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AFTER FERTILISER APPLICATION EARTHWORMS REMAIN AN IMPORTANT COMPONENT OF OUR SOIL-PASTURE SYSTEM

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Abstract

Greater emphasis is being placed on ensuring fertiliser application minimises losses to the environment and is nutrient efficient. Earthworms increase nutrient mineralisation and plant growth. The few studies which have explored the role of earthworms on plant growth after fertiliser application have found varying results depending on soil type as well as nutrient inputs. Here we investigate the contribution of deep burrowing earthworms to pasture growth at three field sites after the application of superphosphate and urea. At each site we selected an area where the deep burrowing earthworm *Aporrectodea longa* was present and an adjacent area where they had yet to colonise. Pasture production was monitored throughout the year on each of three paired areas at each site. On areas where *A. longa* was present pasture production was greater and pasture quality was higher, with growth increasing especially during autumn, winter and early spring when earthworms are most active. Because other factors influencing pasture growth could not be ruled out, caution must be taken in this interpretation. The application of both superphosphate and urea also increased pasture production. Earthworms had a consistent positive influence on pasture production, highlighting their importance in our agroecosystems.

Introduction

During the 1990s there was a rapid increase in fertiliser use, particularly nitrogen in order to promote herbage growth and farm productivity (Clark et al. 2007). While the application of fertiliser grows more forage, there are consequences with losses to the atmosphere and water bodies. Greater emphasis is now on ensuring fertiliser application is nutrient efficient and minimises nutrient losses.

Earthworms promote nutrient mineralisation, increasing nutrient uptake by plants and stimulating plant growth (Schon et al. 2012, Stockdill 1982, Syers and Springett 1984). Vos et al. (2014) found both phosphorus uptake and plant growth were increased with earthworms and the application of fertiliser while Laossi et al. (2010) observed increased plant growth in the presence of anecic earthworms in nutrient rich soil, but observed little additive effect of earthworms with the application of fertiliser. These differing responses are influenced by soil type as well as nutrient inputs and further investigation is required to understand these interactions better.

Earthworm populations in agricultural systems are influenced by management practises. For example, the application of fertiliser stimulates food resources and the earthworms consuming this, while livestock treading pressures can have a negative impact (Schon, et al. 2012). In

New Zealand the earthworms beneficial to our pasture systems are all exotic and arrived accidentally, meaning there are areas which do not have a full earthworm functional diversity and it is the deep burrowing earthworms that are often absent (Schon et al. 2011). It is important to understand the impact earthworms have on nutrient use efficiency after fertiliser application in order to understand the importance of earthworms in our more intensive agricultural systems.

Methods

Three sites where the deep burrowing earthworm species, *Aporrectodea longa* was known to have been introduced previously were selected for measuring the impact of this species on pasture production. All three sites were located on sheep and beef properties and included: 1) Mounganui, in the central Southern North Island on the Taihape-Napier road, 2) Rangitoto, on the East Coast near Rangitoto and 3) Ballantrae an AgResearch farm on the foot hills of the Ruahines near Woodville. Rangitoto would be classified as early lambing country, Ballantrae as mid and Mounganui as late lambing country. The soils at the three sites are described as free draining at Mounganui (Allophanic soil), moderately well drained at Ballantrae (Brown soil) and poorly drained at Rangitoto (Pallic soil).

At each farm site, grazed plots were set up in October-November 2014 in areas where *A. longa* was well established and in an adjacent area, if possible within the same paddock, where *A. longa* had yet to establish. The paired areas were selected to be as similar as possible. On each farm the paired plots were replicated three times and received lime at a rate of 2.5 T/ha. Fertiliser treatments were randomly applied in plots (2x2 m) within the larger earthworm plots at the onset of the experiment. Treatments included a control, a nitrogen treatment (60 kg N/ha as urea, in two applications) and a phosphorus treatment (20 kg P/ha as superphosphate).

Earthworm abundance had been previously assessed and is shown in Table 1 (Schon et al. 2014). Pasture production was assessed every 4-8 weeks depending on pasture growth rates using exclusion cages. Pasture was trimmed to 2 cm, weighed, dried at 60°C and weighed again (Piggot 1989). Pasture samples were collected in October 2015 and assessed for quality using NIRS.

