Hamilton, D.L. & Brown, J.N., 2023. FIELD TRIALS OF MULTISPECIES PASTURES AND ACTIVE BIOLOGICS TO ENHANCE PRODUCTIVITY AND NUTRIENT UPTAKE. In: *Diverse Solutions for Efficient Land, Water and Nutrient Use*. (Eds C.L. Christensen, D.J. Horne and R. Singh). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 35. Farmed Landscapes Research Centre, Massey University, Palmerston North, New Zealand. 11 pages.

FIELD TRIALS OF MULTISPECIES PASTURES AND ACTIVE BIOLOGICS TO ENHANCE PRODUCTIVITY AND NUTRIENT UPTAKE

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Abstract

The recent New Zealand Government *Essential Freshwater* reforms, including the 190 kgN/ha/yr fertilizer cap for pastoral agricultural systems, are placing increased attention to farming nutrient use efficiency and environmental losses. Additional drivers to reduce overall nutrient inputs are the recent increases in fertilizer prices and scrutiny of fertilizer contributions to farm greenhouse gas emissions.

Lower intensity 'regenerative' agricultural systems may offer alternatives that can be incorporated into existing farms to varying degrees. Multispecies or diverse pastures, involving ryegrass amongst other grass species, various clovers, multiple herbs such as plantain and chicory, and even radish plus sunflowers are under investigation. Benefits can include higher overall dry matter production throughout an entire season and broader nutritional properties. Soil bio-amendments also occupy the regenerative agriculture toolbox. Respond® is a proprietary mix of beneficial soil bacteria and fungi, designed to improve soil health, plant nutrient uptake and boost agricultural productivity.

Testing the combination of Respond®+Multispecies pastures on a dairy farm during 2019/20, using large replicated plots, determined that the Respond®+Multispecies combination boosted dry matter production by 37% over the 6-month trial (above ryegrass/clover controls). Full scale paired-paddock field trials of the Respond®+Multispecies versus existing ryegrass/clover pastures began in December 2020. The Respond®+Multispecies paddocks on average produced 96% higher dry matter over the 12-month trial. Herbage testing showed no significant differences in nutritional properties between the conventional and multispecies pastures. Cows enthusiastically grazed the multispecies sward. Nutrient uptake of the Respond®+Multispecies pastures was high, indicating the combination of active biologics and multispecies sward facilitated nutrient availability from the soil. Mean nitrogen uptake of 481 kgN/ha/yr occurred, despite <150 kgN/ha/yr being applied via effluent over the 12-month trial (no artificial fertilizers were applied). Phosphorus uptake averaged 71 kgP/ha/yr, almost twice that of the ryegrass/clover controls.

The combination of the multispecies sward and active biologics can provide a useful tool for 'growing more from less', thereby helping to implement the *Essential Freshwater* reforms.

Introduction

The recent *Essential Freshwater* reforms have placed increased scrutiny on nutrient use within farming systems to maximize their nutrient use efficiency and minimize losses to the environment (MFE 2020). A total allowable cap on nitrogen fertilizer use of 190 kgN/ha/yr has been applied to pastoral agricultural systems (MFE 2021). Additional drivers to reduce overall nutrient inputs are the rapid rises in fertilizer prices and increased scrutiny on their contribution to farm level greenhouse gas emissions (He Waka Eke Noa 2022).

Lower intensity regenerative production systems may offer alternatives that can be incorporated into existing farming systems to various degrees, depending on farm goals (MPI 2022). Multispecies pastures, involving ryegrass amongst other grass species, various clovers, multiple herbs such as plantain and chicory, and even radish plus sunflowers are being widely investigated. Benefits may include higher overall dry matter production throughout an entire season, increased milk yields and lower environmental losses (Roca-Fernandez et al. 2016; Romera et al. 2017; Malisch et al. 2020; McCarthy et al. 2020; Delaby et al. 2022). Bacterial and fungal soil bio-amendments also occupy the regenerative agriculture toolbox (Dellagi et al. 2020). Combining both soil mycorrhizal fungi and beneficial soil bacteria into a single additive may be a way of rejuvenating beneficial synergistic effects within the soil-pasture system to boost productivity, enhance soil health and reduce nutrient losses (Aislabie 2013; Bender et al. 2015; Dellagi et al. 2020; Banerjee et al. 2022; Argumedo-Delira et al. 2022; Romdhane et al. 2022).

