

final report

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Phosphorus Efficient Pastures:

delivering high nitrogen and water use efficiency, and reducing cost of production across southern Australia

Activity B5. Extending the adaptation range of serradella systems: NSW Southern Tablelands

Output 5(a) - Conduct participatory research trials with farmer groups in areas serradella is not used to examine productivity, persistence and potential use.

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Executive summary

This project, conducted in the Southern Tablelands of NSW, was part of a network of farmer participatory studies in temperate Australia aimed at examining the productivity, persistence and potential use of Serradella (*Ornithopus* spp.). In this region pasture productivity is related to how well the legume component performs. The “legume component” varies from a range of naturalised species in less productive pastures to sown species – mostly subterranean (sub) clover. Nitrogen fixation is a key role played by the legume component as it is the source of most of the nitrogen that the pasture relies on. In order to ensure that legumes like sub clover contribute adequately to pasture production and nitrogen fixation, regular (phosphorus-based) fertiliser applications need to be made – to maintain the soil phosphorus at levels where sub clover production is optimised.

Recent research has shown that Serradella spp. are significantly more efficient at using soil phosphorus (P) than sub clover. The prospect of using more phosphorus-efficient legume species is extremely attractive to producers as fertiliser is the largest non-labour cost in most grazing enterprises in this region. Serradellas are currently used in the Western Australian wheat-belt and on acid soils in Northern NSW but not in the Southern Tablelands of NSW. Replacing sub clover with serradella will require data on its adaptation in a range of environments – namely production and persistence data in the context of a typical perennial pasture and in comparison with sub clover. This project was developed to provide this data from the southern Tablelands of NSW and was conducted in association with the Bookham Agricultural Bureau and the Tablelands Farming Systems group.

Simple experiments were conducted in paddocks on two farms in the region one near Yass, the other near Bigga. In two contrasting locations (varying in soil type and/or landscape) in each paddock a replicated experiment with three legume treatments (sub clover, yellow serradella- Avila and pink serradella - Margurita) each sown with phalaris (a perennial grass species) and replicated 3 times were established in 2017. In line with commercial practice the experiments were not grazed in the year of establishment but then opened to stock thereafter (except for a 6-week period in spring – to measure production). Unfortunately, one of these experiments had to be re-sown in 2018 due to a change in land use by the cooperating farmer. The sites were used not only to provide valuable data but also as focal points for the groups participating in the experiments to learn about serradella and efficient soil phosphorus management.

The two serradella species persisted to varying extents at each of the four sites despite very low growing season (April-November) rainfall in each year, 2017-2019. Each of the three legume species established well in 2017 and contributed significantly to the dry matter on offer in spring of that year. At the sites near Bigga, the serradellas persisted through 2018 and 2019 but at lower levels compared to sub clover – ultimately accounting for only 7-35% of the legume found in those treatments as sub clover and naturalised legumes invaded the serradella plots. At Yass Avila had the highest seedling density by 2019 compared to sub clover and Margurita in the trial sown in 2017. For the trial sown in 2018 at Yass, Seedling density was lower for serradella and, as with Bigga, there was significant invasion of the plots by sub clover and other legume species. The results largely confirm the findings from earlier experiments that found serradella species had higher levels of relative dry matter production at lower soil P than sub clover. This conclusion was made when comparisons between legume cultivars were restricted to instances where plant densities of sown species were comparable.

These results, when considered in the context of the very poor seasons, indicate that there is the potential for serradella species/cultivars to play a role in more P efficient production systems in the Southern Tablelands but there will need to be significant follow-up R&D in order to make this happen. Initially, future R&D on serradella in the southern Tablelands should focus on assessing the fitness of a broader range of germplasm in a wider range of environments. One potential niche for serradella could be lower input native/naturalised pastures in the region. A further area for examination would be the ability of serradella to establish from surface sowing as this is particularly relevant for lower input parts of the landscape (hilly, less arable environments). Further work on weed management in serradella systems would also need to accompany any efforts to further develop these species as the current limited herbicide options could be a significant barrier to adoption.

Finally, having reflected on the successful use of these trials to engage growers in aspects of P management, it is recommended that in future such trials should be contain replicated treatments and produce reliable results but be limited to addressing simple issues using measurements that produce data with comparatively low variance. This could translate into the opportunity to run more sites with less intensive measurement regimes on each.

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1 Background

The southern tablelands of NSW are located in the higher rainfall zone of NSW. In terms of pasture production, pastures typically are based on a mix of species including perennial grasses (both exotic and native), legume components (mostly annual species - sown, spread and/or naturalised) and a range of broadleaf species and annual grasses. This pasture base supports wool, lamb and beef producing enterprises.



Figure 1. Location of Southern Tablelands of NSW.

(https://www.researchgate.net/figure/Map-of-the-Southern-Tablelands-region-of-southeastern-New-South-Wales-showing-the-main_fig1_319207161)

Pasture production relies on maintaining a balance between the legume and non-legume component of the pasture. Typically, the nitrogen (N) input for these pastures is via N fixation for the legume component. The dominant legume found in the region is subterranean (sub) clover which can fix up to 25 kg N per tonne of legume grown (Peoples????). Nitrogen can be applied in the form of urea but this is usually to provide short term boosts to pasture production rather than contributing the overall fertility of the soil.

Historically, there are good examples of increases in productivity after “pasture improvement” from a series of case studies reported in the Department of Agriculture, NSW book entitled “Pastures” (Whittet, n.d.). Much of the “improvement” was due to applications of superphosphate to pastures based on either exotic perennial grasses or native perennial grasses. Through time the increase in legume production would have led to higher levels of nitrogen fixation and greater pasture growth and, in turn, levels of livestock production are markedly increased. The transformational role played by superphosphate is due to that fact that the amount of phosphorus required to maximise legume production is higher than that required to maximise grass production (Fig. 2).

A key to maintaining highly productive pastures is to ensure that the appropriate amount of P is applied to optimise legume production. Researchers have developed the “critical value” approach to managing soil fertility. Hence, for pasture production there is a critical soil P value (using either major tests – Olsen or Colwell) that equate to a near-non-limiting level of pasture production. By testing the soil, the current level of soil P and the critical value can be determined. Managing fertiliser is simply a matter of ensuring the soil test value is near the critical value (see Simpson et al. 2009).

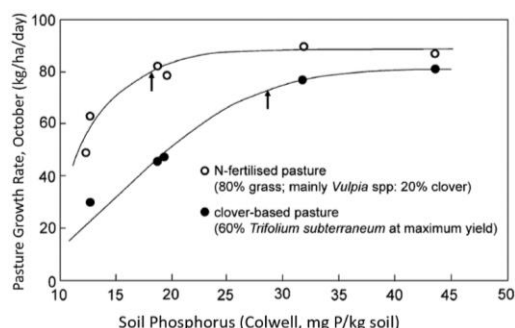


Figure 2. Pasture growth rate versus soil P level in grass dominant (nitrogen fertilised) and clover dominant pastures at Bookham in southern NSW. Arrows indicate the critical soil phosphorus levels for each system. Adapted from Simpson *et al.* (2011).

