

final report

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Participatory Site Coordination Final Report

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Executive summary

Phosphorus (P) is the key fertiliser nutrient applied to pastures containing legumes in southern Australia. This represents a major expense to producers. Fortunately, recent results have demonstrated that a range of serradella species are more efficient at utilising soil phosphorus (P) when compared to the legume species that dominated production in southern Australia – sub clover. The superiority of serradella in this respect is not widely acknowledged, even in regions where serradella is currently grown. Moreover, serradella is not currently used in many parts of southern Australia where extensive livestock production takes place, e.g. the higher rainfall zone in NSW and Victoria.

A network of participatory producer sites was set up as a core component of *the RnD4Profit-Phosphorus efficient pastures* project to address either the management of phosphorus in areas where serradella is currently grown or the performance of serradella compared to sub clover in areas where serradella is currently not grown. Eight producer groups were involved in six hubs – groups in WA and Northern NSW focussed on the management of P in serradella pastures. Groups in Central Victoria, the Monaro region (NSW) and Southern Tablelands (NSW) investigated the comparative performance of serradella.

A common protocol was developed to be applied across all sites. Participants attended a training event to ensure standardised application of the protocol. In addition, all data was stored in simple spreadsheets in a cloud-based file sharing system which allowed progress to be routinely audited.

Whilst ongoing drought did effect each of the sites, the following conclusions are widely supported (across sites) by the data produced

- Sampling of low PBI/sandy soils needs to take into account phosphorus deeper in the profile than the standard 10 cm. There is also a need to redefine the critical P level for serradella when derived from samples taken deeper in the profile. Utilising P from greater depths in the profile will improve the efficiency of fertiliser use for producers who use serradella on these soil types.
- Serradellas are more phosphorus efficient than sub clover and could be used widely in pasture systems of Eastern Australia – *but* more work is required before serradellas can be recommended to growers. Greater diversity of germplasm needs to be tested along with the development of agronomic packages that address difficulties ion weed control and surface establishment.

The results have already had an impact on producers. In WA, the method for soil sampling on farm has already changed partly as a consequence of the work conducted at sites in that state. In addition in southern NSW there is heightened awareness of the potential of serradella even though it is not currently recommended.

Apart of the results obtained from the trials, the involvement of participating groups provided an opportunity to bring researchers and producers together to address issues in serradella management. The use of common protocols, training events and regular auditing played key roles in producing reliable data from the network of participatory sites.

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1 Background

The rationale for this project from scientific and industrial perspectives has been made in other reports and does not need to be repeated in detail here. Briefly, phosphorus is the key fertiliser nutrient applied to pastures containing legumes in southern Australia. This represents a major expense to producers. Fortunately, recent results have demonstrated that a range of serradella species are more efficient at utilising soil phosphorus (P) when compared to the legume species that dominated production in southern Australia – sub clover. The superiority of serradella in this respect is not widely acknowledged, even in regions where serradella is currently grown. Moreover, serradella is not currently used in many parts of southern Australia where extensive livestock production takes place, eg. the higher rainfall zone in NSW and Victoria.

It is no simple issue to replace one pasture species, which has proven to be very well adapted, with another. Sub clover has been the subject of decades of research which has resulted in a range of cultivars that vary in flowering time, tolerance of soil acidity, tolerance to waterlogging, tolerance to red-legged earth mites, response to herbicides, productivity, etc. In contrast, much less effort has gone into serradella. “Serradella” here is being used as a collective term. Actually there are a range of serradella species that have been developed in Australia – the main two being yellow serradella and pink serradella, and there are cultivars of each. How well these cultivars are adapted to environments away from traditional serradella-growing areas is unknown.

The studies that are the subject of this report were set up to provide a means of investigating the management and performance of serradella in areas where it is currently grown and in novel environments. These sites were to address two questions:

- 1) In regions where serradella is currently grown – under farm conditions, what is the critical P levels required for serradella production?
- 2) In regions where serradella is not grown – how does serradella perform relative to sub clover (in perennial pastures) at levels of soil phosphorus that are optimal for serradella?

In order to address these questions and engage and provide a focus for engagement with producers, a network of producer groups was developed. Each of the groups would host a number of trial sites that would be located on local farms to address one of the questions listed above. The producer groups would either manage the trial or engage a local consultant to manage it on their behalf. The grower groups identified were:

Group	Location/Region	Consultant
Asheep	Esperance region, WA	N/A
Southern Dirt	South Western WA	N/A
Boggabri grazing group& Purlewaugh branch of NSW Farmers	North West NSW	Bob Freebairn
Tablelands Farming Systems and Bookham Agricultural Bureau	Southern Tablelands NSW	Jim Virgona
Central Ranges branch Grassland Society of Southern Australia	Central Victoria	Lisa Warn
Monaro Farming Systems	Monaro region - NSW	Doug Alcock

Each of the trial sites was to be located on the property of a member of the participating group. The purpose of this approach was to ensure that the results were directly relevant to the production system(s) of that locality. For instance, in the higher rainfall zones of southern NSW and Victoria pastures are usually sown to one or more perennial grass species and one or more legume species. Hence trials in those regions were designed to compare sub clover with serradella when sown with phalaris (a perennial grass).

The trials were to be simple in design and where appropriate replicated within a paddock in two differing land-classes and/or soil types. The trials were designed to produce data that could be subject to statistical analysis – three treatment each replicated three times and set out in a Latin square design. The three treatments for the regions where serradella is currently grown were three fertiliser rates – attempting to achieve levels of soil P below critical for serradella, at critical and above. In the areas where serradella is not currently grown the three treatments were sub clover, yellow serradella and pink serradella – each sown with phalaris. Cultivar selection within each of these species was made on the basis of the most likely to persist.

A common management and measurement protocol was developed to ensure that all activities were standardised between and within participating groups. This meant that soil sampling (and analysis), pasture sampling, fertiliser management etc. were all carried out according to a common protocol. Each of the participants attending a training exercise to ensure standardised application of the written protocol. Data recording and storage was also a part of the common protocol. Data was to be stored in spreadsheets that were designed to capture all the data produced from a site in a year. There were stored on the cloud-based storage system – “Dropbox”. This approach would allow for routine auditing of group progress.

In addition to details about the trials outlined above, the network of participatory sites was also developed as a vehicle to engage producers in the broader project. It was also hoped that it would provide opportunities for researchers to become exposed to the on-farm relevance of their work.

2 Participatory Site Objectives.

Participatory sites were established to ensure that the following outputs could be delivered:

2.1 Areas where serradella is already grown

The aims of these sites are best encapsulated by referring to the output statement: ***Output 4(b) – Conduct participatory paddock scale trials with farmer groups in areas of WA and NSW where serradella is already grown to improve knowledge of the P-fertiliser and general management of serradella-based pasture systems.***

This Output was altered during the project as a response to results from the participatory sites and research sites. The original output was to “Conduct participatory paddock-scale trials with farmer groups in areas of WA and NSW where serradella is already grown to validate the application of lower critical P levels to management of serradella-based pasture systems”. In essence, the standard

soil testing depth or soil phosphorus (ie 0-10 cm) was found to be inadequate as there were substantial reserves of available soil P deeper in the profile. Once this was realised the Aims of the sites were re-aligned with the output statement above.

2.2 Areas where serradella is not currently grown

The aims of these sites are best encapsulated by referring to the output statement: Output 5(a) - Conduct participatory research trials with farmer groups in areas serradella is not used to examine productivity, persistence and potential use.

2.3 This Report

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 Site by Site Summary

In order to appropriately summarise achievement, challenges and results from the participatory trials network, the first step is to consider these on a site by site basis. Firstly, the sites addressing phosphorus management in regions where serradella is currently grown will be considered (Table 1). Secondly, we will consider the sites in areas where serradella is currently not used and the performance of this species was the focus (Table 2)

The table below contains x headings each of which requires some explanation

- **Key Results** The findings/conclusions from that site that contribute to the outputs that were expected from that component of the project.
- **Challenges** Any issue that may have been encountered by participants depending on relevance, eg. drought, establishment problems, site selection, management problems, application of protocol etc.
- **Other learnings/Comments** These could include any insights that are useful but not part of the original aim and any other relevant information/judgements about the site

3.1 Trials in areas where serradella currently grown

There were two major outcomes of the trials that were originally designed to validate the application of lower critical P levels to management of serradella-based farming systems. Firstly, in phosphorus leaky soils (ie with low phosphorus buffering capacity), it became evident that it was not possible to manage or even define critical levels for serradella production using conventional approaches. At the participatory sites in Western Australia, farmer relevant fertiliser rates were applied to obtain low, medium and high available P levels. Conventional soil sampling (top 10 cm of soil profile) did reflect different rates of application, initially. However, deeper samples were obtained in 2017 at the participatory and adjacent research sites. These revealed that substantial levels of available P existed below 10 cm depth (Table 1). After that, soil P proved very difficult to

manage at the sites managed by Southern Dirt and Asheep in WA. Hence the aims of these sites changed as discussed above (section 2.1). The clear outcome from these sites was that there is a need to develop sampling protocols to quantify the P status of these and similar soil types.

Accordingly, the levels of critical P that are assumed for serradella and other legumes need to be redefined based on the revised characterised P status. For example, this would answer the question – what is the critical level of P in the soil when measure down to a (say) 60 cm depth?

The second major outcome was provided by the sites in Northern NSW (Table 1). Here, despite years of very low rainfall, serradella persisted well enough to confirm lower critical values than sub clover as found in previous work. On the occasions that rain fell, serradella was the dominant species in winter. So while drought conditions were prevalent over the three years of the trial and this meant that dry matter cuts could not be taken every spring. These results combined with very recent observations (post-drought) of the recovery of serradella on those trials means that local producers can be confident of the persistence and lower phosphorus-use-efficiency of seradellas.

Table 1 Summary of key results, challenges and other outcomes from the participatory trials investigation phosphorus management of serradella pastures.

Site	Key results	Challenges	Other Learnings/Comments
<i>Asheep</i>			
Grass Patch	Soil P needs to be sampled below 10 cm because of P reserves at depth.	Pasture persistence poor due to weeds and drought. Site selection meant that plots could not be grazed and serradella populations low. Drought impact.	Some problems with protocol – poor timing of soil sampling, sampling differed between sites. Incomplete pasture measurements. No insights apart from soil depth.
Nerridup	As above.	Poor persistence of serradella, plots overrun with weeds. Site selection – needed serradella to be present. Drought impacted site	As above – pasture performance poor and levels of soil P at depth too high for responses.
<i>Southern Dirt</i>			
Broomehill	As above - soil P reserves at depth were considerable and interfered with a determination of the critical value from the 0-10 cm sample. Future determination of P requirement need to be taken to a greater depth.	Serradella persisted well in trial and dominated pasture in 2017 and 2019. Site required re-sowing in 2018. Weed infestation heavy in 2018. Minimal impact of drought.	Given the problem in soil P measurement, treatments did not achieve differences in soil P between plots. 6.9-fold more available P accounted for when measuring the whole soil profile compared to the topsoil. Serradella performance not consistent between years.
Katanning	As above	As Above except there was no need to re-sow in 2018.	As Above.
<i>Purlewaugh and Boggabri - Freebairn</i>			
Boggabri	Soil P distribution more concentrated in 0-10 cm. Apparent confirmation that the critical P levels for serradella is lower than for sub clover.	Drought had a large impact on production but not persistence of serradella. Production levels very low on the site – unable to be harvested in 2018. Differences in soil P between treatments.	These trials were well conducted, all possible measurements were made. Drought had a large impact. A major finding was the confirmation of the persistence of serradella through adverse climatic conditions and under cattle grazing.
Purlewaugh	Soil P distribution more concentrated in 0-10 cm. Evidence of lower critical soil P for serradella is qualitative – but quantitatively insignificant.	Heavily affected by drought - Very poor spring production but serradella dominant legume species. Unable to harvest in 2018 due to drought. Differences in soil P between treatments.	

3.2 Trials in areas where Serradella is currently not grown

A network of trials in temperate eastern Australia was set up to investigate the persistence and production of serradella in areas where sub clover is the dominant sown pasture legume. The trials were to be conducted on soils with Colwell P values at about two-thirds the critical value for sub clover. The overview of sites is presented in Table 2. In each of the regions four trials were to be sown, ideally at two locations with two trials in at each location – situated to capture variation in landscape/soil factors. Whilst only 12 trials were meant to be sown, by the conclusion of the project 21 trials had been sown. Of the 9 extra trials, four were sown because of poor establishment in initially-sown trials, four were sown because of a mistake that led to sowing of the wrong cultivars in the initial trials and one was sown because the original trial was fenced in to a tree lot by the producer! Whatever the reasons for the extras sowing – they did provide the opportunity to explore the potential for serradella in many more sowing-by-year combinations than originally planned.

When considered together, these trials provide some clear messages about the comparative yield responses of serradella and sub clover, persistence of serradella, difficulties in serradella establishment and problems with weed management. Overall, these results should provide direction to future development of appropriate serradella cultivars and management packages that will be needed if serradella is to fulfil its potential in higher rainfall zone pasture of eastern Australia.