Respond® is a proprietary mix of beneficial soil bacteria and mycorrhizal fungi, designed to improve soil health, plant nutrient uptake and boost agricultural productivity. Using a combination of Respond®+Multispecies pastures, initial large-plot field trials conducted in 2019/20 determined that the combination had boosted dry matter production by 37% over the 6-month trial (above ryegrass/clover controls) (Brown 2020).

The Respond®+Multispecies pastures trial expanded in scale in 2020/21 with the goals of:

1. Trialing Respond®+Multispecies pastures at full paddock scale on a working farm.
2. Boosting farm dry matter production.
3. Testing the nutritional value of the multispecies sward and its acceptability to grazing dairy cows.
4. Increasing nutrient removals from effluent irrigated Cut & Carry areas.

Methods

Trial design

The farms on which the trial took place are part of the Fonterra Pahiatua treated wastewater irrigation system. The farms are irrigated with treated dairy factory wastewater during most months of the year using fixed bayonet irrigators. The farms run a mixed dairying (1.6 cows/ha) and Cut & Carry (C&C) grass silage removal operation (Brown 2016, Brown 2017).

A paired paddock field trial design was selected to maximise both the benefit to the farming system and to have scientific merit through adequate replication. Three paddocks of 2-3 ha in size were chosen, one on each of the farms. These paddocks were O'Brien 3, Tui 17 and FourMac's 26. Each Respond® + Multispecies paddock was paired with an adjacent control paddock of existing pasture of a similar size, same soil type and pasture management. These paddocks were monitored for a full 12 months.

Installation of Respond®+Multispecies mix

Paddocks were sprayed out with weed killer (Roundup) to control existing pasture weeds such as dock and thistle. The sprayed paddocks were then left fallow for three weeks to allow the weed killer to work and for its residues in the soil to degrade prior to the Respond® + Multispecies mix being installed.

Respond® + Multispecies mix were installed in mid-December 2020 (delayed 2 weeks due to very wet weather conditions) using a customised cross-slot drill that installs both the multispecies seed mix (Table 1) together with the liquid Respond® product (1 L/ha) during a single pass of the drill (Fig. 2-4). No ploughing and disking is required and this, together with

the single pass of the drill, helps to minimise soil disturbance and compaction. The paddocks were taken out of the grazing and wastewater irrigation rotations from this time until around mid-January 2021.

Table 1. Multispecies pasture mix for 2020/21 full paddock scale trial

Clovers	Pasture	Other	
Red rascal	Perennial ryegrass	Sunflower	Sheep's burnet
Mid leaf white	Timothy	Hercules plantain	Yarrow
Captain crimson	Meadow fescue	Chicory	Phacelia
	Cocksfoot	Linseed	Grazing lucerne
	Lotus	Radish	

Testing for pasture yield and nutritional value

Pasture 'cages' of 5 x 5 m in area were isolated in each paddock using mobile electric fences (Fig. 1). At roughly 30-day intervals each 5 x 5 m cage was cut using a lawn mower to a standard height of 5 cm. Harvested pasture was collected in a large sack and weighed. Sub-samples were then collected and sent to Hill Laboratories for determination of dry matter, nutritional value and nutrient (N & P) content.

After cutting to determine yield, the cages were moved to a new area within each paddock, which were also cut down to 5 cm. Thus, all yield measurements began from the same standard height of 5 cm. Moving the cages after each cut minimised the influence of inadvertently selecting areas with very low or very high yield due to minor variations in soil nutrient status or compaction.

Figure 1. Respond® + Multispecies pasture about to be cut for the first time to determine yield.

Nutrient and irrigation inputs

All Respond® + Multispecies and control paddocks received regular irrigation with treated wastewater from the Fonterra Pahiatua factory. Monthly treated wastewater inputs averaged 30 mm irrigation depth, 13 kgN/ha and 2 kgP/ha. No other fertilisers were applied, except for 1 T/ha gypsum applied for sodium mitigation.

Figure 2. Cross-slot drill in operation.

Figure 3. Close-up showing one half of the upside down cross-slot T. The green tube delivers seed and black tube Respond ® to the cross-slot.

Figure 4. Paddock surface after Respond® + Multispecies installation.