The determination of the critical value is largely based on the response of the legume component (sub clover) as it plays such a critical role in overall pasture production. Other pasture species, particularly grasses have a lower critical value. For example, Sandral *et al.* (2019) found for Colwell phosphorus test that the critical value was 23 mg/kg for phalaris (cv. Advanced AT) and 33 mg/kg for sub clover (for a range of cultivars). Hence, the frequency and rate of applications of P-based fertiliser is geared to the requirements of the legume component.

On farm, application of P-based fertiliser in this region is profitable but is also one of the largest non-labour costs faced by the producer. This and the finite availability of phosphorus reserves, although not an immediate problem (Cornish 2010), has provided a stimulus to examine legume species for variability of response to P. In short, are there legumes we could use instead of sub clover which have significantly lower critical P values? In turn this has resulted in findings from laboratory, glasshouse and field studies which clearly show that some legume species are much more efficient (dry matter production per unit soil P) than sub clover (Simpson *et al.* 2014; Sandral *et al.* 2019). For instance, a range of serradella species had critical values well below those of sub clover.

Serradella has been cultivated in acidic sandy soils of Western Australia and Northern NSW but has not been broadly examined in other regions. If there were serradella species/cultivars that could persist in pastures of the southern tablelands, then these pastures could be managed to lower levels of soil P with less frequent and/or lower application rates of fertiliser. A reduction of fertiliser inputs would be welcomed by producers as it is a significant item in the annual farm budget. The key question is how well will serradella perform on the southern tablelands?

It should be noted that the introduction and broad-scale adoption of a new pasture species into a system poses significant difficulties. One difficulty is that sub clover, the current dominant legume species, has been developed over a long period. There is an extensive range of sub clover cultivars available varying in response to soil pH, flowering time, hardseededness and waterlogging. In contrast, serradella has attracted far less investment and there are far fewer species/cultivars to test in this environment. Therefore, even if serradella failed to perform adequately in this environment it would not mean that the species is unsuitable but, rather, could mean that the appropriate cultivars are yet to be developed.

The overarching aim of this work was to determine if the productivity and persistence of serradella species was superior to sub clover at soil P levels lower than required by sub clover – in the Southern Tablelands. To answer the question simple experiments were established in paddocks on farm in the

southern tablelands of NSW. Two serradella species Yellow Serradella (*Ornithopus compressus*) and French Serradella (*Ornithopus sativus*) were compared to sub clover at soil P levels that were 50-70% of what is required by sub clover. The trials were to be used as a focal point for participating groups to engage in results coming from these and other outputs from the broader project as well as provide a forum for extension messages regarding phosphorus management.

2 Project objectives

2.1 Extending the adaptation range of serradella systems

The aim of the project reported here was to conduct participatory research trials with farmer groups in areas serradella is not used to examine productivity, persistence and potential use. The project has involved the Tablelands Farming Systems and Bookham Agricultural Bureau groups with one experiment located in each.

2.2 Final Report Requirements

Final report summarising the outcomes from all participatory research activities and the communications and extension activities associated with the sites and farming systems groups. Assess success in meeting the project's original objectives. Outline what has been learned, whether the project will lead to practice change on farms, the new knowledge that has been gained, and future opportunities revealed by the project.

3 Methodology

At two locations – here referred to as Yass and Bigga, paddocks were selected and two sites identified in each paddock. Within the paddocks, sites were located based on variation in soil and/or landscape factors. The sites are referred to as TFS-East, TFS-West (at Bigga and associated with Tablelands Farming Systems) and BAB-Hill and BAB-Flat (near Yass and associated with the Bookham Agricultural Bureau).

A protocol for carrying out these experiments was developed in the early stages of the project. It contained standard methods for design, measurements, sampling, etc.. It will be referred to below as “the protocol”.

3.1 Site Selection

Soils were sampled at potential sites in October 2016 and further sampling took place in December 2016. Four sites on two properties in the Bigga – Reid’s Flat area of the southern tablelands in NSW were investigated. Selection was largely based on the results of soil tests. After the site was selected, it was pegged out and soil was sampled (0-10 cm) in each replicate (averages below, Table 1). Likewise paddocks on two properties were sampled in the Yass area and sites on the Blackburn property identified. The sites were pegged out and each replicate sampled (averages below in Table 1.)

Table 1 Soil [phosphorus (Colwell and Olsen), phosphate buffering index (PBI), calculated critical phosphorus level (Critical P) and pH (CaCl₂).

Location	Site	Colwell P mg/kg	Olsen P mg/kg	PBI	Critical P mg/kg	pH (CaCl ₂)
Bigga	TFSEast	16.9	7.6	60.7	30.1	5.1
	TFSWest	20.8	7.88	59.3	30.0	5.4
Yass	BABHill	9.4	4.7	136.0	36.1	4.8
	BABFlat	9.41	4.8	132.5	35.6	4.9

The phosphorus levels were judged to be appropriate for the comparison of serradella and sub clover – i.e. much closer to the optimum for serradella production and too low for sub clover (i.e. well below critical).

3.2 Trial Design

The experiment at both sites was 3 legume treatments (sub clover (cv. Leura), yellow serradella (cv. Avila) and pink serradella (cv. Margurita)) each to be sown with phalaris (cv. Holdfast GT) and replicated three times. The design was generated in accordance with the protocols and were as follows:

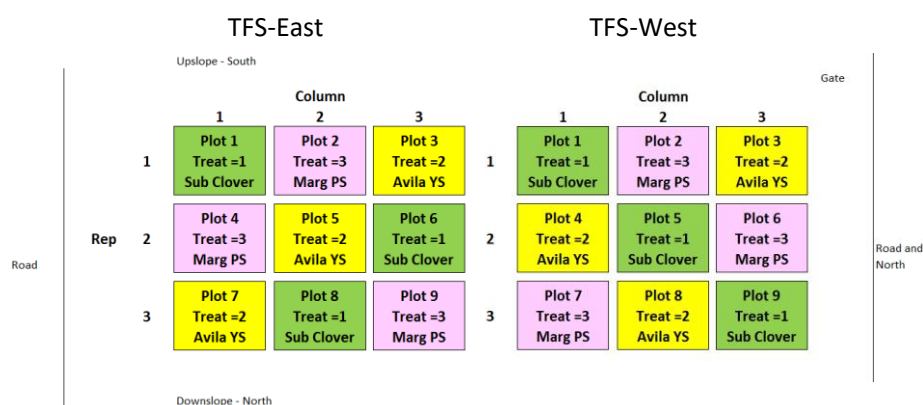


Figure 2. Site plans for TFS-East and TFS-West at Bigga. “YS” – yellow serradella, “PS” – pink serradella.