Table 1 Mean earthworm abundance (ind./m^2) at the three sites in both the *A. longa* and no *A. longa* transects from Schon, et al. (2014).

Species	Mounganui		Rangitoto		Ballantrae	
	A. longa	*No A. longa*	*A. longa*	*No A. longa*	*A. longa*	*No A. longa*
Aporrectodea longa	**327**	**0**	**371**	**0**	**208**	**0**
Aporrectodea caliginosa	**274**	**44**	883	1484	**817**	**336**
Aporrectodea rosea	0	0	170	80	667	693
Aporrectodea trapezoides	0	0	88	239	0	0
Octolasion cyaneum	9	0	0	0	**9**	**31**
Lumbricus rubellus	367	233	0	0	26	26
Natives	27	18	0	0	**4**	**102**
Total earthworms	**1004**	**265**	1513	1802	**1731**	**1188**

Bold indicates significant difference at α = 0.05 between the *A. longa* transect and the no *A. longa* transect at a given site in a given row for a given site.

Pasture production on individual dates were analysed using ANOVA (SAS 9.3) and cumulative pasture production was assessed using two-sample *t* tests assuming unequal variances. This study does not have the ability to remove factors from the analysis that could have contributed to the differences found, other than the presence and absence of *A. longa*. The best we can say is that the areas where *A. longa* was present produced more or less pasture than the areas where they were not present.

Results

The earthworm community composition between these sites was quite varied (Table 1). At Mounganui and Ballantrae total earthworm abundance was greater in the *A. longa* than the no-*A. longa* treatment with more *A. caliginosa* as well as *A. longa* , although Ballantrae had fewer native earthworms. At Rangitoto earthworm abundance was similar between the treatments, only with significantly more *A. longa* in the corresponding treatment.

Pasture production was greater in the areas where A. *longa* was present, than in the adjacent areas where they had yet to colonise (Figure 1). The difference in pasture production between the two areas was significant at all sites, Mounganui ($p<0.001$), Rangitoto ($p=0.088$) and Ballantrae ($p=0.016$). Only two replicates at the Rangitoto site were included in the analysis, as the third replicate was deemed to be an unfair comparison with one of the paired plots located down slope of the other, and as a consequence had higher soil moisture throughout the year.

Differences in pasture growth were observed in the control plots, and remained in the fertiliser treatments. This was significant for cumulative pasture growth at Mounganui with differences between the *A. longa* and no *A. longa* in all three treatments, control ($p=0.018$), superphosphate ($p<0.001$) and urea ($p=0.031$). A significant difference in cumulative pasture growth was also observed between the earthworm treatments with superphosphate at Rangitoto ($p=0.037$) but not at Ballantrae. Significant differences between *A. longa* presence and absence was seen at all sites on individual sampling dates (Figure 1).

The difference in the amount of pasture grown in the control treatments and superphosphate treatments was significant when *A. longa* was present at Mounganui ($p=0.083$) and Rangitoto ($p=0.084$). This was significant ($p<0.05$) at individual dates at Mounganui (23/04/2015 & 21/10/2015), and Rangitoto (11/09/2015). Differences were not significant when *A. longa* was absent.

The cumulative amount of pasture grown between the control treatments and nitrogen treatments was not significant, but was significant at individual dates. Differences were seen when both *A. longa* was present and absent, including at Mounganui (21/10/2015, $p<0.05$), Rangitoto (11/09/2015, $p<0.1$) and Ballantrae (25/05/2015, $p\leq0.1$).

Daily pasture growth rates are shown in Table 2. Lowest growth rates were seen at Rangitoto during the summer and the greatest rates were recorded at Ballantrae during spring. Growth rates are relatively high and reflect the use of cages to assess pasture production which can overestimate actual production by up to 30% (Piggot 1989). Further, the plots at Ballantrae are situated on low slope and stock camping areas, which produce nearly 70% more grass than the average production across all slope classes (Lopez et al. 2003). Higher pasture growth rates were observed on the areas where *A. longa* was present, especially during autumn, winter and early spring.