Results and Discussion

Pasture Yield

The Respond® + Multispecies yield peaked at 3,040 kgDM/ha for Tui 17 for the 1st cut on 14/02/2021, 55 days after installation. FourMac's 26 and O'Brien 3 yielded 2,600 kgDM/ha and 1,750 kgDM/ha respectively (Fig. 5). Control yield was 1,400 kgDM/ha during this period.

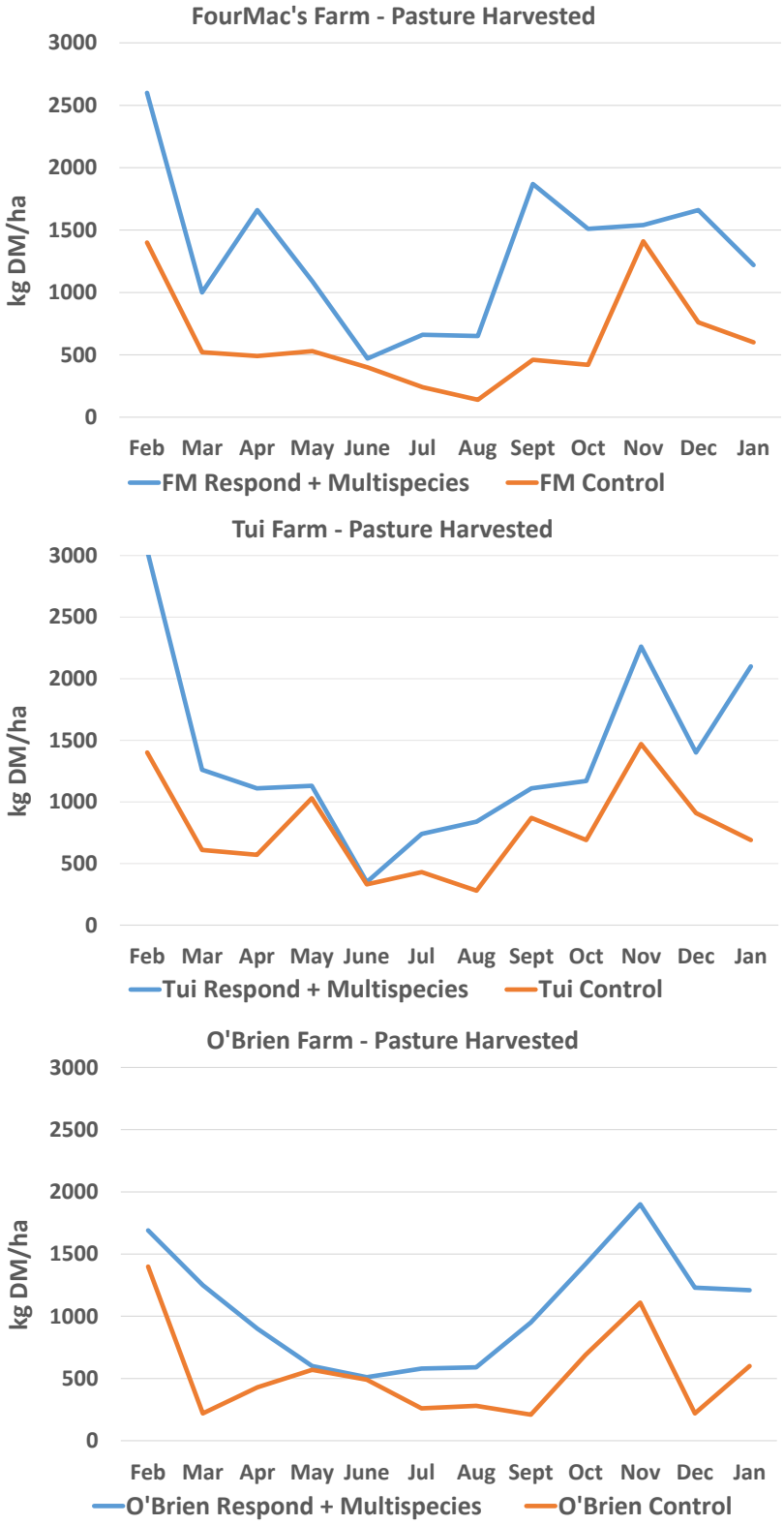

Figure 5. Monthly pasture harvest (kgDM/ha).