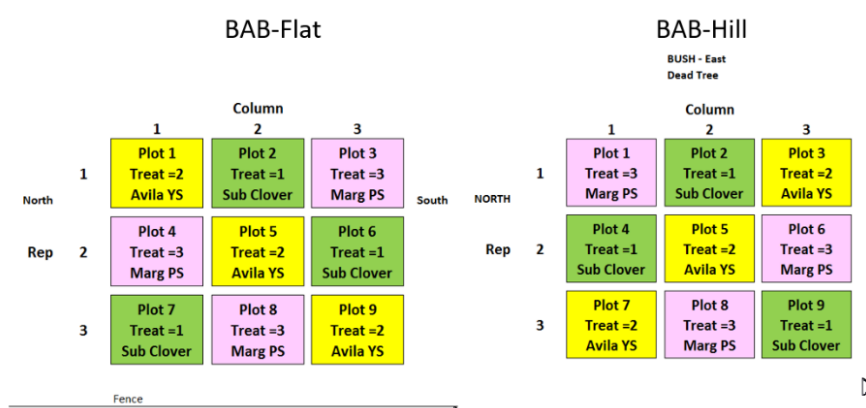


Figure 3 Trial designs for BAB-Hill and BAB-Flat at Yass. “YS” – yellow serradella, “PS” – pink serradella

3.3 Establishment

The sites at Bigga were pegged out on the 12/10/2016 and sprayed out in preparation for sowing on 20/10/2016 with glyphosate by the cooperating producers at commercial rates. Final site preparation took place on May 17, 2017 with an application of herbicide (Glyphosate at 540 g/ha a.i.) immediately prior to sowing. Plots (4 x 10 m) were marked out and then sown with a cone seeder with 18 cm row spacing (Fig. 3, See Plate 9.1). The sowing rate for each species was: phalaris (cv. Holdfast GT) - 5 kg/ha, sub clover (cv. Leura) - 5 kg/ha, yellow serradella (cv. Avila) - 5 kg/ha and pink serradella (cv. Margurita) - 5 kg/ha. Immediately after sowing plots were sprayed with an insecticide to provide immediate and up to four weeks residual control (Bifenthrin 25 g/ha a.i.). The seed was sown with 100 kg/ha of superphosphate (8.8% P) with 0.05% molybdenum.

For the trials located at the Yass site, final site preparation took place on May 18, 2017 with an application of herbicide (Glyphosate at 540 g/ha a.i.) immediately prior to sowing. Plots (4 x 10 m) were pegged and then sown with a cone seeder with 18 cm row spacing (Fig. 3). The sowing rate for each species was: phalaris (cv. Holdfast GT) - 5 kg/ha, sub clover (cv. Leura) - 5 kg/ha, yellow serradella (cv. Avila) - 5 kg/ha and pink serradella (cv. Margurita) - 5 kg/ha. Immediately after sowing plots were sprayed with an insecticide (Bifenthrin 10 g/ha a.i.) for residual insect control and Dual Gold (S-Metolochlor at 192 g/ha a.i.) for control of toadrush (*Juncus bufonius*). The seed was sown with 100 kg/ha of superphosphate (8.8% P) with 0.05% molybdenum.

A decision to place a shelter belt through the BAB-Flat trial meant that it was no longer available – this was unfortunate as all pasture species had established well in this trial. Only establishment, composition and peak dry matter production in 2017 will be presented from this trial. A second trial was sown in the following year and this trial will be referred to as BAB-Flat2.

For the BAB-Flat2 site final site preparation took place on May 29, 2018 with an application of herbicide (Glyphosate at 540 g/ha a.i.) immediately prior to sowing. Plots (4 x 10 m) were pegged

and then sown with a cone seeder with 18 cm row spacing (Fig. 3). The sowing rate for each species was: phalaris (cv. Holdfast GT) - 5 kg/ha, sub clover (cv. Leura) - 5 kg/ha, yellow serradella (cv. Avila) - 5 kg/ha and pink serradella (cv. Margurita) - 5 kg/ha. Immediately after sowing plots were sprayed with an insecticide - Pyrinex Super (Chlorpyrifos at 200 g/ha a.i. + Bifenthrin at 10 g/ha a.i.) to provide immediate and up to four weeks residual insect control. This was mixed with Dual Gold (S-Metalochlor at 192 g/ha a.i.) for control of toadrush. The seed was sown with 100 kg/ha of superphosphate (8.8% P) with 0.05% molybdenum.

3.4 Experiment Management – Weeds, Fertiliser and Grazing

Soils in each plot were sampled each spring. Fifteen cores (0-10 cm depth) were taken from each plot and combined before consignment to the CSIRO laboratories for analysis. Samples were analysed for phosphorus (Colwell and Olsen) each year and potassium and sulphur in 2018. The results were such that for the BA-Flat2 site, 190 kg/ha of Muriate of Potash (50% K) was spread across the site on 6/8/2018. No other fertiliser was spread on the sites throughout the experiment as (see below) the phosphorus values were at or near the theorised optimum for serradella production.

After herbicide application at establishment no other herbicides were applied to the plots throughout the experiment. Weed control was via hand rogueing – with saffron thistle (*Carthamus lanatus*) as the target species. Other weed species that invaded the plots – e.g. chickweed (*Cerastium glomeratum*), capeweed (*Arctotheca calendula* L.), Vulpia spp., sorrel (*Rumex acetosella*) were not managed.

Each experiment was meant to be grazed in common with the surrounding paddock as managed by the co-operating producer. During the establishment year (2017 for all but BAB-Flat2 – 2018) plots were not to be grazed until after December. An establishment failure in the surrounding paddock at Yass in 2017 meant that the paddock was re-sown in 2018 and thus not grazed until the summer of 2018/'19 but the site was mown in 2018 at the time of locking up. The timing of plot opening and closing is presented in Table 2 (next section).

3.5 Measurements

Measurements to be taken on the trials were agreed to by participants. These included annual measurements of serradella and sub clover density, serradella and sub clover frequency, botanical composition in spring and dry matter in peak (or mid-late) spring. The methodology for measurements was set out in the protocol and are briefly described here. The timing of all measurements and activities is set out in Table 2, below.

Table 2 Timing of measurements and activities at each of the sites.

Site	Year	Measurement/Activity					
		Sowing	Seedling	Frequency	Lockup	DM and Comp ¹	Soil Sample
TFS-West	2017	17 May	21 Jul			13 Oct ²	13 Oct
& -East	2018		6 Aug	19 Jul	6 Sep	18 Oct	6 Sep
	2019		9 May	30 Aug	30 Aug ³	17 Oct	17 Oct
BAB-Hill ⁴	2017	18 May	21 Jul			10 Nov	10 Nov
	2018		6 Aug	17 Jul	6 Sep	18 Oct	6 Sep
	2019		9 May	6 Sep	6 Sep	17 Oct	17 Oct
BAB-Flat2	2018	29 May	6 Aug			18 Oct	3 Dec
	2019		9 May	6 Sep	6 Sep	17 Oct	17 Oct

¹ Dry Matter and botanical composition² Dry Matter not cut until 22 Dec³ TFS-East 5 Sep⁴ Bab-Flat all same dates in 2017

3.5.1 Seedling density

For the establishment year seedlings were counted, 10 separate 0.5 m rows. In all other years, seedlings were counted in 10, 5 cm x 5 cm squares across a “mesh” quadrat (50 cm x 50 cm quadrat containing 100, 5 x 5 cm squares). Five measurements were made per plot and the average recorded. Measurements were taken in the winter of 2017, 2018 and 2019.

3.5.2 Frequency

The presence of serradella and sub clover was counted in each of 100 squares in the quadrat described above. The percentage of squares occupied was recorded for 5 quadrats per plot. This measurement was taken to reflect persistence and was made in winter or early spring in 2018 and 2019 on sites established in 2017 and in 2019 only for the BAB-Flat2 site.

3.5.3 Dry Matter

The purpose of this measurement was to reflect the relative productivity of the treatments. At the end of the lock-up period, cuts to ~ 1 cm above ground level were taken from 10 x 0.1 m² quads in each plot. The 10 cuts were bulked into a single sample per plot. Depending on the amount of dry matter cut, the samples were either weighed fresh in the field and a sub-sample taken to determine moisture content (after drying at 80°C for at least 48 h), or the entire sample was dried (as above) before weighing.