3.2.1 Establishment and Persistence of serradella

In a number of trials, serradella failed to adequately establish (Table 2). Ultimately establishment in annual species could be viewed as the number of plants that proceeded to seed production from sowing. This was not measured in these trials. Seedling emergence and seedling regeneration are the best guides to establishment for these trials. This confounds persistence and establishment to some degree but that is unavoidable and so these will be considered together. For sites sown on the Monaro in NSW, establishment was inadequate in 6 out of the 10 sites. It may be that even if only low seedling numbers were achieved in the first year, if they survived to produce seed with a high proportion of hard seed than serradella could have persisted into the following seasons. This appears not to be the case in the six Glenfinnan trials sown in 2017 – so establishment failure is nearly certain. The reasons given were poor prior weed control, drought and perhaps late time of sowing. For two other sites that have apparently performed poorly (Redcliffe sites sown in 2018), establishment numbers were adequate but there was no serradella on these plots in 2019. This may have been due to no seed production in 2018 under drought conditions or there is hard seed still left in the system.

Persistence and/or establishment was also poor in trials sown in central Victoria. Serradella was only present in appreciable levels in two out of six sites by the end of the trial period. Serradella emerged in each of the trials sown but through the combined influences of drought and competitive pressure it failed to persist and possibly did not produce any seed in the establishment year. Of the other two sites sown in central Victoria, in one seedling numbers were very low (Sidn Nth) whilst in the other, serradella established well but was poorer in the second year (Sidn Sth). Interestingly, recent observations on these plots have found a very high level of serradella. This is most likely the results of inadequate hardseed breakdown in the year after establishment.

Table 2 Summary of key results, challenges and other outcomes from the participatory trials investigation serradella performance in regions where serradella is not currently grown. Site column includes year sown.

Site	Key results	Challenges	Other Learnings/Comments
Monaro Farming Systems - Alcock			
Glenfinnan East (A) 2017	Sown to Sub clover and Yellow Serradella Avila and Santorini. No clear conclusions – due to inadequate establishment/persistence	Mistake at Sowing – Santorini instead of Margurita. Insufficient establishment – high competitive pressure from weeds. Glenfinnan South higher soil P than required	Difficulty in establishment an issue – prior weed control and site management raised as an issue. No useful data from these four sowings. Suggestion in hindsight that sowing should have taken place earlier. A hint that Avila may have been able to produce more dry matter than sub clover at low soil P but measurements taken too late to be convincing.
Glenfinnan South(A) 2017			
Glenfinnan East (B) 2017	Sown to correct species/cultivars – sub clover, Avila and Margurita. No clear conclusions – due to inadequate establishment/persistence	Failure to establish, high competitive pressure – sorrel, winter grass, naturalised clovers. Drought impact on emergence?	
Glenfinnan South(B) 2017			
Glenfinnan East 2018	Re-sown in May 2018. No key results, poor establishment and regeneration in 2019.	Drought most likely cause of failure – not enough seed set – no evidence of the weed control difficulties of 2017.	Interestingly, there is sufficient sub clover in the Goulburn treatment – but not confirmed that it is the sown cultivar
Glenfinnan South 2018			
Redcliffe East (A) 2017	Sown to Sub clover and yellow serradellas - Avila and Santorini. Excellent persistence and regeneration of Avila which produced more dry matter than sub clover at low soil P in 2017 and 2019	Mistake at Sowing – Santorini instead of Margurita. Drought impact on magnitude of results – growth.	Successful sites – despite drought conditions demonstrated potential of serradella – particularly Avila at levels of soil P lower than optimum for sub clover
Redcliffe West (A) 2017	Sown as above. Acceptable establishment and persistence of serradella (not as well as above). Concluded that serradella produced as much biomass as sub clover at low soil P in 2017 only		
Redcliffe East (B) 2018	Sown to sub clover Avila and Margurita. Good establishment but extremely poor regeneration in 2019. Dry matter production in 2018 confirmed superior (East) or equal (West) performance of Avila at low soil P.	Persistence from 2018 to 2019 poor – drought most likely as adequate establishment and dry matter production in 2018.	Evidence that Avila equal-to-superior compared to sub clover in terms of phosphorus use efficiency but only in year of sowing.
Redcliff West (B) 2018			

Table 2 Cont'd

Site	Key results	Challenges	Other Learnings/Comments
<i>Grassland Society Central Ranges Victoria - Warn</i>			
Bayn1 2016	Serradella established at low density but did not persist in farmer sown trial – sub clover did.	Dry spring in 2017 may have affected seed set.	No dry matter measurement taken or warranted.
Bayn2 2018	Serradella and sub clover established at low density but only sub clover persisted into 2019	Very dry spring in 2018 may have reduced seed set in all species – persistence of clover may be due to background population. Competition in establishment year also a problem	Conventional participatory site – sub clover versus pink and yellow serradella
Past1 2017	All legume species emerged and established in 2017, regeneration of all serradella cultivars poor in 2018 and worse in 2019. Serradella lack of persistence	Heavy weed infestation in establishment year. Very dry spring in 2017 reduced seed set	Compared 2 cultivars each of yellow serradella, pink serradella and sub clover
Past2 2017	Adequate emergence and establishment, yellow serradella poor regeneration in 2018, both serradella very poor regeneration 2019. Serradella Fails to persist.	Very dry spring in 2017 reduced seed set. Weed burden not mentioned	Conventional participatory site – sub clover versus pink and yellow serradella.
Sidn Sth 2018	Serradellas persisted at this site Avila more than Margurita, subclover better still. Avila most productive legume in establishment year, Margurita the least.	Production of seed despite dry spring in 2018. Serradella less competitive with grass compared to sub clover. Soil P levels too high in 2018.	May be lower levels of hardseed breakdown in Serradellas. Margurita production a function of poorer establishment. In 2019, dry matter production proportional to seedling density.
Sid Nth 2018	Serradella persisted at this site but at very low density. Avila most productive legume in establishment year, Margurita the least.	Established at low numbers – serradellas did not recover by end 2019.	

Table 2 Continued

Site	Key results	Challenges	Other Learnings/Comments
<i>Tableland Farming Systems & Bookham Agricultural Bureau - Virgona</i>			
TFS-West	Serradella established and persisted to some extent eventually outcompeted by other legume species. Dry matter responses compared to sub clover confirmed when sown species dominated legume component	Drought a major problem at these sites – plants dead before seed production in 2019. Saffron thistle present on plots – could not be controlled with conventional herbicide application of MCPA. Soil P values lower than target at TFS-East by 2019	Growing season rainfall 15 th and 5 th centile in 2018 and 2019, respectively. Sub clover and naturalised clovers appeared to persist better than serradellas.
TFS-East			
BAB-Hill	Excellent persistence of both serradella species to 2019. Avila higher density than other legume species in 2019. Dry matter results only confirmed superiority of Margurita in establishment year – 2017.	These results obtained despite very poor rainfall especially in 2019. Soil P values went below target range by 2019	Most successful site of the 5 sown for these groups. Soil P should have been better managed
BAB-Flat	Established well and provided dry matter results consistent with previous work but could not continue due to owner	Management issue – owner fenced off site into a tree lot	Better communication between site manager and owner warranted!!
BAB-Flat2	Poor establishment in 2018. Serradella species persisted through first year but at lower levels than sub clover.	Poor growth due to drought in establishment year. Also background population of sub clover meant that serradella less than 20% of legume dry matter production. Soil P values went below target range by 2019	Poor establishment and performance mainly due to drought but invasion of background legume species suggested the need for better paddock preparation. Soil P should have been better managed

In the trials sown in southern NSW, serradella only persisted well in four out of five trials despite establishing well in all but one. Poor establishment in 2018 was largely as a result of drought – sub clover did not establish better than serradella but the plots eventually were dominated by sub clover because of regeneration from a background population. One of the trials was discontinued due to a change in paddock management by the owner. That leaves two paddocks where serradella did not persist adequately into the third year. Much of this could be the results of continued drought conditions at that site. This is by no means certain as serradella plots were invaded by other legume species mostly sub clover and naturalised clovers (chiefly *Trifolium glomeratum*). The one site at which serradella did persist well (BAB-Hill) was in a region where late rainfall events in the dry springs of 2017, 2018 and 2019 and both serradella species were able to respond at a time when most of the sub clover had died.

To summarise, most establishment problems can be explained by either poor prior weed control and/or drought. In neither case can it be concluded that serradella per se was the problem. Where sub clover appeared to have been able to cope under these conditions, this may have been due to the regeneration of background populations rather than successful establishment. In contrast, the fitness of the serradella species/cultivars examined may have influenced persistence in a number of ways. The sowing of single cultivar representative of each serradella species meant that risk in terms of flowering time and hardseededness levels could not be managed by sowing a range of cultivars. This is the common approach with sub clover but there is not enough variation in available serradella cultivars to do likewise. The flowering patterns, hardseed levels and hardseed breakdown patterns may not be appropriate for the environments being considered here. The fact that serradella cultivars could persist in environments that they were not selected/bred for (those considered in this section plus northern NSW) does provide some optimism for future more targeted development of these species.

3.2.2 Seradella and weed management

It is not possible to separate the impacts of weeds on serradella performance in isolation. There are issues of cause and effect that cannot be clearly separated. For example, did weeds colonise spaces that serradella did not occupy because it failed to regenerate or did those weeds in the previous season have a competitive effect on serradella – especially seed production? Nonetheless, there are some issues relevant to the management of weeds in serradella production systems that can be highlighted as a result of these trials. At some sites (in southern NSW and on the Monaro), hand roguing of weeds, particularly saffron thistle, took place to reduce competition from this species. In sub clover-based pastures on farms, saffron thistle is managed by applications of MCPA. Serradella is susceptible to MCPA so this herbicide is not an option to control saffron thistle or other species that are controlled by this herbicide. Management of serradella in Western Australia is a pasture ley sown as a monoculture. In the pasture-based systems of eastern Australia, serradella would be sown with a perennial grass. This also reduces the range of herbicides that can be applied if serradella is present. The trials in Western Australia used Imazamox (Raptor) which controls a range of grass and broadleaf species. This type of herbicide could not be used in permanent grass-based pasture. Hence, the development of management packages for serradella will need to include herbicide options for common weeds that require control but do as little harm as possible to serradella.

Some site managers made mention of the competitive ability of serradella to explain poor performance at some sites. The upright growth habit, compared to sub clover, may well be an issue but this may have been a result of varying density from season to season. Given the success of serradella in other environments where it is commonly grown it is unlikely to have a fundamental inability to compete.

3.2.3 Dry matter production: comparing serradella with sub clover

The participatory trials were not set up to verify the results from previous studies viz. that serradella has a lower critical soil P level than sub clover. However, the measurements taken have produced data that could be used for that purpose. It is important to be careful in making such comparisons and to remember that in the experiments conducted by Sandral et al. (2019), all legume species were grown as monocultures and re-sown each year. Hence, differences between species in response to soil P levels were likely to be fully expressed. In the participatory trials, by design, the legumes were not present as monocultures and were being examined for their capacity to persist – they were not re-sown each year. In many of the site x year combinations serradella was either not present or at much lower density than sub clover. There were some occasions when plant density was similar for each of the sown legume species, this usually occurred in the year of establishment and, in a few cases, in subsequent years. When these conditions were met it was interesting to note that serradella dry matter production was equal to or superior to that of sub clover (Table 3). Of the 16 instances where at least two of the species were present at comparable densities, a serradella species was superior to sub clover 13 times. Of these, there were three instances in which a serradella was superior to sub clover but the soil P levels were higher than targeted. In addition, there were two other instances where seedling densities were either very low or serradella had much high seedling density than the other cultivars. Nonetheless, the pattern is very clear – serradella, in terms of dry matter production in spring was superior to sub clover when present at comparable plant density.

These results aren't entirely consistent with those found by Sandral et al (2019) who found both yellow (cv Avila) and pink serradella (cv. Margurita) had lower critical P values than sub clover (cv. Leura). Sandral et al. (2019) also found that Margurita could produce as much dry matter as sub clover (cv. Leura) at non-limiting soil P. In contrast they found Avila could not produce as much dry matter as either sub clover or Margurita at non-limiting levels of soil P. The summary of participatory trial results in Table 3 is not entirely consistent with the results of Sandral et al (2019) in that Avila was the most productive legume cultivar in many of the trials. It is interesting to note that Margurita was the most productive cultivar at low levels of soil P at sites in southern NSW (TFS and BAB sites, Table 3) which are situated in a similar environment to where the experiments of Sandral et al. (2019) took place. It would be reasonable to conclude that there is much we are yet to learn about the performance of serradella species/cultivars at a regional level.

Table 3 Relative production of dry matter between legume cultivars. “Year” denotes when the result was obtained (not year of sowing). Standard rules of mathematical symbols apply.