Monthly pasture harvest data for the Tui, FourMac's and O'Brien paddocks for the full 12-month period are detailed in Figure 5. The Respond® + Multispecies paddocks grew significantly more dry matter than that measured in the control paddocks for all months except May and June 2021.

The cumulative dry matter production for the full 12-month period is summarised in Table 2 and Figure 6. Pasture harvested from the control paddocks ranged from 6.48 - 9.28 T DM/ha, with a mean of 7.71 T DM/ha. The Respond® + Multispecies paddocks ranged from 12.83 - 16.51 T DM/ha with a mean of 15.09 T DM/ha. The average extra dry matter produced by the Respond® + Multispecies paddocks was 7.38 T DM/ha, which in percentage terms is an increase of 96%.

Table 2. Annual pasture harvest figures

	Tonnes Dry Matter Harvest/ha (12-months)			
	Control	**Respond® + Multispecies**	**Extra**	**% Extra**
FourMac's	7.37	15.93	8.56	116
Tui	9.28	16.51	7.23	78
O'Brien	6.48	12.83	6.35	98
Mean	**7.71**	**15.09**	**7.38**	**96**

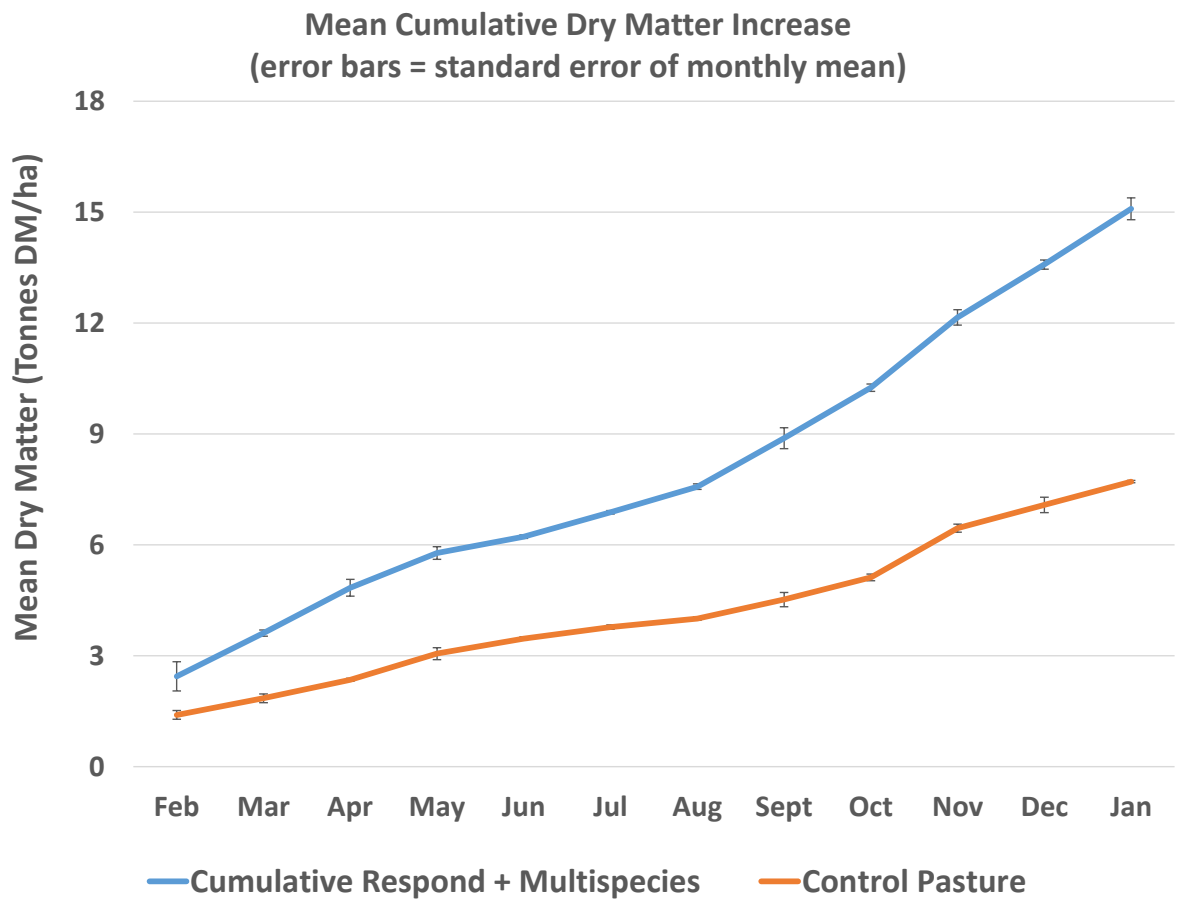

Figure 6. Mean cumulative dry matter harvested over the 12-months Feb 2021 – Jan 2022 (error bars represent the standard error of the monthly mean, n=3).