3.5.4 Botanical Composition

Visual estimates (uncalibrated) of botanical composition were made on pasture within 10, 0.1 m² quads in each plot. The apparent percent contribution of six categories (serradella, sub clover, sown perennial species, annual grasses, broadleaf species, other species) were recorded. In addition, notes were made of the major weed species present on a plot basis.

3.5.5 Soil Sampling

Each year (see Table 2) soil was sampled and analysed. Fifteen samples (to 10 cm depth) were taken in each plot. These were homogenised but not sub-sampled before dispatch to the CSIRO laboratories for analysis. Analysis of phosphorus (Colwell) for each plot. Potassium and sulphur were also analysed but on a replicate basis.

3.6 Analysis

Weather data was obtained from the SILO web site (<https://www.longpaddock.qld.gov.au/silo/>) in Apsim format for each site from 1961-2019. This data was used to model pasture growth and water use at the sites with GrassGro (Moore et al. 1997) using a standard farming system that was based on a phalaris, annual grass and sub clover pasture on a typical soil type and grazed by 12 wethers/ha. Full details can be obtained from the author. The key output from the model was potential evapotranspiration based on a short-grass pasture.

Statistical analysis was performed using R. All analyses were simple analysis of variance using treatment as the only factor. Essentially this meant analysing the trials as completely random designs. Least significant differences were calculated at $P = 0.05$.

4 Results

4.1 Weather

The experiments reported here were conducted in years with relatively low rainfall (Table 3). Annual and Growing season rainfall in any year was no higher than the 40th centile (1961-2019). In particular, both 2018 and 2019 were very poor years. In order to estimate potential evaporation, the weather data was used to model pasture growth using GrassGro. The results are shown in Figures 4 and 5 from the Bigga and Yass sites, respectively. In particular, for both sites, lack of spring rainfall was a feature of these years compared to the median. For both sites, median values reflect an excess of moisture over the winter months

Table 3. Rainfall from the SILO database obtained from <https://www.longpaddock.qld.gov.au/silo/>. Centiles are based on data from the 1961-2019 period. Growing season rainfall (GSR) calculated over the months of April to November.

	Bigga rainfall (mm)		Yass rainfall (mm)	
	Total (centile)	GSR (centile)	Total (centile)	GSR (centile)
2017	702 (31)	383 (17)	659 (36)	378 (12)
2018	550 (12)	373 (15)	523 (10)	311 (8)
2019	502 (10)	274 (5)	496 (8)	253 (5)
Median	856	559	756	498

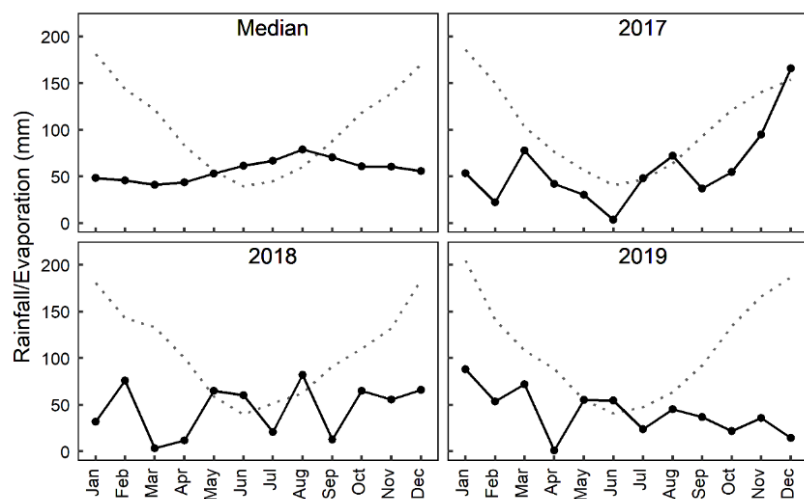


Figure 4 Rainfall (solid line, from the SILO database) and predicted evaporation (dotted line, from GrassGro model) for the Bigga sites. Median taken over the years 1961-2019.

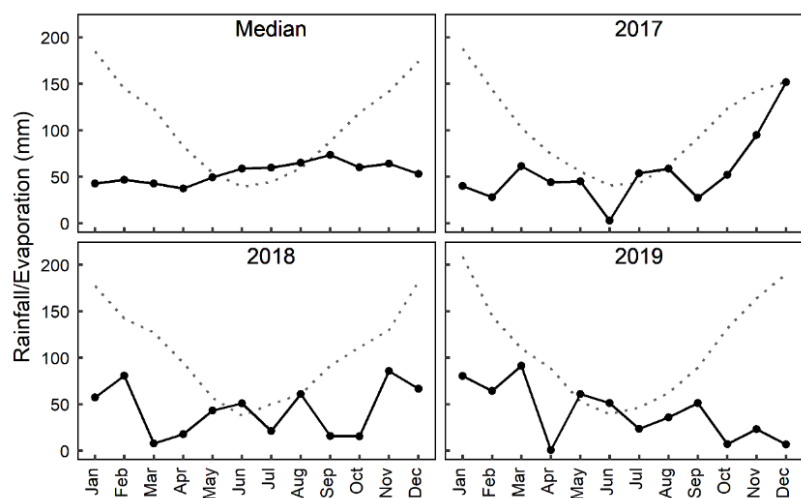


Figure 5 Rainfall (solid line, from the Silo database) and predicted evaporation (dotted line, from GrassGro model) for the Yass sites. Median taken over the years 1961-2019.

4.2 Soils

Soil phosphorus was allowed to decline over the 2017-2019 period at all sites. This meant that after establishment no extra phosphorus based fertiliser was applied at any of the sites. The result is a clear decline across the sites (Figure 6) with the apparent exception of the BAB-Flat2 site. However, the "2017" data from BAB-Flat2 is actually from samples taken prior to sowing the site on 18 May 2018. The increase in soil P from this time to October 2018 at this site followed an application of

fertiliser (100 kg/ha superphosphate ~ 8.8% phosphorus) at sowing on 29 May 2018. The soil results were analysed using a simple completely random design with treatment as a factor. In each year and at all sites there were no significant effects of treatment on soil test P except at the TFS-East site in 2017 with Sub Clover (25.2 mg/kg) greater than Avila (20.3 mg/kg) and in 2019 at the BAB-Hill site with Margarita (11.1 mg/kg) significantly greater than Avila (8.3 mg/kg) and Sub Clover (7.9 mg/kg).

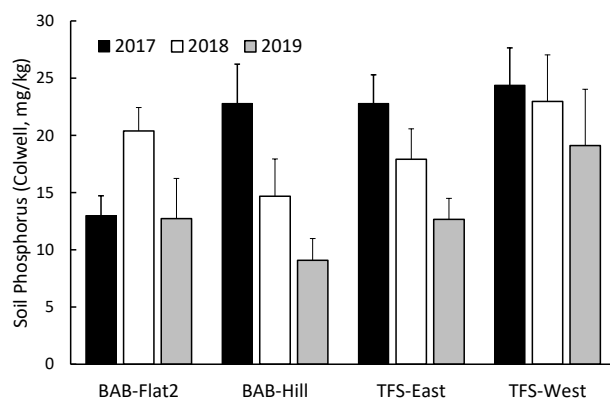


Figure 6 Soil phosphorus (Colwell, mg/kg) for each of the sites measured from soils sampled in spring or early summer. Note the BAB-Flat2 site, the 2017 value was from samples taken in May 2018 before sowing (see text). Error bars represent one standard error.