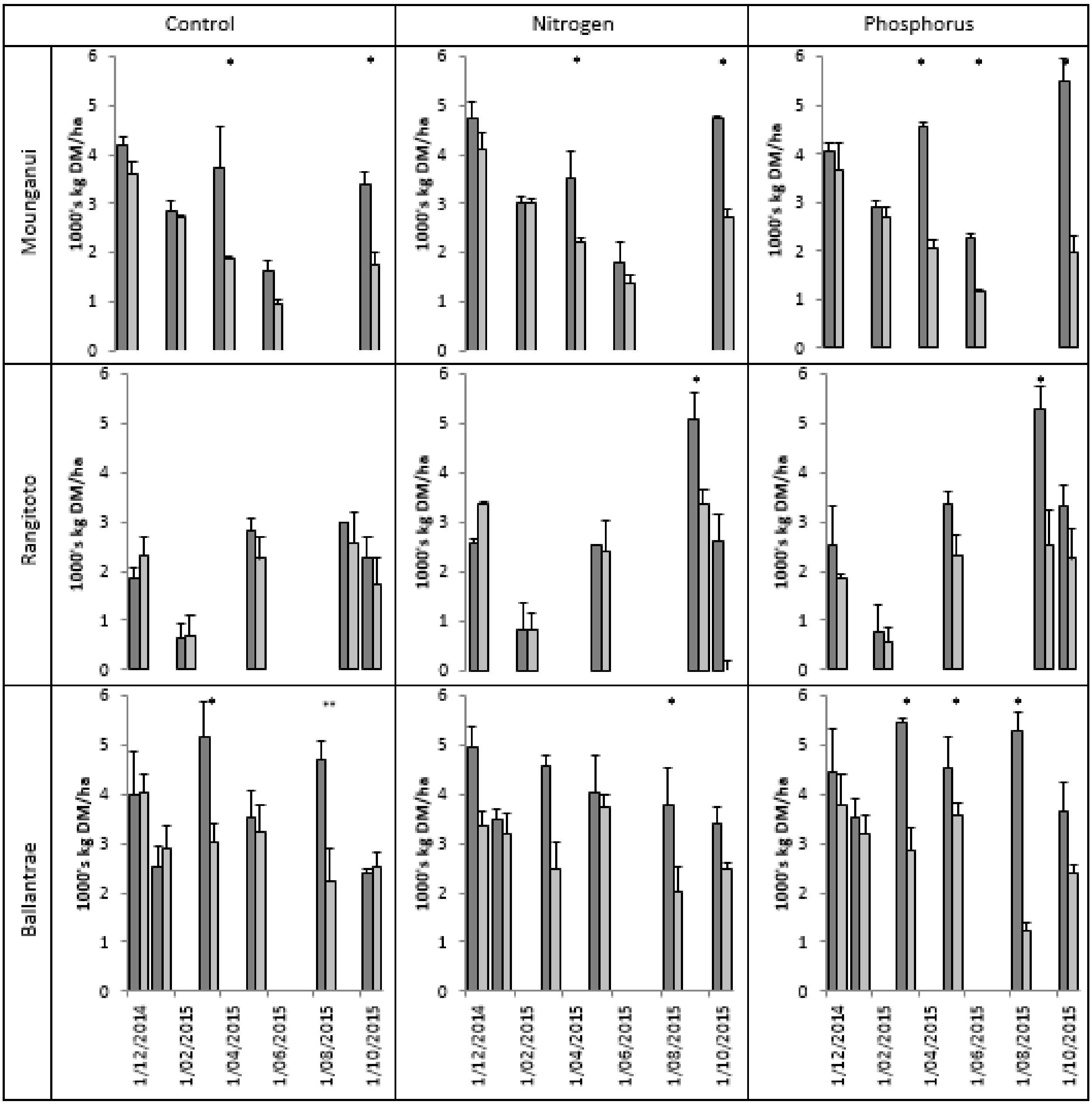

Figure 1 Pasture production (kg DM/ha) measured between December 2014 and October 2015, on areas where *A. longa* is present (■) or absent (■) under the different fertiliser treatments. * significant at p<0.05, **significant at p<0.1. Error bars are SEM.

Table 2 Daily pasture growth rates (kg DM/ha).