Nutritional Parameters

Results for the nutritional parameters are summarised in Table 3. As found in the international review of McCarthy et al. (2020), the inclusion of herbs such as chicory and plantain lowers the % dry matter of the multispecies swards. However, there is a significant increase in overall dry matter production from the Respond® + Multispecies paddocks (Table 2 & Fig. 6).

Metabolisable energy of the standard ryegrass/clover and the Respond® + Multispecies sward were the same within experimental error. This also applied to crude protein, both of which were modestly higher than that from McCarthy et al. (2020). DOMD for both treatments was the same. OMD was also the same for both sward types, with the Pahiatua values being slightly higher than those from the McCarthy et al. (2020) review.

Table 3. Average nutritional properties

	Average pasture nutritional properties					
	% Dry Matter	**Yield (T DM/ha/mth)**	**Metabolisable Energy (MJ/kgDM)**	**Crude Protein (%DM)**	**DOMD* (%DM)**	**OMD$ (%DM)**
Ryegrass/clover	18.0	0.64	10.71	21.42	66.91	75.84
Respond® + Multispecies	**15.3**	**1.26**	10.51	22.09	65.69	75.32
Significant difference (paired t-test, p<0.05)						
	Yes	Yes	No	No	No	No
International review (McCarthy KM et al 2020)						
Ryegrass/clover	19.5			18.2		72.8
Multispecies	16.0			17.6		71.5

*DOMD = Digestibility of Organic Matter in Dry Matter $OMD = Organic Matter Digestibility in-vitro

The cows grazed the Respond® + Multispecies paddocks with enthusiasm (Fig. 7), after getting over their initial curiosity with the longer and much more varied pasture being offered. The Respond® + Multispecies paddocks often had to be break-fed due to the much greater amount of dry matter that they contained.

Figure 7. Cows grazing the Respond + Multispecies pasture on FourMac's

The review of McCarthy et al. (2020) reports that grazing multispecies pastures often resulted in increased milk yield. While the Pahiatua share-milkers did report increased milk in the vat after grazing the Respond® + Multispecies paddocks, the multispecies pastures (20 ha over the three farms) did not constitute a high enough percentage of the cow's overall diet to see a clear increase in annual milk solids production.

Nitrogen and Phosphorus Uptake

Individual monthly measurements appeared to suggest that the Respond® + Multispecies swards had at times a higher percentage of both N and P % dry matter values, thus it was interesting to conduct a paired t-test analysis as for the nutritional properties. Mean values are shown in Table 4.

Table 4. Average nitrogen and phosphorus measurements

	Percentage of Dry Matter		Mean Nutrient Uptake	
	% N	**% P**	**N (kg/ha/mth)**	**P (kg/ha/mth)**
Ryegrass/clover	3.43	0.49	18.43	2.70
Respond® + Multispecies	3.54	0.50	**37.13**	**5.49**
Significant difference (paired t-test, $p<0.05$)				
	No	No	Yes	Yes

While the average %N of the Respond® + Multispecies swards was higher than that of the ryegrass/clover, the differences were not statistically significant. Mean %N values for both sward types were slightly below the 'medium range' of 4.0-5.0 %N reported by Hill Laboratories. The values in Table 4 of 3.43-3.54 for %N are typical of those measured on the wastewater irrigation farms which can receive less N than many other pastures. The majority of the wastewater-N comes from slow-release organic-N forms rather than mineral nitrate-N.