4.3 Establishment, Production and Persistence

The key pasture outputs reflecting the performance of the serradella and sub clover treatments are presented in Tables 4 and 5 (following sections) and include:

- “Total Dry Matter” – the total dry matter harvested after the spring lock up period (usually in mid spring)
- “Legume Dry Matter” – legume dry matter derived by multiplying total dry matter by the estimated proportion of legume (all legume species) present.
- “Proportion Legume Sown” - the proportion of Legume Dry Matter accounted for by the sown legume species. Note with respect to sub clover there is probably an upward bias due to difficulty in differentiating sub clover dry matter from that of naturalised species.
- “Frequency Sown Legume” – frequency of the sown legume in each treatment, an indicator of persistence
- “Density Sown Legume” seedling density of the sown legume species, used to gauge the effectiveness of establishment and species regeneration in proceeding years.

Treatments are referred to as “Avila” – for yellow serradella (cv. Avila), “Margurita” – for pink serradella (cv. Margurita) and Sub Clover for subterranean clover (cv. Leura).

4.3.1 Sites at Bigga

Each of the legume species established satisfactorily at both sites (Table 4 - 2017 data, see Plate 9.2). The seedling density of Margurita was significantly higher than those of Avila or Sub clover at TFS-

East with no treatment differences at TFS-West. Sub clover was not found in the plots sown to serradella at either site. Regeneration of the sown species was evident in all plots in 2018 and 2019 but the seedling density varied widely. In 2018 Avila had the highest number of seedlings on both sites (only significant at TFS-East) and in 2019 Sub clover had the highest seedling counts (significantly only at the TFS-West site).

Frequency measurements were made to reflect persistence of the various species. At the TFS-East site there were no significant differences in frequency between species in either 2018 or 2019 (Table 4). In contrast, at the TFS-West site in 2019 the frequency of Margurita was significantly less than that of either Avila or Sub Clover. It interesting to note that Margurita did have the lowest mean frequency (not significant) at the TFS-East site in 2019. Also Sub Clover had the lowest frequency at both sites in 2018 but this had little impact on levels in the following year (or 2019 seedling densities).

At both of the Bigga sites, after the first year there was no effect of treatment on total dry matter production or legume dry matter production, in spring (Table 4). The high levels of production in spring 2017 were, most likely, the result of stored soil moisture (pre-sowing fallow) and adequate spring rainfall. In 2018 and 2019 low spring rainfall reduced production significantly. In particular, by the time dry matter cuts were made in spring 2019 (17 Oct) almost all the legume present was dead – with the exception of naturalised legumes (in particular, *Trifolium glomeratum* – cluster clover) which had re-established on the plots.

The proportion of legume dry matter contributed by the sown species provides some useful insights on the performance of the two serradella species. For reasons stated above, this measurement is less useful for sub clover but can be relied upon for the serradella species. In 2019, the sown species only accounted for low proportions of the total legume present – at TFS East 17% and 22%, and at TFS-West 35% and 7% for Avila and Margurita respectively. Hence, most of the legume in both treatments was not serradella.

Table 4. Key pasture measurements for the Bigga sites, TFS-East and TFS-West 2017-2019. See text for explanation of the variables. Treatment means followed by different letters differ significantly ($P < 0.05$) between rows, within years and sites.

Site	Treatment	Total Dry Matter (kg/ha)	Legume Dry Matter (kg/ha)	Proportion legume sown	Frequency Sown Legume (%)	Density Sown Legume (m ⁻²)
2017						
TFS-East	Avila	6531 ^a	1984 ^{ab}	100	-	57 ^b
	Margurita	7600 ^a	2929 ^a	100	-	101 ^a
	Sub Clover	4481 ^b	1111 ^b	100	-	61 ^b
	2018					
	Avila	3034	979	65 ^b	44	941 ^a
	Margurita	2494	713	65 ^b	34	483 ^b
	Sub Clover	2728	843	100 ^a	33	243 ^b
	2019					
	Avila	1153	558	17 ^b	74	453
	Margurita	1087	505	22 ^b	64	381
	Sub Clover	907	471	94 ^a	98	525
2017						
TFS-West	Avila	4512 ^b	1399 ^b	97	-	49
	Margurita	6061 ^a	2544 ^a	100	-	86
	Sub Clover	4031 ^b	983 ^b	100	-	55
	2018					
	Avila	2505	803	59 ^b	67 ^a	1203
	Margurita	2213	626	64 ^b	53 ^{ab}	725
	Sub Clover	2588	728	100 ^a	44 ^b	840
	2019					
	Avila	480	204	35 ^b	88 ^a	499 ^a
	Margurita	600	240	7 ^c	43 ^b	109 ^b
	Sub Clover	713	389	100 ^a	91 ^a	600 ^a

The proportion of legume dry matter contributed by the sown species provides some useful insights on the performance of the two serradella species. For reasons stated above, this measurement is less useful for sub clover but can be relied upon for the serradella species. In 2019, the sown species only accounted for low proportions of the total legume present – at TFS East 17% and 22%, and at TFS-West 35% and 7% for Avila and Margurita respectively. Hence, most of the legume in both treatments was not serradella.

4.3.2 Sites at Yass

Establishment was successful at both BAB-Hill and BAB-Flat sites in 2017 with average seedling density of sown legume species above 100 m⁻² in all treatments. Unfortunately, the BAB-Flat site could not be used on a continuing basis so a second sowing took place in 2018 on the BAB-Flat2 site. Under the drier conditions of that year, seedling density was barely adequate in the Margurita and Sub Clover treatments. Sub clover was also found in the Avila and Margurita treatments at each site averaged across these treatments the densities of sub clover were 5.8 m⁻², 8.4 m⁻² and 7.1 m⁻² for the

BAB-Flat, BAB-Hill and BAB-Flat2 sites, respectively. Hence, it is likely that the actual density of sown sub clover was lower than counted. In 2018 at the BAB-Hill site, there a large variation in seedling density between plots – hence although there were sizeable difference between the mean densities one of these were statistically significant. In 2019 at this site, Avila had a much higher seedling density than the other two treatments. At the BAB-Flat2 site 2019 was the only regeneration year and seedling densities were much lower than those found on the BAB-Hill site. Sub Clover has greater sown density than either of the serradella species all at levels less than 400 m⁻².

Table 5. Key pasture measurements for the Yass sites: BAB-Hill, BAB-Flat (2017) and BAB-Flat2 (2018-19). See text for explanation of the variables. Treatment means followed by different letters differ significantly ($P < 0.05$) between rows, within years and sites.