Site	Year	Soil P Mg/kg	Results in terms of legume dry matter production & Comments (all differences are significant unless specified)
SIDN Nth	2018	14-16*	Avila > sub clover, Margurita density too low. Soil P levels higher than ideal.
SIDN Sth	2018	17-20*	Avila > sub clover, Margurita density too low. Soil P levels higher than ideal.
TFS-West	2017	23	Margurita > Avila > sub clover.
TFS-East	2017	24	Margurita > than sub clover. Avila intermediate and not significantly different from other two cultivars
BAB-Hill	2017 2019	23 9	Margurita > (Avila = Sub clover). No differences between cultivars despite Avila having twice the seedling density of others
BAB-Flat	2017	13	Margurita > (sub clover= Avila)
Redcliffe East (A)	2017 2019	14-15	Avila > sub clover, Santorini intermediate and no different from other cultivars Avila > other cultivars but had much higher seedling numbers
Redcliffe West (A)	2017	12-21	Avila > sub clover, Santorini intermediate and no different from other cultivars
Redcliffe East (B)	2018	24-30	Avila > sub clover. Margurita intermediate and not different from other cultivars
Redcliffe West (B)	2018	36-51	Sub clover = Avila = Margurita. Soil P levels too high
Glenfinnan South (A)	2017	49-52	(Avila = sub clover) > Santorini. Very high soil P. Avila also greatest seedling density.
Glenfinnan East (A)	2017	20-25	Avila > (sub clover = Santorini). Santorini density much lower than others
Glenfinnan South (B)	2018	58-81	(Avila = Margurita) > sub clover. Seedling densities equal but low. Very high soil P.
Glenfinnan East (B)	2018	40-41	(Avila = Margurita) > sub clover. Equal seedling density.

*Olsen P – all other Colwell P.

3.2.4 Summary – Sites where serradella currently not grown

To summarise this section, the participatory sites have provided valuable insights into the performance of serradella in on-farm environments and provide some direction for future development, these are:

- Serradella performance at soil P levels that were sub optimal for sub clover were, in broad terms, confirmed.
- Current serradella species/cultivars are not well adapted to the environments in which the participatory trials were conducted. Future development of these species should include the examination of a range of germplasm in these and other target regions.
- Registered herbicides provided difficulties for site managers which would translate into major barriers to adoption on farms.
- Persistence of serradella is a major issue and future R&D on those characteristics known to be related to persistence are warranted. These would include but should not be limited to:

hardseed levels, hardseed breakdown patterns, flowering time, flowering period and seed production.

- Weed control options will present real challenges if serradella is to be adopted in perennial pastures of eastern Australia. In particular, a wider range of weed species and the need to consider non-target perennial species need to be considered. Further R & D should address this problem if serradella is to penetrate these markets.

4 Summary of conclusions from participatory reports

Some of the lessons that have been learned at a local level and were not captured in the previous sections can be drawn from conclusions from the participatory reports. These are summarised for each group in this section.

4.1 Asheep

Unabridged

Findings from these farm group participatory trials confirm data produced by the co-located research – that monitoring soil phosphorus (P) in the surface (0-10 cm layer) of sandy soils in the region is not adequate. Soil monitoring regimes that sample to at least 60 cm need to be developed in order to properly manage soil P. As a consequence, the differential response of pasture legumes to soil P levels needs to be quantified with respect to levels of soil P derived from deeper sampling. This should be the next step for R&D prompted by the results produced from these trials.

There is enough data from one of these sites that suggests serradella can persist at low levels of soil P – much lower than recommended for optimal production. However, there is a need to carry out further research on weed control in serradella pastures as this was an ongoing issue for both of the sites.

4.2 Southern Dirt

Abridged

Changes to soil testing practice: Findings from the trials have driven change in soil sampling practices – from 0-10 cm now down to depths between 30-60 cm. Findings from these experiments have promoted discussion around the distribution of P in the WA soil profiles and the value of the bulge of legacy P found at depth at both trial sites. Further improvements in the efficiency of P fertiliser use can be made by understanding when the soil profile contains legacy P and by planning soil P fertility management to include any reserves of legacy P that may be held deeper in the soil profile. Because serradella pastures are known to be very deep rooting in sandy soils (e.g. up to 1.5 m depth), they appear to be ideally suited to exploitation of deep soil P reserves.

Future research should address the following questions:

- How best to take deeper soil cores: what depth, sampling pattern etc.
- Can serradella access all of the P at depth in sandy soils and sub clover miss out of deep P because of its comparatively shallow root system?

4.3 Freebairn – Purlewaugh and Boggabri

Abridged

The current research was conducted over three years of below average rainfall. Despite these conditions, the data have shown that serradella can perform at near maximum capacity at soil P levels of about 20 mg/kg (Colwell P), which is lower than the levels required for subterranean clover (+30 mg/kg P).

Other findings from this research include knowledge of soil P profile and species persistence. Deep soil P levels indicated no P bulge at deeper layers. There was also minimal P movement down the profile on these lighter sandstone-based soils. The dry seasonal conditions have also shown the superiority of serradella compared with subterranean clover on these soils in dry conditions.

4.4 Warn – Central Rangers Grassland Society Branch

Abridged

Overall, sub clover established and regenerated better than Yellow and French Serradella at all 6 trials. The establishment and regeneration of the serradella cultivars was variable across trials and years. The most successful establishment and regeneration of all three legume species was at SIDN STH. The SIDN STH trial did indicate that Avila yellow serradella could establish and yield as well as Goulburn sub clover in the establishment year and perhaps if the spring had not been so dry Avila may have been able to set more seed and regenerate at a greater density. The lateral spread of the sub clover meant it was more effective than the serradellas at keeping annual grass weeds out of the sward in year 2.

Future opportunities for research work should focus on comparing different establishment techniques and times. In this environment there is a small window to get legumes sown in autumn (after some rain/weed control) before soil temperatures get too cold for germination and growth. When growing conditions improve in late September, there is a high risk of competition from late emerging annual grass weeds. Some establishment options could be sowing the legumes in September (risky if the spring cuts out early), sowing experiments as pure legume swards to ensure flexibility with post-emergent weed control, summer sowing (drill) hard seed/pods, or broadcasting seed before the autumn break. Broadcasting seed with fertiliser would be a low-cost option for low fertility hill country. This land-class is less likely to already have a strong sub clover base and may be the right niche for serradella in this region.

The project has made producers more aware that different legumes have different critical soil test value for phosphorus and that growing more phosphorus efficient legumes could reduce the inputs and costs of fertiliser. The project has also encouraged producers to undertake more soil testing to be more targeted with fertiliser applications. The real opportunity or niche for serradella in the Central Ranges region would be the low fertility, steep/rocky hill country. These land-classes are where there would be the greatest potential for adoption of serradellas and the Grassland branch are keen to investigate low cost options to establish serradellas in those areas.

4.5 Alcock – Monaro Farming Systems

Abridged

This research has effectively demonstrated the adaptation and potential productivity of Serradellas in the Monaro environment where establishing and maintaining legumes in perennial pastures has often proven difficult. While it has proven to persist in the long term sub clover is very subject to false breaks and years of very low biomass production. The apparent staggered germination of serradella and its tolerance of some extremely dry conditions during these experiments demonstrate that the industry has another option for an annual pasture legume worthy of consideration.

Paddock scale trials of pasture mixes with Avila would be a useful adjunct to this small plot research in order to convince producers of its utility in the Monaro and other tablelands environments especially if established in paddocks of known marginal P levels where historical performance of sub clover has been poor. This approach would also give the opportunity to demonstrate the expected livestock performance of animals grazing pastures with significant serradella content.

Further research will be needed to determine the impact of grazing timing and intensity on the ability to set seed. Research to address this should include variations in the timing and severity of harvest with regard to its impact on the amount of viable seed set. Further work on the longevity/persistence of hard seed across several seasons would also assist in determining how many consecutive years serradella varieties may regenerate after each major seeding event. While Avila performed credibly in this research it is worth noting that it is a public variety which was first registered in 1987. There is no doubt great potential for plant breeding to increase its level of adaptation to the tableland environment as well as its productivity.

4.6 Virgona - Tablelands Farming Systems and Bookham Ag. Bureau

Abridged

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). 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.

4.7 Summary of Participatory Report Conclusions

For the most part the conclusions made by site leaders align very closely with the site-by-site analysis in section 3 of this report. The key conclusions in common from these reports and the analysis above are:

- The need to develop soil sampling strategies that adequately represent the P status of soils with low PBI – mainly sandy soils.
- The need to develop critical P values for serradella growth on low PBI soils.
- That serradella can grow quite successfully in some environments and that previous results showing that serradella has a lower critical soil P levels have been confirmed in a range of environments.
- Serradella failed to persist in many trials and a considerable R&D effort will need to be applied in order to comprehensively address this problem.
- Agronomic packages for serradella in areas where it is not currently grown will need to address the widespread problem of weed control and herbicide options.

However, there were some issues raised by several participants in their conclusions that could not be drawn from the site-by-site analysis. Firstly, two of the trial operators mentioned the potential for serradellas in low input pasture systems in southern NSW and Central Victoria. In terms of the efficiency with which phosphorus is used, adapting serradella for lower input hill country makes sense – less P is generally applied in these systems and serradella would be a good fit as there would be opportunities to maximise legume production. There are some barriers that need to be overcome – quite apart from the generalised problems of persistence of current cultivars. These include the ability of serradella to establish from surface sowing, the need to ensure effective inoculation under surface-sown conditions and also problems with weed control in such systems. Some reports specified the range of research that would be required to address the persistence issue – this included: impacts of grazing on seed production, seed longevity and hardseededness, examining establishment options – eg. sowing pods and seeds and assessing performance of serradella at the paddock scale.

In general, there is close agreement between site operators on the future directions for R&D into serradella-based pasture systems. There is also a range of potentially valuable insights from the individual participants that should be drawn upon in formulating future efforts in this area.

5 Management and Coordination

The network of participatory sites was established to provide useful data on serradella performance and engage local grower groups in the R&D. In this section an overview of the coordination between sites is provided.

5.1 Protocols

Two protocols were developed during this project. The first was developed to help participants locate appropriate sites for the participatory research component. Two separate protocols were

developed – one for sites where serradella was already grown, the other for sites examining the potential for serradella. These protocols can be found in appendix 11.1.

The second protocol dealt with the management and measurements of the sites and in an abridged form can be found in Appendix 11.2. This protocol was designed to ensure that all site-related activities were standardised. This included experimental design, application of treatments, soil sampling, and pasture measurements (seedling counts, frequency and dry matter harvests). In addition, trial management was also addressed – including grazing, weed and fertiliser management. A meeting of all site managers and with various researchers associated with the project took place in December 2016 before the trials commenced. The protocols were reviewed at this meeting and accepted by participants

5.2 The Data Repository

Rather than build a project database, a simpler approach was taken. The protocol specified the steps required to store data collected from the trials. Spreadsheets were developed for participants to record all data and included a worksheet for a site diary to record all activities at the site. There was a separate data file for each site in each year. These were stored on Dropbox in separate directories for each participating group. This allowed the coordinator to check progress at sites and put in place an informal auditing process. The coordinator was able to produce a summary table of progress at each site for milestone reports during the project. This system worked well – by the conclusion of the trials all the site data sheets were up-to-date (but see below). This does not mean that all measurements were taken – as there were cases of site failure but it does mean that all the data that could be taken had been stored in the spreadsheets file – with the exception of soils data. Soils data was meant to be deposited in the site and year specific Excel spreadsheets, this did not happen for most sites as soil data was distributed as a “master” spreadsheet – in common for all project participants. Most did not see the purpose of copying this data into their spreadsheets.

5.3 Problems with protocols and data

There were some problems with the application of protocols and there was also the need to develop novel approaches in response to unexpected issues at some sites. For instance, one participating group used two different soil sampling regimes at two of their sites for no apparent reason. Another group, in an effort to increase the density of serradella in a (serradella-only) trial decided to mix the serradella seed with sub clover. There are probably a few other similar instances. Mostly, these sort of problems arose on sites managed by inexperienced personnel – in one case the trial site was managed by four different operators over three years. Problems with protocols could easily be managed through communication with the coordinator or Dr Richard Simpson (CSIRO). If similar projects are attempted in future, some effort should be made to determine the capacity of the groups and personnel involved and if it is deficient, greater involvement by experienced operators (eg. researchers) should be encouraged.

6 Survey results

Two surveys were designed during the project. The first was a comprehensive survey to determine baseline knowledge of phosphorus management and legume responses. Disappointingly, only a small proportion of participating group members took part. The first survey was long and detailed and this, combined with apparent survey fatigue, may have explained the poor response. A second less detailed “rapid-response” survey was designed a single page survey to be handed out at field days and other events. Results and details are highlighted in the following sections.

6.1 “Baseline” Survey of Producers – Selected Highlights

The purpose of the survey was to gain an understanding to current approaches and attitudes to managing phosphate fertiliser. In addition, the survey presented an opportunity to gauge current knowledge of key concepts that underlie phosphate management. Survey questions and results can be found in Appendix 11.3. As mentioned above, only a minority of producers took part in this survey and some groups were better represented than others (Table 4). The survey was made available on the web and most participants responded by early 2018.

Table 4. Number of respondents for initial soil P survey

GROUP	Respondents
ASHEEP	13
Southern Dirt	0
Boggabri grazing Group; Purlewaugh NSW Farmers	5
Monaro Farming Systems	17
Bookham Agricultural Bureau	11
Tablelands Farming Systems	7
Central Ranges Grassland Society	8
Not a member of any participating farming group	7

There were many issues canvassed in this survey but the summary (see appendix 11.3) captures most of the key points and is reproduced here:

“In summary, this survey has revealed much about producers’ knowledge, attitude and practices with respect to soil P management. Despite efforts to encourage a high number of participants, the level of response was less than expected (64). Key messages to emerge from the results are:

- *Currently, a majority of producers use soils tests to guide decision about soil P management. This is a positive result but there are problems in interpretation and sampling strategies.*
- *Producers need further education on factors that govern soil P management. Those who have attended the Five-Easy Steps course tend to have the advantage in this area – but there is considerable scope across the board to improve soil management skills.*
- *Sampling strategies are a problem in terms of coverage of properties and frequency. This needs to be addressed in messages coming out of the P4Pastures project.*

- *Tailoring soil P management to legume species is not widely practiced. As this will be one of the key messages to emerge from the P4Pastures project, a targeted approach will be required.”*

There was one result, in particular, that can be used as a guide to how well growers understand management of phosphorus in pasture systems – the concept of critical value. This is the value of soil P at which pasture production is near maximum (ie 95 % of maximum value if P were not limiting). In this survey only 42% of respondents understood this concept. Clearly if the project were to have an impact on soil P management this should have improved.

