to black beetle adult feeding (Ball *et al.* 1994) it is thought that larval feeding is not directly affected by endophyte presence (Popay & Ball 1998) so it is important to reduce adult populations thereby reducing egg laying in spring and subsequent summer larval populations.

Grass grub populations were significantly lower in renewed pastures (Table 2). However, the densities were generally low (0–33/m^2): damaging populations are considered to be above ca. 75/m^2 for ryegrass/white clover swards (East *et al.* 1982). It is well known that grass grub can build up to damaging population levels ca. 2–3 years after pasture renewal (East *et al.* 1980; Watson *et al.* 2000). This is especially true if cultivation

Table 2 Raw mean soil insect and earthworm abundance (number/m²) (means of natural log transformed data in parentheses). Note: * = P<0.05; ** = P<0.01.

	Not renewed	Renewed	SED
Black beetle	50.8 (3.7)	26.4 (2.8)	(0.30)**
Clover root weevil	14.4 (2.4)	20.5 (2.3)	(0.34)
Grass grub	9.0 (2.2)	0.7 (1.1)	(0.28)**
White fringed weevil	17.1 (2.7)	5.9 (1.7)	(0.40)*
Earthworms	139.4 (4.5)	60.2 (3.5)	(0.37)*
Total specimens	265.8 (5.5)	141.6 (4.7)	(0.29)*

Table 3 Raw mean soil nematode abundance (thousands/m²) (means of natural log transformed data in parentheses). Note: * = P<0.05.

	Not renewed	Renewed	SED
Total nematodes	7480	9510	2250
Root-knot (*Meloidogyne*)	423 (-2.1)	930 (-1.9)	(0.83)
Cyst (*Heterodera*)	81 (0.08)	235 (0.24)	(0.059)*
Lesion (*Pratylenchus*)	720 (-1.4)	1062 (-0.8)	(0.53)
Pin (*Paratylenchus*)	1506 (-0.3)	1050 (-0.5)	(0.52)
Spiral (*Helicotylenchus*)	127 (-2.4)	109 (-2.7)	(0.56)

is used which disrupts the important grass grub/*Serratia entomophila* pathogen relationship (Robertson *et al.* 1999).

Both the clover root weevil (*Sitona lepidus*) (range 0–130/m²) and white fringed weevil (0–43/m²) populations were generally low, although the former is likely to be underestimated due to the sampling method used here being sub-optimal for adult weevil capture.

Earthworm numbers were significantly lower in renewed pastures. Earthworms contribute to soil structure (Francis & Fraser 1998) and plant decomposition (Springett *et al.* 1992). However, they are susceptible to soil cultivation (e.g. Aslam *et al.* 1999), especially in soils with low bulk density (Yeates *et al.* 1998), as is likely the case for many of the soils in the present study. Identifying those paddocks which were not cultivated, and distinguishing between the different types of cultivation used in the renewal process, will allow for a more subtle examination of the effects in Bay of Plenty soil of different renewal practices on earthworm populations.

Significantly fewer total soil macro-fauna specimens were found in renewed paddocks (Table 2). In addition, there were fewer "taxa" per paddock in renewed (mean 7.3, range 4–10) than non-renewed paddocks (8.8, 7–11) suggesting that the diversity of these organisms may also be reduced by the renewal process.

In addition to the insects listed in Table 2, small populations of soldier fly (*Inopus rubriceps*) (mean 11/m² over all paddocks), wireworms (Elateridae) (6/m²), ladybirds (Coccinelidae) (2/m²), five unidentified beetle (Coleoptera) species (total 2/m²), four unidentified moth/butterfly (Lepidoptera) species (1/m²) and two unidentified weevil (Curculionidae) species (total 0.2/m²) were present.

There was no significant effect of pasture renewal on total nematode abundance but cyst (*Heterodera* sp.) and root knot (*Meloidogyne* sp.) nematode abundance was increased (significantly for cyst nematodes) in renewed paddocks (Table 3). This was probably due to the increased abundance of their host clover plants also observed in renewed paddocks (Table 1). The individual genera of plant feeding nematodes listed in Table 3 are in order of their potential to damage pasture plants so that the high population levels of root knot (range 0–5459 × 10³/m²) and cyst nematodes (0–509 × 10³/m²) observed in some paddocks is likely to be of concern. As is the case for grass grub, these nematodes can increase rapidly in the first 2 to 3 years after establishment of new pasture (Sarathchandra *et al.* 2000), even after cropping has been used to remove plant hosts as Watson *et al.* (2000) found at a Bay of Plenty site.

Some of the variables measured were significantly ($P<0.05$, n=24) correlated with each other. Those which were biologically sensible were: total DM, grass DM, total earthworms, total soil macro-fauna and total nematodes all positively correlated to percent soil moisture (r^2 = 0.326, 0.478, 0.521, 0.410 and 0.310, respectively); total black beetle to percent other grass (r^2 = 0.188) (weed grasses being important hosts for black beetle (King *et al.* 1981)); and lesion (*Pratylenchus* sp.) nematodes positively correlated to grass DM (r^2 = 0.202) (grasses are hosts for lesion nematodes in New Zealand (Watson *et al.* 1995)).

From this initial sampling it appears that the main benefits of the pasture renewal conducted were increased clover production and decreased insect pest populations, particularly black beetle. The major downside was reduced earthworm populations with potential future risks from increased clover nematode and grass grub populations. Future work will replicate this study over time and will more fully investigate renewal × cultivation × cultivar × pest effects on pasture production, composition and invertebrate populations. We will also look at these effects on pasture persistence and farm system profitability.

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