Site	Treatment	Total Dry Matter (kg/ha)	Legume Dry Matter (kg/ha)	Proportion legume sown	Frequency Sown Legume (%)	Density Sown Legume (m ⁻²)
2017						
BAB Hill	Avila	369	162 ^d	95	-	130
	Margurita	439	278 ^a	98	-	203
	Sub Clover	273	114 ^d	100	-	142
	2018					
	Avila	2303	1162	75 ^b	70 ^b	1384
	Margurita	2216	687	69 ^b	54 ^c	517
	Sub Clover	1898	731	95 ^a	92 ^a	1179
	2019					
	Avila	3647	2053	96	66	1517 ^a
BAB Flat	Margurita	2845	1460	95	59	704 ^b
	Sub Clover	3132	1097	100	54	611 ^b
	2017					
	Avila	426 ^{ab}	125 ^b	94	-	116
	Margurita	464 ^a	253 ^a	100	-	181
	Sub Clover	349 ^b	140 ^b	100	-	135
	2018					
	Avila	337	70	25	-	119 ^a
	Margurita	372	91	65	-	29 ^b
BAB Flat2	Sub Clover	357	66	71	-	44 ^b
	2019					
	Avila	1352	406	19 ^b	38 ^c	189 ^b
	Margurita	1324	300	16 ^b	17 ^b	131 ^b
	Sub Clover	1634	417	99 ^a	59 ^a	389 ^a

Frequency results also reflect the high levels of persistence at the BAB-Hill site compared to the BAB-Flat2 site. For the BAB-Hill site, frequency varied significantly in 2018 with sub clover the highest (92%) and Margurita the lowest (54%). In 2019, all species had similar frequencies (59-66%) and did not significantly differ. Frequency of serradella and sub clover at the BAB-Flat2 site in 2019 reflect the poor establishment of serradellas from 2018 and better apparent persistence of sub clover.

There was no evident effects of treatment on either total or legume dry matter production in spring. In 2017 on the BAB-Hill and BAB-Flat sites, the Margurita treatment produced more legume dry matter than the Avila and Sub Clover treatments. Other than those, there were no other significant

effects including the re-sown BAB-Flat2 site. It is worth noting that the sown legume species accounted for almost all (>95%) of the legume dry matter at the BAB-Hill site by the end of the experiment (2019) whereas the serradella species made up less than 20% of legume dry matter in 2019 at the BAB-Flat2 site.

Finally although not captured in the data, it was clear that both serradella species had the capacity to respond (increase growth) to the late spring rainfall events in 2017 and 2019 at the BAB-Hill site. In contrast, sub clover had matured by this time and could not respond.

4.4 Engagement

As stated above, the aim of the project reported here was to conduct participatory research trials with farmer groups in areas serradella is not used to examine productivity, persistence and potential use. In turn, the trials were to be used as a focus for communication and engagement. The two participating groups, Bookham Agricultural Bureau and Tablelands Farming Systems, played an important role in ensuring that their members and, where possible, the wider community were engaged not only in the results from the trials reported here but those being produced from research activities within the RnD4Profit-15-02-016 Phosphorus efficient pastures project.

Introductory events were held at both sites for members of the participating groups – a twilight pasture walk at Bigga on 4 Dec 2017 (Plate 9.3) and a pasture walk incorporated with a seminar on managing soil phosphorus at Blackburn on 30 Jan 2018.

After the initial events participating group members were kept engaged in the project through a number of presentations. In both 2018 and 2019 joint group updates (Bookham Ag Bureau and Tablelands Farming Systems - TFS) were incorporated into Field Days held at the Merrill research site (managed by Richard Hayes). These events took place on 5 Dec 2018 (Plate 9.4) and 12 Nov 2019.

At the 2018 field day producers were surveyed to gauge their knowledge and attitudes regarding soil phosphorus management and legume response. The results and interpretation are provided in Appendix 9.1. In brief most participants (65%) understood the concept of critical soil phosphorus levels and 70% could nominate a critical soil P level. However, only 24% could nominate a typical phosphorus buffering index for their soil(s). Producers demonstrated a sound knowledge of legume management on issues related to soil P and beyond. Almost all growers (94%) knew that critical soil P varied between pasture legume species and 82% of growers knew that serradella had a lower critical P than sub clover. Whilst growers knew that serradella sets seed aerially (82%) they questioned whether serradella could persist in the Southern Tablelands environment (82% unsure). The various activities associated with the project had helped growers appreciate the central role of soil testing with 82% agreeing with the need to test more frequently and 94% intending to test more paddocks.

In addition, updates on progress of the project were provided at meetings of the TFS Soils Club, on 12 April 2018 and 16 April 2019. Results from the trials as well as the broader project were also highlighted in talks given by the author at the following meetings:

- Tarcutta Landcare Group (Feb 2019)

- Kyeamba Landcare Group (Mar 2019)
- Grasslands Society of Southern Australia (Jul 2019)
- Graham Centre Livestock Forum (Jul 2019)

5 Discussion

The aim of this work was to conduct participatory research trials that were designed to compare the performance of two serradella species versus sub clover under soil phosphorus conditions that were sub-optimal for sub clover. Although there are clear indications from the trials that serradella has potential as a useful pasture species in the region, there was no evidence that it was superior in terms of persistence or productivity compared to sub clover. Before considering this conclusion further, it is important to address the conditions under which the trials were conducted.

5.1 Weather and Soil

The data in Figures 4 & 5 clearly shows that rainfall was below median in autumn and spring of all years during the trial which occurred in what is now recognised as a widespread drought in Eastern Australia. At both sites, paddocks were fallowed over the summer of 2016-17 and with the rainfall that did occur in May 2017, conditions were adequate for establishment. In contrast, establishment was far worse in 2018 due to the rainfall being significantly lower than median over autumn and winter. In 2017 early spring rainfall was poor but significant falls at both sites from mid-October meant that seed set in the establishment year occurred under favourable conditions. In 2018 and 2019 rainfall (annual and growing season) was historically low at both sites (less than 20th centile – Table 3). This had a clear impact on pasture growth as reflected in spring dry matter (Tables 4 and 5). At no time in the 1961-2019 period had there been successive sub- 20th centile years for either total or growing season rainfall until 2018 and 2019. Hence, soil moisture conditions were very low by the conclusion of the trial in summer 2019 and the production in spring of that year was much lower than would be expected in a median rainfall year. On this basis the persistence of serradella, particularly yellow serradella, was of some interest. This may have been due to the deeper rooting habit of serradellas in general (Ozanne et al. 1965), but even that is of little advantage once available soil moisture is exhausted. The weather conditions may have favoured serradella in another way. It is widely recognised that serradella does not tolerate waterlogging.

Soil conditions also should be considered when comparing serradella with sub clover. The critical value for sub clover on these soils, as derived from the phosphorus buffering indices (Table 1) are approximately 30 mg/kg for Bigga (TFS sites) and 36 mg/kg for Yass (BAB sites) locations. Soil phosphorus, after sowing was allowed to decline from values in the 20-25 mg/kg range as no further P-based fertiliser was applied. As a result, P levels fell considerably by the conclusion of the trial: BAB-Flat2 - 12.7 mg/kg, BAB-Hill 9.1 mg/kg, TFS-East, 12.7 mg/kg and TFS-West – 19.1 mg/kg. In terms of P alone, these conditions should have favoured serradella as demonstrated by Sandral et al. (2019).