	Mounganui		Rangitoto		Ballantrae	
	A. longa	No *A. longa*	*A. longa*	No *A. longa*	*A. longa*	No *A. longa*
November	103.0	90.5	43.9	54.2	112.9	94.0
December	103.0	90.5	43.9	54.2	112.9	94.0
January	48.7	46.8	9.7	10.8	88.2	84.3
February	48.7	46.8	9.7	10.8	97.0	51.9
March	61.7	31.9	31.4	28.8	97.0	51.9
April	61.7	31.9	31.4	28.8	71.2	60.0
May	37.7	23.5	31.4	23.3	71.2	60.0
June	37.7	23.5	31.4	23.3	49.8	19.6
July	34.9	16.6	31.4	23.3	49.8	19.6
August	34.9	16.6	31.4	23.3	49.8	19.6
September	34.9	16.6	62.3	54.8	62.6	50.3
October	34.9	16.6	62.3	54.8	62.6	50.3

Pasture quality tended to be greater in the presence of *A. longa* at all sites (Table 3). Pastures had higher levels of nitrogen and metabolisable energy and lower amounts of lignin.

Table 3 Pasture quality as measured by NIRS at each site in October 2015.

	Mounganui		Rangitoto		Ballantrae	
	A. longa	No *A. longa*	*A. longa*	No *A. longa*	*A. longa*	No *A. longa*
Nitrogen (%)	3.4	3.0	3.8	3.2	3.4	2.9
Lignin (%DM)	3.0	3.6	2.7	4.0	3.2	5.2
Metabolisable Energy (MJ/kg DM)	11.9	11.1	11.8	11.3	11.8	10.0

Discussion

Pasture growth was found to be higher (5-50%) in areas containing the deep burrowing *A. longa* earthworms than in adjacent areas where they had yet to establish. The differences were more pronounced in autumn, winter and early spring when earthworms are most active. Additional pasture growth at this time of the year has a much greater value to the farm system than additional growth in the summer. Pasture quality was also greater with higher concentrations of nitrogen in the presence of the deep burrowing earthworms. However, caution needs to be taken in the interpretation of these results, as factors other than the presence and absence of *A. longa* that could have contributed to the differences found cannot be excluded from the analysis. Certainly the areas where *A. longa* was present produced more forage and the fact that the results were consistent across the sites, provides some confidence that earthworms (including *A. longa*) had a positive influence on pasture growth, and is likely to be a result of earthworm contribution to nutrient cycling and maintenance of soil structure. Evidence from other studies would also tend to suggest deep burrowing earthworms increase plant growth (Laossi, et al. 2010, Syers and Springett 1984, Vos, et al. 2014).

Differences in pasture production between the earthworm treatments were still apparent after fertiliser application, especially after the addition of superphosphate. The biggest differences in pasture growth were observed at Mounganui, the site where there was also the largest difference in earthworm abundance between plots with *A. longa* and those without. At this site cumulative pasture growth in the presence of *A. longa* was significantly higher under all treatments (control, urea, superphosphate). Here, at Mounganui there were very few earthworms in the absence of *A. longa*, and the difference observed in pasture production between the two treatments highlight the importance of having earthworms in the soil. However, even at the other sites where earthworm abundance was already high, the addition of *A. longa* still stimulated pasture production albeit to a smaller extent.

Fertiliser stimulates pasture growth and indirectly makes more organic matter available to earthworms under both organic and inorganic fertiliser application (Vos, et al. 2014). The application of both superphosphate and urea increased pasture growth in comparison to the control. Under the application of phosphorus, the amount of forage grown in the presence of *A. longa* was greater than where they were absent. In contrast, under the application of urea there was no difference in the pasture response between the two *A. longa* treatments. This may simply reflect the relatively small impact of nitrogen versus phosphorus on the amount of additional forage produced and available for consumption and recycling by earthworms.

Deep burrowing earthworms remain absent from large areas across New Zealand (Schon, et al. 2011). A one off capital investment into the introduction of earthworms has potential to stimulate pasture production by 5-50% and improve herbage quality. An increase in the pasture growth in the order measured in this study would be able to increase stocking rates by two stock units per hectare, similar to that reported by Stockdill (1982). This one off investment into earthworms will increase stocking rates and farm profitability. The stimulation of earthworm functional diversity would appear to be a valuable investment into the future sustainability of our farming systems.

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