6.2 Rapid Survey of Producers

A second survey was developed to examine if progress had been made in key areas related to soil phosphorus management. The survey was developed to be handed out as a single sheet at field days and other events or even to be used in group mode – responding by show of hands. The survey questions can be found in Appendix 7.4. The table over summarises the results that have been obtained from all of the groups except Asheep. The results have been delivered either in site final reports or previously in milestone reports. The summary here represents responses to some key questions only. These have been selected because they can be directly related to questions asked in the original survey.

In the baseline survey, 42% of respondents could not correctly define the meaning of “Critical Value” with respect to soil P. It is apparent that there was not much change to this level of knowledge over the life of the project. Results from the rapid survey question regarding the definition of critical value varied widely. In southern NSW 65% of producers correctly define the term whereas in southern WA only 13% could. The average over all sites was 36%. A related question asked respondents if they could nominate a critical value for a typical soil on their property. Originally, in the baseline survey, 57% of producers could not nominate a typical critical value (ie 43% could). In the rapid response surveys, again there was considerable variation between groups. Cohorts in Victoria, on the Monaro and in southern NSW varied in their response but all were over the original 43% (Table 6). In WA and Northern NSW, the proportion of respondents who could nominate critical soil P values were quite low.

The variation in phosphorus-use-efficiency between legume species was targeted in two questions. In the baseline survey, 59% of producers treated all legume species, with respect to fertiliser application as the same. A further 31% of respondents only grew one species of pasture legume. Accordingly, the rapid response survey included questions about knowledge of variation in phosphorus requirements of legume species that respondents should have been familiar with (given that it was the point of the project). A high proportion of respondents (68-100% depending on location) correctly disagreed with proposition that “all pasture legumes have the same phosphorus requirement”. The cohort related to the Southern Dirt sites in WA included 42% of respondents who agree with the proposition. Elaborating further, responses were sought to the following proposition: “Serradella has a lower phosphorus requirement than sub clover”. A high proportion of respondents from Victoria and Southern NSW agrees (82-100%) but this was not the case at other locations – even in regions where serradella is commonly grown. In northern NSW 50% of respondents could not agree that serradella had a lower phosphorus requirement than sub clover and alarmingly 88% of respondents in WA disagreed with the proposition.

The rapid survey also included questions regarding soil sampling. Responses to two of these are presented in Table 6. When asked if they saw value in sampling deeper than 10 cm, many growers agreed with the proposition. In retrospect the question was poorly worded and should have been restricted to sampling deeper than 10 cm for characterising soil P status. Respondents may have interpreted as sampling for pH or some other factors. There is one aspect to the responses that is telling – only 29 % of respondents from WA – where leaky soils had led to the need for deeper sampling in the participatory trial sites – saw value in sampling beneath 10 cm. This points to a clear need to package information that has come from this project more effectively to growers in that region. A second question on soil sampling asked if growers saw value in sampling more of their paddocks – and most did. Only in WA was the response more equivocal.

Can we conclude anything from these surveys? At first glance the results are underwhelming – far too many growers do not have sound knowledge of the basics of P management in their pasture systems. As pointed out above, there are regions where knowledge and/or practices have improved but generally it is hard to detect much progress overall. The definition of critical phosphorus is a case in point. That concept forms part of nearly every communication that is associated with the project and yet it is not well understood by managers. While this may appear to be a sign of failure, some thought should be given to the possibility that targeting growers as respondents may have been a mistake. Most growers have an agronomist or advisor (even if a local reseller) who they rely on for advice on fertiliser management. If advisors have a sound knowledge of critical P, PBI, varying fertiliser regimes according to legume species, etc. does it really matter that the producer does not understand the details? In retrospect, recognising the influential role they have, more attention should have been paid to the attitudes of advisors and the like.

There is one other aspect to the survey that has been touched on above. The variation in responses between regions is marked. Responses were not necessarily aligned with regional concerns. For example, the 88% of WA respondents who thought serradella did not have a lower phosphorus requirement than sub clover compare to the 100% of Victorian respondents who knew serradella was more efficient. This reflects well on those communicators who have been able to “sell the message” in their regions but, more importantly, it tells us that future messaging will need to be targeted on a regional basis *and* taking into account the level of knowledge that has been demonstrated in these surveys.

Table 6 Responses (in terms of percentage of respondents) to key survey questions in the rapid survey.

Question	Southern Dirt WA	Northern NSW ^a	Southern NSW TFS & BAB ²	Monaro Farming Systems	Central Ranges Victoria
<i>Which best describes your understanding of “critical test value”</i>					
- I am not familiar with this term	38	29	6	19	0
- The minimum required for adequate production	50	32	29	38	62
- The value that soil must not exceed to avoid toxicity	0	7	0	4	0
- Value when pasture production is near maximum	13	25	65	38	38
- Value that gives best animal health outcome	0	7	0	0	0
<i>Can you nominate a typical critical phosphorus soil test value for a pasture that you fertilise</i>					
- Yes	33	13	70	50	76
- No	58	47	18	31	5
- Not Sure	8	30	12	19	19
<i>All pasture legumes have the same phosphorus requirement</i>					
- Yes	42	5	6	4	0
- No	0	68	94	81	100
- Not Sure	58	26	0	16	0
<i>Serradella has a lower phosphorus requirement than sub clover</i>					
- Yes	0	50	82	42	100
- No	88	21	12	8	0
- Not Sure	12	29	6	50	0
<i>Do you see Value in sampling deeper than 10 cm?</i>					
- Yes	29	100	35	65	81
- No/Not Sure	71	0	65	35	19
<i>Do you see value in sampling over more paddocks?</i>					
- Yes	54	100	82	100	76
- No/Not Sure	46	0	18	0	24

7 Engagement

All of the engagements events that have taken place during the project have been captured in the communications report by Dr Richard Simpson. These have been edited to include only events/communications that involved either the site leaders and/or the associated participatory groups. These include field days and field walks, newsletter articles, presentations to grower groups and conferences, articles in newspapers and other media and twitter activity.

Direct contact with producers and representatives of industry occurred at participatory sites and/or nearby research sites. Approximately 1372 producers and industry representative attended such events during the project. This does not include 8 events for which no attendance have been measure. Regular reports were made in newsletters to groups associated with the trials. The aggregate reach of these publications was 1633 members/farm businesses and 23 articles were written regarding the project and its progress. Results and progress at the participatory sites and the project in general were made at a range of industry events to groups not directly associated with the participatory sites. Presentations and circulations reached 1375 recipients via this routes.

The project was regularly referred to by Bob Freebairn in his regular column in “The Land” weekly rural newspaper in NSW. In addition the project was also promoted in the “Weekly Times” in Victoria. The reach of these papers is > 400,000 on a weekly basis. Finally, attempts to engage were also attempted on social media. A number of Twitter posts were made related to progress at participatory sites. These are listed in Appendix 11.5 as well.

This project took place when much of Australia was in drought – in Northern NSW throughout 2017-2019, in Southern NSW, Victoria and Western Australia in 2018-2019. AS a result, field days were often not appropriate (“nothing to see”) or were poorly attended due to the preoccupation with prevailing conditions. Nonetheless, many growers and industry representative did attend events and progress was circulated via established channels. The number quoted above attest to the efforts made by the participating groups, associated site managers and researchers.

What value was there in the participatory sites in terms of fostering engagement? There is not a straightforward numerical answer to this questions. For instance, many of the research sites were co-located with participatory sites making it difficult to estimate how many growers were engaged by on or the other or both. The value of the participatory network need not be gauged in such narrow terms. The groups associated with the participatory site played a key role in providing a ready conduit to likely first adopters of outputs from the project. Just as important, events that allowed producers and researcher to mix provided opportunities for researchers to further understand key issues in the management of serradella-based farming systems.

8 Conclusions/recommendations

8.1 Research and Development

The participatory sites have provided important results on management and development of serradella-based pasture systems. The conclusions reached from these trials can be listed as:

- 1) The relative performance of sub clover and serradella at low-moderate levels of soil phosphorus have been confirmed in a range of trials. That is, serradella produced more dry matter in spring than sub clover in most trials at low-moderate P levels. One caveat applies – the densities of the serradella and sub clover cultivars in those trials had to be comparable for the superiority of serradella to be expressed.
- 2) Serradella failed to persist adequately in many of the trials. Given that the trials were conducted over only 3 years and in many cases 2 years, there may yet be a possibility that serradella seed is in the seedbank but yet to soften. Nonetheless, for broad-scale adoption of serradella by producers in the high rainfall zone, persistence will have to be demonstrated over a wider geographical area and over a longer time span. Investigations into serradella persistence would need to include evaluation of a diverse set of serradella germplasm and a series of studies on the reproductive biology of serradella in the target environments.
- 3) Serradella may be well adapted to lower input, steep/rocky country in the higher rainfall zone of eastern Australia. Fertilising this country is expensive, so a lower P-requiring legume would provide some clear benefits. Adapting serradellas to lower input systems would require research into aerial establishment and associated factors – e.g. inoculation, timing and weed control.
- 4) Adapting serradella to new environments will also require development of agronomic packages that can be used by producers to ensure successful adoption of serradella. Much of the content of such a package could be provided from accumulated experience with serradellas over the past few decades in Western Australia. There is, however, one strand of management that will need particular attention if serradella is to be successfully adopted in permanent pastures of the higher rainfall zone in eastern Australia - weed control. In many of the trials weeds were a persistent problem but could be dealt with in ways that cannot be extensively applied. Many of the weeds that are problematic in eastern Australian grazing systems are controlled by herbicides that serradella cannot tolerate (saffron thistle controlled by MCPA is an apt example). Research and development focussed on weed control will be crucial for the future of serradella in these systems.
- 5) Management of soil fertility under serradella pastures on sandy/low PBI soils needs to be re-examined on the basis of the results found at the participatory sites and at the associated research sites in Western Australia. A change in soil sampling practices is already under way with producers and researchers sampling down to 30-60 cm instead on 10 cm. This is a useful first step but it will need to be accompanied by a redefinition of the critical soil P values for serradella (and other species) based on the P status over these greater depths.

8.2 Participatory trials and their management

In addition to the need for further work outlined above some conclusion can be drawn from the management of the participatory trials and the involvement of grower groups

- 1) The implementation of a common protocol was an important feature of this project. For the most part, there were few deviations from the measurement and management protocols that were agreed upon. Training in the protocols at the commencement of the project was crucial. It should be noted that some problems did occur with staff turnover in cooperating groups.
- 2) The Central data repository using simple spreadsheets was also a useful approach. This allowed the (participatory sites) coordinator to “audit” progress regularly (with each milestone report) and taken action where necessary to ensure that participants remained on task.
- 3) The impact of the drought on trial results was obvious enough but it probably also had an impact on producer engagement. Producers were generally reluctant to participate in surveys during the life of the project. This can be put down in part to the drought but also for some groups it is widely acknowledged that “survey fatigue” has been an issue in some regions. Amongst the participating groups, associated consultants and project researchers there is limited skill in devising engagement strategies and designing surveys. In future it may be more useful to engage social researchers to be active in that space.
- 4) On a more positive note, the network of participatory sites allowed interactions between researchers and producers that would otherwise be less likely to take place. These interactions were not confined to the conduct of, and results from, the participatory trials but ranged widely over the related topics in the general area of pasture nutrition, soil sampling, serradella ecology etc.

9 Key messages

The network of participatory sites developed as part of this project have played an important role in the development of more phosphorus use efficient farming systems. Each of the separate site reports have produced a set of key messages. Taken together, these can be summarised as:

- Sampling of low PBI/sandy soils needs to take into account phosphorus deeper in the profile than the standard 10 cm. Utilising P from greater depths in the profile will improve the efficiency of fertiliser use for producers who use serradella on these soil types.
- Serradellas are more phosphorus efficient than sub clover and could be used widely in pasture systems of Eastern Australia – *but* more work is required before serradellas can be recommended to growers.
- Participatory trials provide an opportunity to bring researchers and producers together to address agricultural problems via the involvement of producer groups. The use of common protocols, training events and regular auditing played key roles in producing reliable data from the network of participatory sites.

10 Bibliography

Sandral Graeme A., Price Andrew, Hildebrand Shane M., Fuller Christopher G., Haling Rebecca E., Stefanski Adam, Yang Zongjian, Culvenor Richard A., Ryan Megan H., Kidd Daniel R., Diffey Simon, Lambers Hans, Simpson Richard J. (2019) Field benchmarking of the critical external phosphorus requirements of pasture legumes for southern Australia. *Crop and Pasture Science* **70**, 1080-1096.

11 Appendix

11.1 Site Selection Protocols

Site Selection Protocol: Farmer Participatory research in existing serradella areas/paddocks

Background

Aim: To confirm in farm paddocks that maximum production by farm-scale serradella-based pasture can occur at its expected 'low' critical P requirement.