5.2 Serradella versus sub clover

5.2.1 Establishment

There were four sites in this series of trials but as one site had to be abandoned 8 months after sowing and a further site established in 2018 (BAB-Flat2) this meant that there are 5 site-years of data available on establishment. In 2017 serradella established as well if not at higher seedling numbers than sub clover (Tables 4 and 5) on all sites. The levels of sub clover in the serradella plots (from background populations) were very low – none at the TFS sites and below 10 m⁻² on average at the BAB sites. Spring legume production in 2017 also reflect the success of establishment – each species accounting for a significant proportion of the total dry matter when harvested. In short the trials demonstrated the ability of yellow and pink serradella to achieve adequate populations when sown in May on the southern Tablelands

5.2.2 Persistence

Two measurements contribute to an appreciation of differences in persistence from these trials: frequency and proportion of the legume dry matter accounted by sown species. In terms of frequency, the results are mixed. By 2019 at the TFS-West sites frequency was higher for Avila and Sub Clover than for Margurita, whereas at TFS-East there were no significant differences. At the BAB-Hill site there was no difference in frequency between treatments but the levels of frequency (above 50%) combined with subsequent legume production reveal adequate persistence (Table 5). In contrast, at the TFS sites, the dry matter results reveal that whilst present, the two serradella species were not the major species contributing to legume dry matter on those plots (Table 4). As noted above any comparison, on the basis of proportion of sown legume in legume dry matter, with sub clover should not be made as it is difficult to differentiate sub clover from other clover species when making visual estimates of composition. However, the proportion of sown legume in the Avila and Margurita treatments reveal considerable invasion by other legumes species (including sub clover) into these plots. Frequency data from the BAB-Flat2 site reflects regeneration after the establishment year and given this short period and the poor establishment results, will not be considered here.

In summary, persisted results were mixed depending on the locations. Both serradella species persisted at each of the sites but there were signs at the TFS sites that other legume species were contributing more dry matter than either of the serradella species. At the BAB-Hill site this was not the case – serradellas persisted and dominated the legume component (see Plate 9.5).

5.2.3 Dry Matter Production

Measurement of dry matter production was restricted to a single period – ideally the first 6 weeks of spring each year and meant to reflect peak spring growth rate. Trials were not fenced in the establishment year – as they were located in paddocks that were also being established and were unlikely to be grazed. At Bigga (TFS) the co-operator started grazing the surrounding paddock in September – which meant the plots were grazed as well. As a result the measurements that were meant to be taken in mid spring were delayed significantly – until 22 December. At other sites and in other years the measurements took place much closer to mid-October (Table 2). In general, neither total dry matter nor legume dry matter were affected by treatment at any of the sites after the

establishment year. This observation held regardless of the level of contribution that the serradella species made to legume production.

There are similarities and contrasts with results (obtained in the southern Tablelands) that demonstrated superior phosphorus use efficiency by both pink and yellow serradella compared to sub clover (Sandal et al. 2019). In those experiments both serradella species achieved greater growth at much lower soil P than sub clover *relative* to the maximum growth at unlimited P supply for each species, respectively. Sandral et al. (2019) found yellow serradella had lower yield at high levels of soil P than sub clover. The results from the trials are consistent with this finding in that yellow serradella was growing closer (slightly below) its critical soil P and sub clover well below its critical soil P. Hence in absolute terms, sub clover could grow as well as yellow serradella at low P but well below its potential growth at higher levels of soil P. Sandral et al. (2019) found that pink serradella (cv. Margurita) could grow as well as sub clover at their respective critical soil P levels. However, the results from these trials are mixed with respect to the performance of Margurita. On five occasions the sown legume species accounted for greater than 90% of legume production in spring. On four out of five of those occasions (ie each trial in 2017 – see Tables 4 and 5), Margurita produced significantly more dry matter than sub clover. Sown legume accounted for 90% of legume production at the BAB-Hill site in 2019 and while there were no significant differences in legume production, it is interesting to note that the two serradella species averaged greater dry matter production than sub clover. On all other occasions, there were no significant effects of treatment on legume dry matter in spring but this may have been due to the decreased prevalence of serradella in those site/year combinations. The results obtained by Sandral et al. (2019) were obtained from plots that were near-monocultures (above 90% sown legume; Sandral, pers. comm.) because they were reseeded in each year at very high rates. We can conclude that these trials have, in the main, confirmed the superior phosphorus use efficiency of pink serradella at low soil P. However, such confirmation can only be expected where sown legume species dominate the total legume production of the pasture. If plant density was sub optimal for dry matter production then it is possible that responses to soil P levels, in term of dry matter production, were not fully expressed.

There are other influences on production that may have had an impact on the dry matter results. The work reported by Sandral et al (2019) was performed on monocultures of each of the legume species. The trials being considered here were sown with phalaris (*Phalaris aquatica*) as it is common practice by most producers in the region. Hence, the dry matter response of the legume species which represents less than half of total dry matter would have been significantly dampened. The trials reported here were grazed up until early spring in 2018 and 2019 whereas dry matter harvested in the work by Sandral et al. (2019) represented all growth from establishment up until harvest (approximately 6 months). So the time frame to express differences in growth rate was limited. This combined with poor growth conditions in 2018 and 2019 may also have contributed to absence of any significant difference in production between the treatments.

In short, it is worth considering that results from these trials, designed to examine the productivity, persistence and potential use of serradella in novel environments, were only in agreement with previous results when sown legumes dominated legume production ie similar under conditions that were similar to previously published work. When other legume species invaded plots sown to serradella then, naturally, expression of superior P use efficiency was masked.

Commented [A1]: I assume you meant 2018 and '19 not 2017 and '18?

5.3 Farm-relevant trials – limitations and opportunities

These trials were designed to both provide useful data on the performance of serradella relative to sub clover and as a focus for engagement of participating farming groups. The sites have provided positive results in terms of the ability for serradella to establish and persist in some environments in the Southern Tablelands region. This is particularly important in terms of regeneration – there has been little work on serradella pastures in the region and, as a result, very little data on persistence. The persistence data is particularly regionally relevant because each of the legume species was sown in pasture mixes commonly used on local farms. The establishment and persistence data from these trials is therefore, valuable and can be used to help in direction-setting for future serradella research.

The absence of any influence of legume species on production characteristics has been partly explained in the previous section. There are other limitations to the design and conduct of these trials that could also have contributed to the results obtained. The resources and intensity of measurements that characterise proper agronomic research cannot be applied to trials like these. Hence, there are fewer replicates and fewer measurements. As a result, variance of measurements is high and statistical significance more difficult to demonstrate than it would be for routine agronomic research. The question arises...does this really matter?

Firstly, the trials have been used to focus the attention of growers on phosphorus management and this has been a useful by-product of the participation of the groups. At every meeting or field walk, key elements of soil phosphorus management were explained and outlined. Secondly, growers were able to witness serradella growth in the field and build familiarity with the species. This will help contextualise other outputs from the broader project as they are converted into key messages. In short, none of the deficiencies of the conduct or results from the trials have any influence on these outcomes. The main point is that there were trials acting as focal points during the project.

This raises yet a deeper question. Did the focal point have to be small replicated trials? On one hand, we have seen above that the trials had significant statistical limitations. The trials were designed as a latin square with replication in rows and columns but the data had to be analysed with treatment as the only explanatory factor ignoring row or column otherwise degrees of freedom were too low for analyses to be of much use. In addition, trials of this nature cannot attract the resources needed for the intensity of measurement that is required in properly designed scientific studies. Whilst on the other hand, some useful data was obtained. Accepting that a trial (or even demonstration) serves as a useful focal point for members of participating groups and an opportunity to engage but has resourcing and statistical limitations, perhaps the best resolution is to use small trials but focus on a limited set of measurements that are likely to yield the most reliable results.