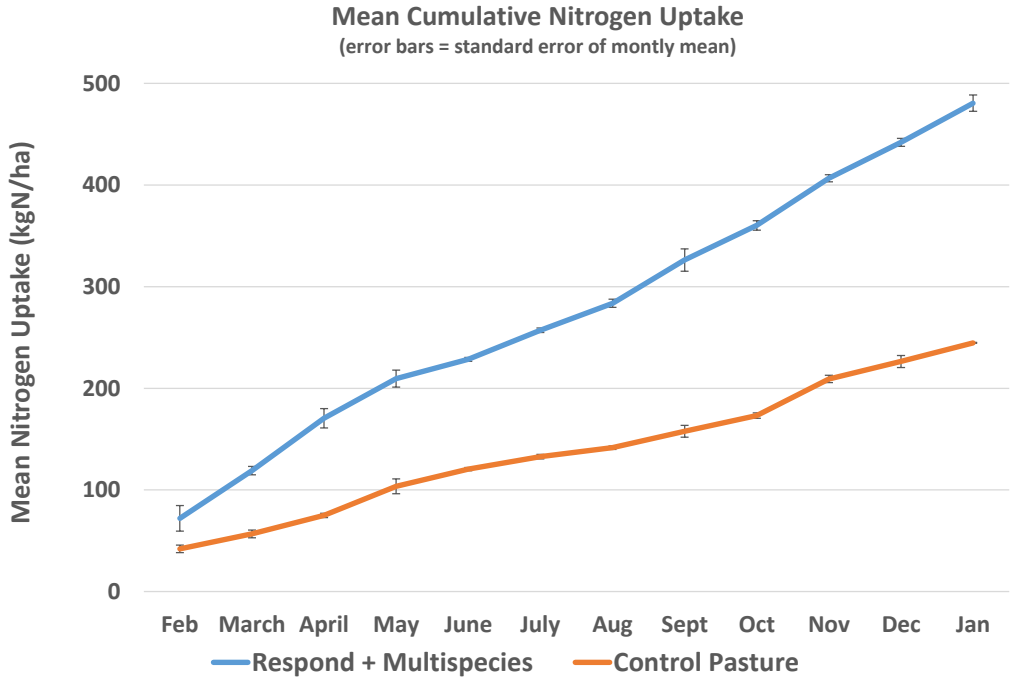

Figure 8. Mean cumulative nitrogen uptake over the 12-months Feb 2021 – Jan 2022

The mean uptake of N of 37.13 kgN/ha/mth by the Respond® + Multispecies swards was significantly higher than that for ryegrass/clover of just 18.43 kgN/ha/mth (Table 4), due to the higher dry matter yield of the Respond® + Multispecies swards (Table 3 and Fig. 6&8).

For P, the average %P of the Respond® + Multispecies swards of 0.50% was marginally higher than that of the ryegrass/clover at 0.49%, but the differences were not large enough to be statistically significant. Both pasture types displayed values for %P that were higher than the 'medium range' of 0.38-0.45 %P reported by Hill Laboratories. This is likely a result of the soils of the wastewater irrigation farms having high soil Olsen P that comes through from the wastewater (Lizarralde et al. 2021 & 2022), allowing the growing pasture to uptake more P than usual.

The mean uptake of P of 5.49 kgP/ha/mth by the Respond® + Multispecies swards was significantly higher than that for ryegrass/clover of just 2.70 kgP/ha/mth (Table 4), due to the higher dry matter yield of the Respond® + Multispecies swards (Table 3 and Fig. 6&9).