(e.g. in soil with Phosphorus buffering Index =50-100, this means 95% of maximum production should be achieved at ~20 mg/kg Colwell P (~10 mg/kg Olsen P)).

Explanatory notes: Mixed pasture managed (ideally) below ['nil P'], at ['optimum P'] and above ['high P'] the critical STP level in existing farm management systems is to be monitored for yield, botanical composition and legume persistence to test the hypothesis that "maximum production by serradella pasture can occur at the expected 'low' critical P requirement of serradella". At the start of this work we only have experimental evidence from recent Yass/Wagga area experiments that the serradellas have a critical P of about 10 mg P/kg soil (Olsen P) or about 20 mg P/kg (Colwell P for soils when PBI is ~50-100). However, these farmer groups will also be involved with Murdoch Uni and NSW DPI researchers in separate "small plot" experiments to determine whether the local critical soil-test-P requirement of serradella monocultures is similar to, or differs from those determined in the Yass/Wagga area experiments.

Approach

The following is not an in-depth account of the experiments to be conducted but covers those issues that will impact on site selection.

Location

Sites will be established in two regions:

- Northern NSW: Purlawaugh NSW Farmers, Boggabri Grazing Group managing one site each in conjunction with Bob Freebairn.
- Western Australia: Southern Dirt (Kojonup) and ASHEEP (Esperance) managing two sites each and using their in-house project officers to manage the experiment, collect data , etc..

Experimental

At each site, a field scale experiment will be established consisting of three replicates of three treatments – differing in annual fertiliser rates to achieve: (e.g. for a soil with PBI=50-100) **less than 20** e.g. 10-15? (with nil P applied), **~20** (maintenance P will be applied) and **30-40** mg/kg Colwell P (high P application). The details on how this is to be done (e.g. including how fertiliser is to be spread, size of plots etc.) will be fleshed out late this year and specific protocols developed.

It is envisaged that there will also be research (small plot) work established at each site or at a nearby site but operated entirely by a researcher associated with the project. See the notes from Richard Simpson below.

Measurements

The key measurements required from each site include seedling counts each Autumn recording target and non-target species (e.g. serradella, broadleaf weeds and grass weeds). Each spring, at approximately 5% flowering pasture yield (dry matter) measurements are to be completed along with botanical composition. Stock will have to be excluded from plots over the spring measurement period so some fencing will have to take place. The measurements will have to be made from 2017-2020 on each site.

Site Selection Criteria

Given the nature of the work to be conducted at each site then the following criteria should be addressed in the selection process:

- 1) Site to ideally have soil P levels of about 4-6 (certainly <10) mg/kg (Olsen) or about 10-15 (certainly <20) mg/kg (Colwell)
- 2) Adequate serradella populations should be present (e.g. > 50 plants m⁻²; or >25% serradella biomass by dry weight)*.
- 3) The experiment is to be conducted over 4 years starting in 2017 with site selection to occur from August 2016. The cooperating farmer needs to understand the length of the commitment. Likewise paddocks that are in a crop rotation due to be sown before 2021 should be avoided.
- 4) Temporary fences will need to be erected in the paddock to exclude stock from the plots at key times – the cooperating farmer will need to consent to this.
- 5) Is the farmer willing to also host the small plot work to be associated with the participatory sites? NB: The “small plot” research requires paddocks with very low soil P levels, so it may not always be possible to co-locate it with the paddock-scale experiments described here (see detail below).
- 6) Access to the site – for the staff involved, but also in terms of holding field days.
- 7) Does the farmer group rank the site highly? Their attitude will be important but cannot override the above (especially the first criterion)

*If below these thresholds and no alternative sites exist, then grass weeds should be controlled in 2016 before mid-September with Select herbicide at 500 ml/ha and broadleaf weeds with Spinnaker at 70g/ha to strengthen the serradella content (the researcher linked to the farmer groups may be able to assist with this weed control)

Selection Process

Given the importance of the current level of soil P in determining site suitability then it is important that the selection process commence ASAP. To narrow down the list of potential paddocks, try to access any previous soil results (Olsen P or Colwell P + PBI) – paddocks with for which there are very recent results indicating soil P levels markedly out of range can be rejected immediately. In addition, having some idea of the fertiliser history will also help. Once a shortlist has been established then it is vital that soil P be measured ASAP – before the end of August. These results will hopefully narrow the shortlist of paddocks that can be further refined according to the above criteria. Also, if the soils are sampled and results made available ASAP then that will give group time to organise weed control if warranted.

Soil Sampling

Soils (0-10 cm depth) can be collected by taking **30-50 soil cores** across the proposed experimental area. It is a bit difficult at this stage to be prescriptive regarding the extent of the area to be sampled, so confine sampling to a part of the paddock that would best suit the experiment (i.e. serradella present, clear of trees, camps, etc.....the usual considerations). If possible take the samples in a transect across 2-3 ha of a suitable area and record a GPS track of your transect. Keep the GPS transect – it may come in handy for location of fertiliser plots.

These are bulked to form a single sample which is to be posted immediately to:

Adam Stefanski
CSIRO Agriculture and Food
GPO Box 1600, Canberra ACT 2601.

Other Criteria

Make an assessment of the serradella in the part of the paddock where the experiment is likely to be – i.e. in the same area that the soil samples were taken from. Perform 30-50 visual estimations of the proportion of serradella (using a quad – size is not critical). Record these observations and average them. With respect to all criteria, use the sheet below to help with selection – It is important that the criteria are explicitly addressed as this will help avoid any pitfalls down the track.

Contact

If you have any queries or need to discuss any of the above, please contact: Jim Virgona 0431137144

SELECTION CRITERIA

Farmer _____

Property _____

Paddock _____

Criteria	Observation/Response	Comments
Soil P level – is it Olsen=10 or Colwell =20 mg/kg or thereabouts (within a few ppm)?		
Do you know, or can you guess the likely Phosphorus Buffering Index (PBI) value of this soil?		
Average serradella composition of the pasture it is above 25%?		
Length of experiment – explained to grower		
Attitude of grower to fencing the field scale plots		
Attitude of grower to co-location of small plot research if it is to be conducted at the site?		
Access to site – how easily can staff/researchers/field day participants access the site		
Attitude of farmer group to the site – is the paddock's situation relevant to the local farming community		

Site Selection Protocol: Farmer participatory research in areas that currently DO NOT grow serradella

Background

Aim: To determine how well serradella species are adapted to landscapes traditionally sown subterranean clover.

Explanatory note: French and yellow serradella monocultures have been grown in the Yass and Wagga areas with reasonable success although the yield of yellow serradella in winter and spring has often been less than that of French serradella and sub clover. The serradellas had lower critical P requirements for near-maximum yield (e.g. ~10 mg P/kg soil (Olsen P) or ~20 mg P/kg (Colwell P for soils when PBI is ~50-100) than sub clover (cvs Leura and Narrikup) (critical STP was ~15 mg P/kg (Olsen P) or ~35 mg P/kg (Colwell P)¹. It has been observed in the years after the experimental work that ground cover in these experiments is potentially problematic for the serradellas with sub clover (Leura) > yellow serradella (Avila) > French serradella (Margurita) > yellow serradella (Santorini). In other work, the serradellas (and other alternative legumes) have not persisted where sub clover does persist (e.g. Hayes et al. 2015 <http://www.agronomy2015.com.au/papers/agronomy2015final00332.pdf>). Farmers have been asking whether a serradella pasture will persist in the usual variable landscapes of large paddocks (i.e. different aspects, waterlogged areas, etc.). Mixed pastures of yellow and French serradella and sub clover should be sown and managed at the critical soil test P level for serradella under existing farm management systems but ideally across contrasting paddock landscapes to assess yield, botanical composition and legume persistence.

Approach

The following is not an in-depth account of the experiments to be conducted but covers those issues that will impact on site selection.

Location

Sites will be established in conjunction with four farming groups:

- Monaro Farming Systems in conjunction with Doug Alcock (Grazprophet P/L)
- Tableland Farming Systems in conjunction with Jim Virgona (Graminus Consulting P/L)
- Bookham Agricultural Bureau in conjunction with Jim Virgona (Graminus Consulting P/L)
- Central Ranges Grasslands Group in conjunction with Lisa Warn (Lisa Warn Ag Consulting P/L)

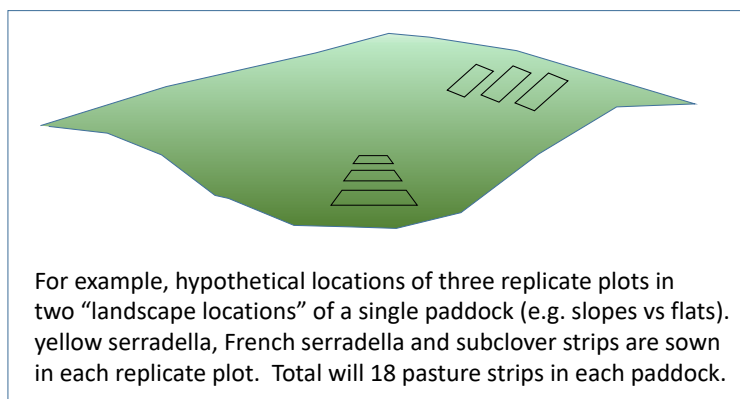
Experimental

Paddocks that are already being prepared for sowing to pasture in 2017 are the preferred location for these experiments so that we can take advantage of weed control that is already underway. Paddocks coming out of a crop will also be useful provided they meet the soil P fertility guidelines (see below).

Small scale experiments will be established to compare the performance of serradellas (French [also known as 'pink'serradella] and yellow) with sub clover in two parts of a paddock landscape. The soil P fertility level needs to be ~10 mg P/kg soil (Olsen P) or ~20 mg P/kg (Colwell P for soils when PBI is ~50-100).

Hence, the experiments will consist of **three** plant species treatments each replicated **three** times (9 plots) and located in **two** parts of the paddock landscape at each site – ie 18 plots in all. These legumes will be sown with a perennial grass species that the farmer would normally use as a companion pasture species. Further details on how this is to be done (e.g. size of plots etc.) will be fleshed out later this year when specific establishment, measurement and management protocols will be developed.

¹ NB: Current guidelines predict a critical Colwell P of ~30 mg P/kg for soils in this PBI range.



It is envisaged that there will also be research (small plot) work established at each site but operated entirely by a researcher associated with the project (Richard Hayes for the NSW sites; Lisa Warn for the Victorian site). See the notes from Richard Simpson below.

Also it is possible that sowing of the plots on the NSW participatory sites may be able to use NSW DPI seeding equipment with help from Richard Hayes. However, this is still to be finalised/negotiated.

Measurements

The key measurements required from each site include seedling counts at establishment and then each Autumn - recording densities of target and non-target species (e.g. serradella, broadleaf weeds and grass weeds). Each spring at approximately 5% flowering, dry matter estimates are to be completed along with botanical composition. Stock will have to be excluded from plots over the spring measurement period so some fencing will have to take place. The measurements will have to be made from 2017-2020 on each site and again, protocols regarding these measurements will be developed and circulated later this year.

Site Selection Criteria

Given the nature of the work to be conducted at each site then the following criteria should be addressed in the selection process:

- 8) Site to have soil P levels of ~10 mg/kg (Olsen) or ~20 mg/kg (Colwell)
- 9) Paddock to be sown to a perennial pasture in 2017 and sprayed out in spring 2016 as per usual practices – before seed set by annual species...including early flowering grass species.
- 10) The experiment is to be conducted over 4 years starting in 2017 with site selection to occur from August 2016. The cooperating farmer needs to understand the length of the commitment. Likewise paddocks that are in a crop rotation due to be sown before 2021 should be avoided.
- 11) Temporary fences will need to be erected in the paddock to exclude stock from the plots at key times – the cooperating farmer will need to consent to this
- 12) Is the farmer willing to also host the small plot work to be associated with the participatory sites? (Details can be provided)
- 13) Access to the site – for the staff involved but also in terms of holding field days.
- 14) Does the farmer group rank the site highly? Their attitude will be important but cannot override the above (especially the first criterion)

Selection Process

Given the importance of the current level of soil P in determining site suitability then it is vital that soil P be measured ASAP – before the end of August. These results will hopefully help determine a shortlist of paddocks that can be further refined according to the above criteria. Also if the soils are sampled and results made available ASAP then that will give the group time to organise additional weed control to ensure good pasture establishment.

Inadequate weed control is the most frequent cause of poor outcomes when sowing pasture.

Soil Sampling

Soils (0-10 cm depth) can be collected by taking **30-50 soil cores** across the proposed experimental areas – two locations in each paddock. It is a bit difficult at this stage to be prescriptive regarding the extent of the areas be sampled, but a reasonable approach would be to take samples in a transect across 1-2 ha of a suitable area and record a GPS track of the transect. The GPS file (usually a .gpx file) of the transect will come in handy for location of fertiliser plots.

The soil samples are to be bulked for each area within the paddock (i.e. 2 samples per candidate paddock) and posted immediately to:

Adam Stefanski
CSIRO Agriculture and Food
GPO Box 1600, Canberra ACT 2601.

Other Criteria

With respect to all criteria, use the sheet below to help with selection – It is important that the criteria are explicitly addressed as this will help avoid any pitfalls down the track.