6 Conclusions/recommendations

6.1 Conclusions and Future R&D

The main conclusion based on the results from these trials is that it is likely that serradella species/cultivars could play a role in the development of more phosphorus efficient grazing systems

on the Southern Tablelands. The ability of the two serradella species to establish and persist under adverse drought conditions means that further investigations and development of these species is warranted. Initially, future R&D on serradella in the southern Tablelands should focus on assessing the fitness of a broader range of germplasm in a wider range of environments. In the short term, there is not enough convincing data from these trials to suggest that either of the serradella cultivars that were examined would be successful.

Serradella could also be assessed in sown as well as native/naturalised pastures. Given that serradella can use phosphorus more efficiently than sub clover, then perhaps they have a role in lower input systems in less productive parts of the landscape. A further area for examination would be the ability of serradella to establish from surface sowing as this is particularly relevant for lower input parts of the landscape (hilly, less arable environments). Overall, it should be remembered that the development of sub clover has continued for over 100 years in temperate Australia whereas, serradella development has been less intensive and over a much shorter time frame. It is possible that there are varieties of serradella that could be very useful in this environment that are yet to be examined.

Weed management emerged as an issue during these trials. Because of the limited range of herbicide options on serradella and small size of the plots, hand rogueing was used to control saffron thistle. On a broader scale, herbicide options will need to be developed to address management of weeds in serradella pastures. The class of herbicides that control weeds like saffron thistle cannot be used on serradella pastures – if issues like this are not addressed future adoption of serradella could be quite limited.

Small trials can be used to focus engagement in projects such as this. The trials should be replicated and produce reliable results but be limited to addressing simple issues using measurements that produce data with comparatively low variance. This could translate into the opportunity to run more sites with less intensive measurement regimes on each.

7 Key messages

The key messages to emerge from these trials are:

- 1) Serradella shows promise as a phosphorus –use efficient species that can persist in the Southern Tablelands environment.
- 2) The ideal cultivars for the southern Tablelands environment are yet to be identified and to do so will require further R&D.
- 3) The use of small replicated trials to produce reliable data and focus engagement of local farming groups has been vindicated and should be continued.

At present, it is not recommended that growers include serradella in their pasture mixes. The need for more cultivar development – and data on persistence over longer time periods is required before such recommendations can be made. In addition, without the necessary research on weed control in serradella-based systems, the species is unlikely to penetrate the market – especially where it is susceptible to herbicides used to control common broadleaf weeds (e.g. saffron thistle).

Ultimately, a grazing system in which serradellas play a key role would be characterised by lower phosphorus inputs and that would be desirable in terms of profitability (less spent on fertiliser) and environmental outcomes (e.g. lower phosphorus in the off-farm environment). These outcomes are worth pursuing with further work to develop serradella.

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9 Appendix

9.1 Survey of participants

At a field day held in December 2018, participants were asked to fill in a survey that was designed to gauge current knowledge of issues relevant to the project - in particular knowledge of soil phosphorus management and legume responses to phosphorus. The survey was completed by 17 producers and the results can be found below.

P-efficient pastures: Project Evaluation – Five Questions

Q1. The term “CRITICAL soil test value” is often used when interpreting soil tests; which of the following best describes your understanding of the term:

	% (number)
I am not familiar with this term	6 (1)
The minimum amount required for adequate pasture production	29 (5)
The value that soil must not exceed to avoid toxicity	0 (0)
The value at which pasture production is near maximum	65 (11)
The value that will give the best animal health outcome	0 (0)

Interpretation: There are indications that most growers understand the “critical soil test value” concept – ie the value at which pasture production is near maximum. However, there were still around one-third who did not, so there is still some work to embed the concept.

Q2. Can you nominate the “critical” phosphorus soil test value for a typical area of pasture that you fertilise?

	% (number)
☐ Yes – the value is * _____	71 (12)
☐ No	18 (3)
☐ Not Sure	12 (2)

*each of the respondents who replied “Yes” could nominate a reasonable critical P level of range.

Interpretation: just over 70% of growers being able to nominate a realistic critical soil P value is encouraging.

Q3. Do you know the soil Phosphorus Buffering Index (PBI) test value for the same area of pasture?

	% (number)
☐ Yes – the value is * _____	24 (4)
☐ No	41 (7)
☐ Not Sure	35 (6)

*each of the four respondents nominated a reasonable level for PBI – it was consistent with the critical P level nominated.

Interpretation: Many fewer growers could nominate a realistic PBI level than a critical P level. Whilst the actual PBI level is not remembered, the fact that most can remember the critical level is more important for P management. Nonetheless, it would be interesting to know how growers would define the meaning of PBI.

Q4. Please indicate whether you agree or not with the following statements

- a) All pasture legumes have the same phosphorus requirement

	% (number)
☐ Yes	6 (1)
☐ No	94 (16)
☐ Not Sure	0 (0)

Interpretation: A central message of the project has been to promote legumes that have a lower P requirement. Clearly this message has got through

- b) Serradella has a lower phosphorus requirement than sub clover

	% (number)
☐ Yes	82 (14)
☐ No	12 (2)
☐ Not Sure	6 (1)

Interpretation: see above

c) Serradella buries its seed just like sub clover

	% (number)
☐ Yes	12 (2)
☐ No	82 (14)
☐ Not Sure	6 (1)

Interpretation: most growers knew that serradella is an aerial seeder – it is likely that they have learned this through exposure to this project and/or its predecessor.

d) Serradella persists adequately in my region

	% (number)
☐ Yes	6 (1)
☐ No	12 (2)
☐ Not Sure	82 (14)

Interpretation: this result is totally reasonable as one of the main objectives of the participatory research sites is to examine the persistence of serradella in current grazing systems.

e) Every so often serradella needs a late spring grazing break to help it set enough seed.

	% (number)
☐ Yes	65 (11)
☐ No	0 (0)
☐ Not Sure	35 (6)

Interpretation: It is probably more important to graze serradella lightly in the first years after establishment. Beyond that serradella is adapted to continuous grazing. Future research and development will need to address serradella grazing management.

Q5. Considering how you have previously used soil tests, do you now see value in soil sampling...

	Yes	No
Deeper than 10 cm	35 (6)	65 (11)
More frequently	82 (14)	18 (3)
Over more paddocks	94 (16)	6 (1)
To map paddock fertility	94 (16)	6 (1)

Interpretation: For soil P management of soil of the southern tablelands it is not necessary to sample below 10 cm – this need to be more widely discussed. Data from the farm where the field day was hosted, clearly showed the temporal and spatial variability in soil P levels – this message was well understood by participants. Finally, although not addressed, participants clearly viewed that sampling and management of soil P at sub-paddock scale needs to be pursued. Rigorous research will be required before this can become part of the standard management approach.

9.2 Colour Plates



Plate 9.1 Sowing at TFS-West– May 2017



Plate 9.2 Checking germination at TFS East, July 2017



Plate 9.3 Field Day at TFS Sites – December 2017



Plate 9.4 Tablelands Farming Systems and Bookham Agricultural Bureau Field Day at Merrill Dec 2018.



Plate 9.5 Soil Sampling at the BAB-Hill site, October 2019. Note the flowering pink serradella in the background.