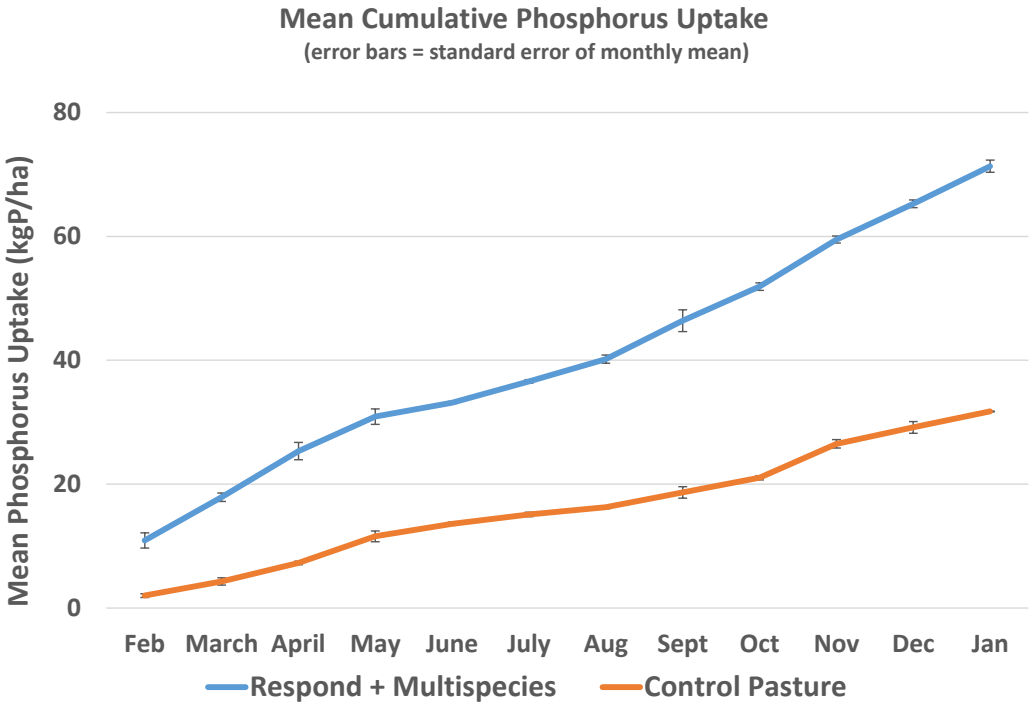

Figure 9. Mean cumulative phosphorus uptake over the 12-months Feb 2021 – Jan 2022

The higher uptake of both N and P by the Respond® + Multispecies swards is best seen by plotting their mean cumulative uptake over the 12-month study period. The total uptake of N for the Respond® + Multispecies was 481 kgN/ha/yr versus 245 kgN/ha/yr for the ryegrass/clover controls (Fig. 8). This equates to an increase of 236 kgN/ha/yr or 98%. A similar pattern was evident for P. Total uptake of P for the Respond® + Multispecies was 71 kgP/ha/yr versus 32 kgP/ha/yr for the ryegrass/clover controls (Fig. 9). This equates to an increase of 39 kgP/ha/yr or 130%.

Environmental implications

The results for the Respond® + Multispecies pastures clearly show a much greater degree of nitrogen uptake from the soils. Nutrient inputs from the treated wastewater irrigation averaged 110 kgN/ha/yr over the 12-month trial period. No artificial N-fertilizer was applied. The

difference between the mean uptake of 481 kgN/ha/yr and that supplied by wastewater was 371 kgN/ha/yr. This nitrogen balance was supplied by a combination of the N-fixing clovers and legumes in the multispecies sward, and by the active Respond® biologics either directly fixing nitrogen into the soils and/or allowing greater access to that already present in the soil profile (Aislabie et al. 2013; Dellagi et al. 2020; Argumedo-Delira et al. 2022; Banerjee et al. 2022). The high rate of nitrogen uptake in the Respond® + Multispecies pastures will likely lower nitrogen leaching losses as compared to the control ryegrass/clover pastures (Bender et al. 2015; Jaramillo et al. 2021).

The significantly higher rates of phosphorus uptake for the Respond® + Multispecies treatment suggest that the added bacteria and fungi were enhancing the availability of phosphorus from within the soil profile (Ferrol et al. 2019; Argumedo-Delira et al. 2022). Several environmentally beneficial outcomes may result from this. Where soil phosphorus is at optimal levels for pasture production, the Respond® + Multispecies combination is likely to be able to maintain high dry matter production with reduced (or nil) inputs from artificial fertilisers. If soil Olsen P levels are above optimal, which is the case for many dairy and wastewater irrigated soils, then the Respond® + Multispecies combination allows an opportunity to over time 'mine' the stored phosphorus from the soil profile, particularly if the pasture is exported as silage or baleage. Reductions in P-fertiliser additions and decreased soil phosphorus are known to reduce losses of phosphorus to surface water (Lizarralde et al. 2021; Smith et al. 2023).

Conclusions

The Respond® + Multispecies pastures significantly increased dry matter production against the ryegrass/clover controls. The nutritional properties of the multispecies sward were similar to those for the conventional ryegrass/clover controls. The dairy cows grazed well on the multispecies sward. The uptake of nitrogen and phosphorus was much higher with the Respond® + Multispecies pastures. The combination of the multispecies sward and active biologics can provide a useful tool for 'growing more from less', thereby helping to implement the *Essential Freshwater* reforms.

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