Contact

If you have any queries or need to discuss any of the above, please contact:

Jim Virgona
Graminus Consulting P/L
0431137144
jim@graminus.com.au

SELECTION CRITERIA

Farmer _____

Property _____

Paddock _____

Criteria	Observation/Response	Comments
Soil P level – it is Olsen=10 or Colwell =20 or thereabouts (within a few ppm)		
Do you know, or can you guess the likely Phosphorus Buffering Index (PBI) value of this soil?		
Paddock to be sown in 2017 and sprayed out in spring 2016		
Length of experiment – explained to grower ie 4 years		
Attitude of grower to fencing the plots		
Attitude of grower to small plot work to be conducted at site?		
Access to site – how easily can staff/researchers/field day participants access the site		
Attitude of farmer group to the site – is it relevant to local farming practices.		

11.2 Participatory Research Site Protocols

P4PASTURES PARTICIPATORY SITES

Protocol & Policies

This protocol is to be used for the Participatory sites for the *RnD4Profit-15-02-016 Phosphorus efficient pastures* project – hereafter referred to as the *P4Pastures* project. At this stage the protocol is in draft format and will be finalised after the workshop to be held in Canberra on Dec 6-7 2016.

Introduction and Rationale

The purpose of this document is to ensure that all members of the project are using the same methodology when carrying out the project. This includes design, measurements and management of experiments, reporting results and publicising outcomes. There are a range of influences that need to be accommodated in the way we conduct the project, some internal and some external.

The participatory site network is part of a larger project, the aim of which is to “*reduce the phosphorus (P)-dependence of Australian temperate pastures by expanding the use of high yielding pasture legumes that have lower fertiliser-P requirements*”. There are two major components to the project – a research component that will be conducted by a network of scientists led by Dr Richard Simpson. The second component is the on-farm participatory sites that will examine the performance of Serradella in response to phosphorus and in comparison to sub clover.

For the on-farm participatory sites, it was thought that rather than carry out large scale farm demonstrations, smaller (simple) experiments could be established and managed in a farm-relevant context to provide useful data to benefit the overall project. However, to maximise the use of the data from these smaller scale experiments, they need to be implemented and managed with common protocols. Data from these experiments will thus be easier to analyse and interpret thereby adding considerable weight to any conclusions reached from the work. Hence, it is vital to the performance of the project that participatory site managers use an agreed set of policies and protocols.

The aim of the workshop is thus to work through the draft protocols and policies in this document, edit them as necessary and participate in hands-on training.

Finally, this project is funded jointly primarily by the federal Department of Agriculture and Water Resources (DAWR) and Meat and Livestock Australia (MLA) with further support from Dairy Australia and Australian Wool Innovation Ltd. The capacity of these agencies to fund research is enhanced when farmers and the general public recognise their investments. Consequently all of the agencies require us to acknowledge their research investment, so it is important that we do not forget to include acknowledgements on all publications, promotional materials, signage and activities relating to the programme and this agreement including but not limited to: (a) events and announcements: national, state and local (at all programme stages/phases), (b) media releases (c) media activities, including newspaper and radio interviews, (d) public relations activities including workshops, forums and conferences, (e) display materials such as banners, posters and all on-ground programme and project signs, (f) publications such as reports, books, case studies, information kits and fact sheets, (g) websites, including all regional web home pages. The format and process for seeking ‘approval to publish’ is outlined in the initial ‘communications policy’ (Appendix 4).

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Terminology

Just so we are sure that we are referring to the same things here is a brief list of terms that will be used throughout the project with definitions.

Term	Definition
Participant(s)	Collective term for the group and/or associated consultant involved in the project
Location	The paddock/property in which individual experiments/trials will be conducted. Could be referred to using closest town, eg. Bigga/Cooma, if not confounded by another Location in the same area
Site	An experiment at a location. At most locations there will be two experiments – <i>usually</i> in contrasting parts of the landscape within a single paddock
Existing	This is shorthand for the sites where existing stands of serradella are being examined for their response to phosphorus supply. Namely, Northern NSW and WA locations
New	This is shorthand for sites that will examine the comparative performance of sub clover and two serradella species at levels of soil P thought to be critical for serradella. Namely Central and Southern NSW and Central Victoria
Plot	Single experimental unit upon which a treatment is applied
Rep	Replicate in the Site experiments – for the most part there will be three replicates of three treatments at each of the sites
#P4Pastures	Twitter# tag for the project

Annual Checklist

Here is an annual checklist of the measurements & actions that must be made on the sites. Both types of sites are included and the list is in approximate annual order. This is for your own use to help jog your memory – it does not need to be sent/collected.

Measurement/Activity	When	
Fertiliser Application	March for most sites – at the break	☐
Seedling Counts	Within one month after the “break” or when appropriate	☐
Frequency	Late winter – before more than 1500 kg DM/ha accumulates	☐
Soil Sampling	Early spring while soil still moist – >3 months after fertiliser application	☐
Site “lock-up”	September-October; 4-5 weeks before anticipated peak of spring feed	☐
Dry Matter	October – November; 4-5 weeks after site lock-up	☐
Botanical Composition	Same day as Dry Matter measurement	☐

Data handling – Drop box

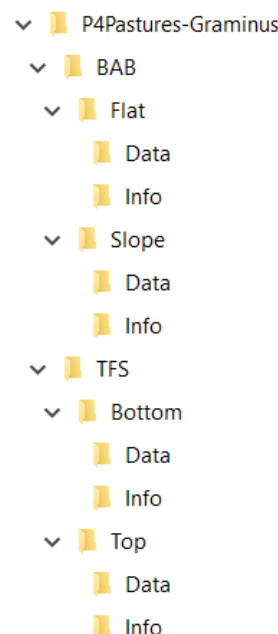
Data will be exchanged between the participants and the coordinator (Jim Virgona) via Dropbox. Each participant will have access to two drop box directories. Firstly there is the master directory that will contain any templates, documents or other files that need to be stored in common for all participants. A Dropbox directory for this purpose has already been shared with you. This protocol (when finalised) will also be stored in that directory.

Each participant will also have their own Dropbox directory for storing data from the sites that they manage. Only the participant running those sites and the coordinator will have access to this Dropbox location. The directory structure will look something like this

Main Directory – *P4Pastures-Graminus* (unique directory name for each participant)

Sub Directories for each location: */BAB* (acronym for Bookham Ag Bureau site) and */TFS* (the acronym for Tablelands Farming Systems site at Bigga)

Sub-Sub Directories for the sites at each location. Try to make the Names for sites distinct and meaningful – eg. for the TFS sites I have “Bottom” and “Top”. Within each site directory there will be a further two subdirectories – *Data* (which will only contain spreadsheets related to the site); *Info* – any other site information, photos etc. that may be relevant.



Dropbox and Web addresses

One advantage of using Dropbox is that files can be accessed using web addresses. For instance if you created a field day flier and stored it in a Dropbox location then it could be downloaded even by people who aren't on Dropbox, just follow the directions here <https://www.dropbox.com/help/167>. It would be possible to share a file with users of Twitter by including the web address in your tweet (see below).

Site Data -

Site data will be captured in a spreadsheet that will be designed for each site. Each worksheet will contain the data from a particular measurement. In order to use the spreadsheet you will have to enable macros to run in Excel. The spreadsheet will be named using the location and site descriptors followed by “Data” then followed by year eg., “TFSTopData2017.xlsm” and will be placed in the site data subdirectory after the workshop. In the rest of this document this file will be referred to as the **SiteData spreadsheet**.

A second spreadsheet will be available to help record the estimates of botanical composition. This is adapted from one that we use in our business. However, you will need a windows-based tablet/notebook with touch screen to use it as it is based on macro-enabled Excel. Output from this spreadsheet will need to be copied into the **SiteData spreadsheet**...more on this below. This spreadsheet will be named with location and site descriptors as above eg. “TFSTopPastureComp2017.xlsm”. Both spreadsheets will be demonstrated at the workshop. **NB it is**

important that data is stored in these spreadsheets as they will be accessed by the coordinator for the purposes of reporting and analysis.

Site establishment

Experimental Design

At each site a simple design will be used – 3 treatments replicated 3 times. The design will be a set out as Latin square – 3 x 3. Replicates (or rows) should be laid out in the direction where you expect the least variation – ie. in the figure below less variation would be expected between plots 1,2 & 3 compared to plots 1, 4 & 7.

		Column		
		1	2	3
Rep	1	Plot 1 Treat 1	Plot 2 Treat 2	Plot 3 Treat 3
	2	Plot 4 Treat 2	Plot 5 Treat 3	Plot 6 Treat 1
	3	Plot 7 Treat 3	Plot 8 Treat 1	Plot 9 Treat 2

Existing sites: the treatments will be three levels of soil phosphorus –

- Lo-P (allow to drop under the optimum for serradella);
- Med-P (adequate for Serradella) and
- Hi-P (above serradella optimum)

Based on soil the results of soil tests, annual fertiliser rates will be determined in consultation with Richard Simpson.

New Sites: The 3 treatments* will be newly sown pastures containing a perennial grass and either

- Sub clover;
- Pink Serradella (Margurita)
- Yellow Serradella (Avila or Santorini).

**The selection of sub clover and serradella cultivars along with perennial grass species should be carried out in consultation with Richard Simpson and Richard Hayes.*

Generating Designs:

Open the **SiteData spreadsheet** and go to the **Design** page. Select the type of site you are operating (New or Existing) then click the *Design* icon. A design will appear – if you are happy with it, then click the *Lock* icon – this means that the design will be protected from editing. This is important as the other worksheets draw data from the **Design** sheet.

Site Layout

How the plots are arranged need not be prescriptive. However, there are a few related issues worth raising that will have an influence on plot layout

Plot Size

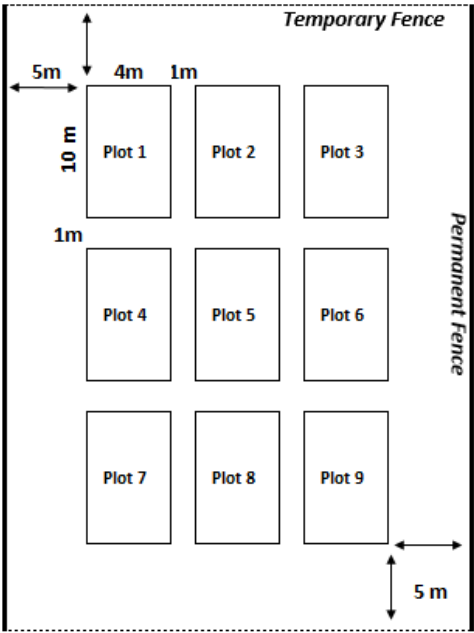
New Sites - probably approx. 4 m x 10 m (likewise for Existing sites that need to be sown). This is equivalent to 2 sowing widths of the plot seeder that will be used x 10 m.

Existing Sites – not necessary to be prescriptive but remember that the larger the plots are, the more difficult the task of spreading fertiliser accurately. One suggestion would be no larger than the plots for New sites.

Other Considerations

- Buffer between site and rest of paddock – thinking about fertiliser spreaders that may inadvertently spread on plots, say 5 m. Buffers between plots were deemed unnecessary.
- Fencing –this is related to the Grazing Management Policy – grazing management must be through exclusion only – for animal ethics purposes. Hence fencing out becomes an issue for size. Plots will be locked up once a year in spring in order that productivity (dry matter production) can be measured. If there is an excess of feed on the plots then we will have to mow and remove the dry matter – this also influences size of the plot/site. All these are reasons to minimise plot size as far as reasonable. **Timing:** it is important that fertiliser is not spread over the sites before the experiments commence, so the quicker the sites are fenced out or, at least, marked out the better!
- Fencing – a useful idea would be to fence along two parallel sides of the trial with more or less permanent fences and erect the two perpendicular fences temporarily when plots need to be locked up.
- Location of the site and fences – important to consider the requirements of the collaborating producer, of course. In addition the use of electrical tape can also be considered.

A Sample Layout could be:



Initial Soil Sampling

Although an initial soil sampling was done when the site was selected, further soil analysis is needed to determine the amount of fertiliser to be applied on either New or Existing sites.

- As suggested above, the sites should be marked out as soon as possible in order to avoid any actions by the producer (fertilising, weed control..?) that may be a problem for the experiment. Try to complete this initial soil sampling at the same time.
- Soil Sample – Sample each replicate by taking 15 soil samples to a depth of 10 cm*. Bulk the 15 samples within each rep and send to :
Adam Stefanski C/-

CSIRO Food and Agriculture

PO Box 1700

Canberra ACT 2601

- Label the sample with the following: **Labelled**: Location, Site, Rep, Date sampled.
- On sites with sandy soils sampling may need to be deeper than 10 cm – consult with Richard Simpson over this.

*An alternate method of taking 5 soil plugs per plot and bagging separately can also be applied.

Measurements

Approaches to Sampling

In the following sections a range of measurement protocols are set out. The successful implementation of these protocols will, in part, depend on sampling the plots in a representative manner. The key to this is to avoid any practice that will bias the measurement of sampling of the plot. One sure way around bias is to determine the sampling strategy before commencing the measurement and stick with it. For example, when cutting dry matter quadrats or assessing pasture composition, 10 samples per plot are required (see below). If this is the case why not sample in a diagonal line across the plots and stop to sample every 1-2 steps or so (some evenly-spaced distance that will allow a sampling of most of the plot)? Having decided on such a course then stick to it – even to the point of not looking directly in front of you so as to avoid biasing quadrat placement (on high or low areas).

A similar approach could also be made with soil sampling, seedling counts and frequency – only the distances need be varied according to how many samples are required. Besides this, common sense should be employed:

- Do not sample close to the edge of the plots
- If part of a plot is affected by an unforeseen event that has nothing to do with the experiment (eg. herbicide drift) then avoid sampling it
- Avoid any effects of variation between operators by getting one person to do a particular measurement across all the plots in the experiment – eg. the same person cuts all the dry matter quads at one time; takes the soils samples etc. This is even more important for methods (like pasture composition) that require estimation – the same person does the whole experiment. Variation in operators between experiments (sites) is less of a concern – ie. one operator could cut Site A while another cuts Site B – each cutting all of the plots on their respective sites.

Annual Soil Sampling

As response to soil phosphorus is fundamental to the experiment then this will be measured every year.

Method

Sample 0-10 cm in spring while the soil is moist to monitor soil P levels. Take 15 samples from each plot and **package each plot separately**. Sample should be homogenised/mixed but **NOT** subsampled. Samples can be sent fresh or dried. If the sample is too large talk to Richard Simpson.

Send sample to:

Adam Stefanski C/-

CSIRO Food and Agriculture

PO Box 1700

Canberra ACT 2601

Label the sample with the following: **Labelled**: Location, Site, Plot, Date sampled.

When

Each spring for the term of the experiment – the levels of soil P from this measurement will be used to determine the amount of fertiliser to be applied in the following year.

Notes.

- be careful to ensure that your sample extends to 10 cm. Problems that can occur are – tip wear (so check the length of your sampler) and ensure that the base-plate of the sampler can reach the soil surface – kick the plant litter away
- Sample bags – there are a range that can be used – we use heavy duty (100 µm) plastic bags with writing panels available from QIS packaging (<http://www.qispackaging.com.au/Product/resealable-press-seal-bags-zipper-bags/Heavy-Duty-100um-Write-On-Panel.aspx>)
- The results of analyses will be returned to you – please store these on the site spreadsheet. The format is yet to be determined.
- Soil sampling will be demonstrated at the workshop.
- Like the other measurements, the results of soil analyses will be stored in the Site Data file. A worksheet in the file has been set aside but has not been specifically designed as yet – there may be considerable variation between sites on sampling and analyses. At the bare minimum, soil P will be recorded on every plot in every year.

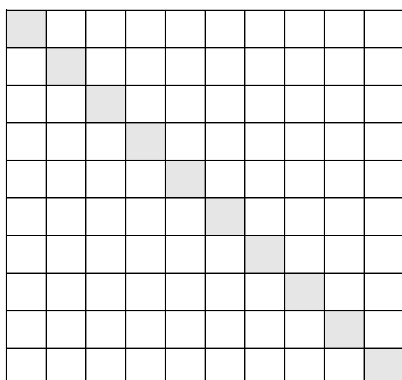
Seedling Counts

The number of sub clover *and* serradella seedlings are to be counted on each plot in each year regardless of treatment. How this is to be achieved will depend on the type of experiment and whether the counts take place at establishment or in subsequent years.

Method

For the first year at any site that has been newly sown, count the seedlings that occur in 10 separate 0.5 m rows. To do this place a 50 cm ruler between two rows and count the number of seedlings that occur in the rows either side of the ruler; you need to record row spacing as well. Repeat this 5 times in the plot being careful with your sampling technique. Record the data on the sheet provided (see Appendix 1) and transfer to the **SiteData spreadsheet** onto the **Seedling Counts** worksheet in the area under the heading “Newly Established Sites Only”.

In all other years on New sites and every year on Existing sites, count seedlings in 10 of the small squares diagonally across the frequency quadrat (50 cm x 50 cm mesh quadrat with 5 x 5 cm squares – see below). Record the total number of sub clover and serradella seedlings summing the 10 small squares (ie. count cumulatively) on the sheet provided. Do this 5 times for each plot. Store the data in the **SiteData spreadsheet** on the **Seedling Counts** worksheet in the area under the heading “Annual Seed Counts”.



Make sure you count in each square but record the sum of all 10 squares for each quad.

When

About 1 month after initial break in early winter but early enough for individuals to be distinguished.

Frequency

Frequency gives us a chance to measure the persistence of key species. In this case Serradella and sub clover.

Method

A 50 x 50 cm mesh quadrat divided into 5 x 5 cm squares (ie 100 squares) is used and the object is to record the presence of serradella and or sub clover (as appropriate) within any of the squares – the resulting number being the percentage of squares occupied.

This should be done on 3-5 quads per plot – if highly variable increase the number of quads assessed per plot. Record the number on the sheet provided (see example in Appendix 2) and transfer to the appropriate sheet in the **SiteData spreadsheet**.

Sampling: try to be consistent with respect to where you position the quad – eg. perhaps in a diagonal line across the plot at a certain number of steps – it is important not to bias the measurement in any way.

Timing

Around mid to late winter when pasture height less than ~ 4 cm (approximately less than 1500 kg DM/ha on plots).

Pasture Composition

These will be based on visual estimation of the major pasture components. This does amount to “guesswork” but the key to getting useful results is to be consistent*. We will record each of the following species/groups as appropriate for each plot:

- Serradella
- Sub clover
- Sown perennial species
- Annual grasses
- Broadleaf species
- Other species.....non-sown species

Also include notes on which were the major weed species present ie. – barley grass as a major annual grass, capeweed for broadleaves (BLWs) etc.

Method

Estimate within 10 quads per plot along a predetermined path. You could walk diagonally across the plot and record every one or two steps or use a rope with notches (knots) equally spaced along the length and position it between fixed pegs (plot boundary markers).

Quads (0.1 m²) with handles will be supplied.

There are two ways to record.

- 1) Use the specially designed spreadsheet supplied (“PastureCompCalculator.xlsm” – best to rename this when you save it – incorporate location, site and year in file name) – if you have a Windows Tablet/notebook that runs full Excel then using this spreadsheet will save a lot of time. Instructions on how to use this spreadsheet can be found in it on the start page. This spreadsheet will not work for IOS, Android operating systems or mobile office. When you have completed the estimates, copy columns K to S on the **Results** sheet and paste as values over Columns K to S on the **Pasture Comp** sheet in your site data file.
- 2) The second way of recording the data is to print out the recording sheet provided (in the file “PastureCompSheet.xlsx”) and enter the data by hand in the field. The data can then be entered into the **Results** sheet of the specially designed spreadsheet supplied (“PastureCompCalculator.xlsm” – best to rename this when you save it). Follow these steps:
 - a. Place the data for each sample (make sure you write the plot number for each sample) in columns A to H – this follows the order on the recording sheet
 - b. You will notice that plot averages are being calculated as you fill out the data. Once you have finished entering the numbers for a plot, type the grass weeds and BLWs in columns R and S as appropriate
 - c. When you have completed entering all the data then copy columns K to S on the **Results** sheet and paste as values over Columns K to S on the **Pasture Comp** sheet

Finally - ensure the same operator assesses each plot at a particular site – better still, use two operators for each plot at each site and take the average.

When – each spring before dry matter cut (see below)

*Calibration

If you are not confident with your estimations then it may help to calibrate. To do this it is best to select (say) 5 quads of varying composition (covering the range in your plots but avoiding extremes). Place the small 0.1 m² quad and make estimations of each component. Then cut the pasture in the quad just above ground level. Sort the harvested material into the components listed above. Place each component into a paper bag and dry at 70° C for 48 hours. Weigh each component and calculate the percentage of each. Sorting plant material can be very time-consuming. If the sample is too large then consider sub-sampling before you sort. Make sure that you obtain a representative sample by thoroughly mixing the sample before sub-sampling. Your sub sample should be at least 25% of the original sample.

Dry matter measurement

The purpose of this measurement is to reflect the relative productivity of the treatments. It will only cover the period of peak spring growth each year. If the plots are noticeably uneven at the commencement of the lock-up period, the site should be mown to a level that will even-up the feed available across the site.

Method

At the end of the lock-up period (see grazing management for when to lock up). Cut 10 x 0.1 m² quad cuts per plot. Cut to ~ 1 cm above ground level – avoid dirt in the sample – otherwise wash out. Bulk the 10 cuts into a single sample per plot. You can either:

- 1) Weigh the bulked sample fresh in the field, record that value then thoroughly mix the sample and sub-sample it....perhaps ~ 20-30%. Record the fresh weight of the subsample then dry it as above and weigh. Use the moisture percentage of the subsample to calculate the dry weight of the whole sample. Enter the data into the **Dry Matter** worksheet in the **SiteData spreadsheet** into the cells headed “Sub Sampling Method” – the calculations are done automatically.

or

- 2) Dry the whole sample if you have access to drying facilities. Dry for at least 48 hours (or until dry – this may take longer so check by monitoring your samples and checking weight change) at 65-80°C then weigh for dry weight, excluding the weight of the sample bag. Enter the data into the **Dry Matter** worksheet in the **SiteData spreadsheet** in the cells under the heading “Total Sample” - the calculations are done automatically.

When

Each year at the completion of the annual lock up period in spring (see above).

Policies

Adherence to protocols

The policy for the group should be to adhere to protocols as much as possible. If there is a problem with a protocol or you don't understand the protocol or an issue on a site that would prevent a measurement being made then contact either Jim Virgona (0431 137 144) or Richard Simpson (026246 5364) and the issue will be addressed.

Also any changes to protocols are to be put before the whole group. There are degrees of change as well – eg. changing when or if measurements take place is critical – this needs to be discussed. Lesser issues, like number of samples in a measurement (eg. quads cut per plot) can be locally determined – but ensure you make necessary changes on the spreadsheet and always record actions (and relevant observations) in the diary.

Diary

Please record all major events on the diary page of the **SiteData spreadsheet**. This includes when measurements were taken, spreading fertiliser, sowing, pesticide use, when plots are locked up, any other important item - even variations to the protocol (see above). Even if you have already recorded the date in your measurement data, it will pay to have the diary complete.

Grazing Management

Grazing management is by exclusion only, for animal ethics reasons we are not permitted to lock stock in plots – there is no way around this. For New sites – exclude from grazing until safe to graze – locally determined but for phalaris usually seed production in year 1. Perhaps where perennial ryegrass is sown, grazing could be utilised in the first year to control competition – this is up to the local site operators.

On an annual basis, the plots will be open for most of the year to how the producer runs the paddock. However, for one month of the year grazing will be excluded from the plots this will occur to capture the peak spring growth period. Given the variation in environments it is not possible to be prescriptive about timing but generally earlier in the West and later in the higher rainfall zones of NSW and Victoria. Ensure that date of lockup and opening are recoded in the diary. Remember if the plots are noticeably uneven at the commencement of the lock-up period then they should be mown to a level that will even them up (see above).

Fertiliser Management

Each year the sites will need to be fertilised. For Existing this is obvious enough as varying rates of P addition is what the experiment is about. For the New sites some base level of P will need to be added each year to maintain fertility at the level required (about adequate for serradella). In terms of a policy the following should be adhered to

- Fertiliser rates (and types) for all sites will be determined in consultation with Richard Simpson. These will be determined using the results from analyses of soil sampled in the previous spring.
- Spreading fertiliser on plots will be a labour intensive process but it is important that it is done accurately. Do not try to spread the entire amount of required fertiliser on the plot without subdivision – the results will be too variable. Plots should always be subdivided (stringed) and the appropriate amount of fertiliser spread in each sub section. The number of subdivisions depends on the size of the plot. For instance, for plots measuring 10 x 4 m reasonably accurate spreading was achieved at the workshop by dividing the plot area into 4 equal sized sections.
- Every year make sure the amount and type of fertiliser are recorded in the site diary (in the **SiteData spreadsheet**). Also record the date on which fertiliser was applied.

Weed Management

Weed management will be largely via herbicides. For this the conservative approach will be taken ie. there should be no herbicide unless failure inevitable. The following guidelines should apply:

- In the first instance do not consider off-label applications. Try to find a product for which Serradella and/or sub clover are on the label. If this is not possible then.....
- Consult within the group – best not to go off on own. Serradella will present the greatest challenges so use the P4Pastures participant network as much as possible – there are participants who have a lot of experience with the species.
- Consider the damage done to the legumes not just in terms of herbage damage but also seed production.
- Try to set local thresholds for weed control eg. 25% serradella or 50 plants.m².

Diseases

Triggered by observation of disease – in particular any disease occurrence on serradella to be noted. If observed, then try to identify the disease. It is suggested that an email be sent to all participants from the workshop including a picture to help in the ID process. If necessary, then take sample and post to NSW DPI (address below), and score plots for severity: 5, 10, 15, 20% etc.

Andrew Price

Wagga Wagga Agricultural Institute

PMB, Wagga Wagga NSW 2650

Twitter & Promoting the Project

As noted above it is important that participants in the project are active in promoting project results, achievements and activities. This can be very time consuming, so to reach a wider audience, the use of Twitter could be a real asset. This is especially the case as Twitter analytics can produce data around the number of engagements as well as the demographics and locations of followers. When using Twitter, project participants should consider the following:

- Our aim is to get all participants on Twitter as it will serve as the major route for project publicity.
- The project Twitter handle will be #P4Pastures – this should be on any Tweet that is related to the project
- When using the #P4Pastures handle please promote only relevant project information – the “Twittersphere” is full of nonsense and trivia, it would be best if project related Tweets were restricted to project related activities – eg. Field Days, Results and Progress, pictures that are informative and have promotional value etc. More of this at the workshop

11.3 Appendix – Survey of Producers

SOIL PHOSPHORUS (O) MANGEMENT FOR PASTURES – A SURVEY OF PRODUCERS

Jim Virgona and Richard Simpson

PURPOSE

The purpose of the survey was gain an understanding to current approaches and attitudes to managing phosphate fertiliser. In addition, the survey presented an opportunity to gauge current knowledge of key concepts that underlie phosphate management.

METHOD

The survey was circulated to members of each of the participating farming groups: Asheep (WA), Southern Dirt (WA), Boggabri Grazing Group (Northern NSW), Purlewaugh NSW Farmers (Northern NSW), Tablelands Farming Systems (Southern Tablelands NSW), Bookham Agricultural Bureau (Southern Tablelands NSW), Monaro Farming Systems (Monaro, NSW) and Central Ranges Grasslands Branch (Central Victoria). The survey was made available via Google Forms to the members of each of these groups. In addition the survey was made available in hard copy at a range of field days. A copy of the survey as it appeared on Google forms can be found here:

<https://goo.gl/forms/Ucz9zED99pJPtKPa2>.

RESULTS

The responses to most questions can be found below. The data is presented in terms of the percentage of respondents or the raw number of respondents as appropriate. Questions were not numbered as originally presented but are in the section below for convenience. A brief commentary is provided at the end of each of the survey section. A further “Analysis” section presents an analysis of the results with respect to key concepts/practices.

RESPONSES

Some background to your survey answers

1) *Location of property – nearest town and state or postcode*

	No. of respondents
Monaro – southern NSW	17
Southern Tablelands, NSW	18
Western Australia - South	13
Central Victoria	8
Northern NSW	5
Central NSW	3

- 2) What proportion (to the nearest 20%) of your farm(s) area is occupied by the grazing enterprise? (64 responses)

	% Respondents
100%	56.2
80%	28.1
60%	12.5
40%	3.1
20%	0

- 3) Which livestock enterprises do you run – indicate percentages as proportion of gross livestock income to the nearest 20%?

	Number of respondents	Median Contribution
Lamb	40	20%
Wool	43	60%
Mutton	30	20%
Beef	38	40%
Other*	7	20%

*A number of responses to this question under the 'Other' category made little sense and should be ignored.

- 4) Please indicate if you are a member of or associated with any of the following groups:

	No. of respondents
Monaro Farming Systems	17
ASHEEP	13
Bookham Agricultural Bureau	12
Not a member of any farming group	8
Central Ranges Grassland Society	7
Tablelands Farming Systems	5
Boggabri Grazing Group or Purlewaugh NSW Farmers	1

Commentary

It was unfortunate that the survey was completed by so few respondents. This highlights the problem of “survey fatigue” that is commonly expressed by producers. In Western Australia No members of one of the participating groups in Western Australia (Southern Dirt) filled out the survey and this was put down to Survey fatigue – a common problem in the WA wheat belt. Nonetheless, the survey does provide some worthwhile results from a cross section of pasture managers in temperate Australia. Most respondents were members of one of the participating farmer groups with only 8 out of 63 unaffiliated. Geographically, southern NSW was represented by 35 of the 63 respondents. Central & Northern NSW and Victoria were represented by 8 respondents each. Members of Asheep made up the entire Western Australian response (13) – along or near the southern coast from Esperance east.

Almost all respondents (96%) had at least 60% of their properties devoted to livestock production - 56% of respondents had 100% of the property occupied by the grazing enterprise(s). There was a spread of enterprise types with wool and beef production

SOIL PHOSPHORUS (P) MANAGEMENT

- 5) *Which of the following statements would best describe the phosphorus fertiliser management of your pasture paddocks in recent years? (63 responses)*

	% Respondents
All paddocks regularly fertilised	55.6
Improved paddocks regularly fertilised, native paddocks sometimes or never fertilised	20.6
Fertiliser spread when budget allows	12.7
No fertiliser applied on the pasture because P fertiliser is mainly applied during the cropping phase	7.9
Never fertilise with P-based fertiliser, below please state why and go to the subsection headed "Soil Testing" (below)	3.2

- 6) Which of the following is the **most important** consideration (choose one only) in determining the **rate** of fertiliser applied (i.e. kg/ha): (63 responses)

	% Respondents
I use soil test results to modify the rule of thumb application rate that I would normally apply	38.1
Soil test results are always considered and used to determine amounts to be applied	31.7
Rule of thumb e.g. 125 kg/ha every year or second year, regardless of whether soil tests have been taken	14.3
I typically have a budgeted amount of money to be spent on fertiliser each year	6.3
The amount of fertiliser applied depends on my cash flow situation and may vary each year	6.3
What my agronomist recommends	3.2

Commentary

Amongst the respondents fertiliser was used regularly on improved pastures according to 76% of respondents. Only 2 respondents didn't use phosphorus-based fertiliser. Of the balance phosphorus fertiliser was either added in the cropping phase or limited by budgetary considerations. Overall, this means that the group who completed the survey were engaged in the ongoing management of legume based pastures with phosphorus-based fertilisers. In considering *how much fertiliser* should be applied, 70% of respondents were guided by the results of soils tests to some extent. The balance of producers did not take into account soil test results but were guided by rules of thumb, budgetary considerations or advice from an agronomist.

SOIL TESTING

- 7) When soil testing do you test: (64 responses)

	% Respondents
Some representative (monitor) paddocks	64.1
Only the paddocks that you think need to be tested	15.6
All or most farm paddocks	14.1
Paddocks are tested irregularly	3.1
Paddocks are rarely, if ever, tested	3.1

8) Please nominate the frequency with which you do soil tests, every: (64 responses)

	% Respondents
Year	43.8
2 years	23.4
5 years	10.9
3 years	10.9
4 years	6.3
Rarely	4.7

Commentary

Most respondents (80%) tested soil in representative paddocks or a selection of paddocks that they thought needed to be tested. Only 14% tested all or most across the property. This means that there could be considerable variation in paddock to paddock levels of P that is not picked up in the current testing regimes. In terms of frequency of soil testing, 67% of respondents tested every 1-2 years. Whereas testing frequency was equal or greater than every four years for 22% of respondents. Further analysis should determine if there is correspondence between sampling coverage and sampling

SOIL ANALYSIS INTERPRETATION

9) The term "Critical soil test value" is often used when interpreting soil tests; which of the following would best describe your understanding of the term: (64 responses)

	% Respondents
The value at which pasture production is near maximum	42.2
I am not familiar with this term	34.4
The minimum amount required for adequate pasture production	21.9
The value that soil must not exceed to avoid toxicity	1.6

10) Currently, to determine soil phosphorus status, which soil test(s) would you normally use? (64 responses)

	% Respondents
Colwell	68.3
Olsen and Colwell	14.3
Olsen	12.7
Not Sure	3.2
Nullogic	1.6

11) Thinking about the soil P test that you use most often, can you nominate the approximate soil P level(s) that you have across your farm? (62 Responses)

	% Respondents
--	---------------

Yes (see below)	69.4
No, its not something I would know off the top of my head	30.6

If you answered “Yes” to the question above please indicate either the average soil test value or the typical range of test values on your property – indicate whether Olsen or Colwell:

There were 42 responses of which 3 made no sense. There was large variation in the range reported.

- 12) For the Olsen P test, which value represents a typical critical P level for your farm (to the nearest 5 mg/kg – equivalent to ppm) (36 responses)

	% Respondents
Don't Know	36.1
Not Applicable	25.0
15 mg/kg soil	11.1
25 mg/kg soil	11.1
10 mg/kg soil	5.6
20 mg/kg soil	5.6
Other – comments etc.	5.6

- 13) For the Colwell P test, which value represents a typical critical P level for your farm (to the nearest 5 mg/kg – equivalent to ppm): (54 responses)

	% Respondents
20 mg/kg soil	27.8
Don't Know	20.4
30 mg/kg soil	16.7
25 mg/kg soil	9.3
35 mg/kg soil	7.4
40 mg/kg soil	5.6
60 mg/kg soil	1.9
5, 10, 15, 75 or “Vary between 20 and 80” mg/kg soil	9.5

14) Can you also nominate a typical Phosphorus Buffering Index (PBI) test value for your farm? (62 responses)

	% Respondents
Yes	53.2
No	43.5
Not Applicable - I don't use the PBI test	3.2

If you answered "Yes" to the question above please indicate a typical PBI on you farm

There were 33 responses (the number who answered "Yes") – variable as expected

Commentary

In this section the technical knowledge of producers with respect to soil P was being gauged. Less than half of respondents understood the concept of "Critical soil test value". This is alarming given that it is a central concept (or should be...) in advice on soil phosphorus nutrition. Only 70% of respondents could nominate a soil test value (or range thereof) that would be found on their property. When those producers who use the Olsen test were asked to nominate a typical critical value for their farm only 15% (total excludes those who chose "not applicable") could accurately do so – the answer should be 15 mg/kg. The same question when asked with respect to Colwell phosphorus requires further analysis as the nominated critical value is related to the phosphorus buffering index (PBI). However, it is clear that around 30% of respondents either did not know or could not nominate a realistic level (ie PBIs of 5, 10, 15 and 75) are either impossible or very unlikely). Only 53% of respondents could nominate a typical PBI, leaving a sizeable minority that are not aware of current soil fertility parameters. There

EDUCATION AND AWARENESS

15) Which of the following soil fertility management courses/workshops/tools have you attended and/or used: (62 responses)

	No. of respondents
Five Easy Steps (P management tool)	18
Landscan	4
Decide	0
Holistic management/Grazing for Profit	8
Not attended any course/workshop	23
Other, please specify:	
LLS /DPI workshops	3
Grassland Productivity project – P rate Tool	1
GrowProfit	1
B.Sc.Agr.	1
Healthy Soils Healthy Profits	1
MFS Soils Days	1
TFS Farming Systems Workshops	1
Various	1

16) Do you think that knowing more about soil P management would help your business? (64 responses)

	% Respondents
Strongly agree	46.9
Agree	42.2
Not Sure	7.8
Disagree	3.1

17) Which of the other following soil nutrients do you consider when determining pasture fertiliser applications?

	No. of respondents
Sulphur	54
Molybdenum	43
Potassium	34
Nitrogen	22
Copper	6
Zinc	4
Aluminium	2
Calcium:Magnesium ratio	1
Calcium	1
None	2

Commentary

In terms of education, a range of workshops/activities etc. have been attended by respondents. The two largest categories were – no workshop/course attended (23 respondents or 37%) and Five Easy Steps (18 respondents or 29%). Given the centrality of critical phosphorus in the Five Easy Steps program it will be interesting to note if these producers were familiar with the concept (see below). It was encouraging to find that 89% of respondents agreed or strongly agreed that knowing more about phosphorus management would help their business. This means that despite misunderstandings on some key concepts there is still a receptive market for messages involving soil phosphorus. Finally most growers were aware of other soil nutrients that need to be managed in their systems. Amongst these sulphur, molybdenum, potassium

PHOSPHORUS MANAGEMENT AND PASTURE LEGUMES

18) Which of the following pasture legumes do you use?

	No. of respondents
Subterranean Clover	56
Lucerne	18
White Clover	18
Serradella	17
Balansa Clover	13
Annual Medics	10
Biserrula	5
Arrowleaf clover	4
Gland	2
Vetch	1

19) What proportion of legume do you typically achieve in your permanent pastures (please circle)? (62 responses)

	% Respondents
20-30%	32.3
30-40%	19.4
10-20%	19.4
70-100%	8.1
40-50%	8.1
0-10%	6.5
50-70%	6.5

20) Do you have a comment on legume production in your pasture? (26 response -Comments varied and can be classified along into the categories found in the table below)

	No. of respondents
Disappointed or difficult to manage	10
Positive or satisfied with legume performance	8
Variable due to landscape or season	5
Variable due to management or disease	3

21) *What proportion of legume do you ideally want to have in your permanent pastures (please circle)?*
(62 responses)

	% Respondents
30-40%	29.0
20-30%	25.8
40-50%	19.4
50-70%	11.3
70-100%	8.1
10-20%	6.5

22) *Do you vary your fertiliser management according to pasture legume species (eg. lucerne, sub clover, serradella etc.)? (63 responses)*

	% Respondents
Not applicable – I only have one main type of legume in my pasture.	31.7
No, I follow the same basic rules for applying P to all pasture legume types.	58.7
Yes, some sorts of pasture legume get more P-fertiliser than others.	9.5

23) *Is there anything else you would like to comment on?*

Nine comments were made and are reproduced below as they cannot be classified:

- Interested in raising pH to help establish perennial pastures (non arable areas)
- Mainly sub clover with white and balansa for hay
- Bob I think there is a workshop needed on this work. I had to think a bit on some of the questions
- I have a high P from biosolids applications during the crop phase.
- i would use more if fertiliser wasn't so expensive.
- We crop every 2nd year. There is usually enough residual P to carry the pasture through.
- Regular soil testing and super application has increased our production substantially,
- We use N fertiliser to not rely solely on legume N, especially in autumn so we can fill the winter feed gap. This also increases our critical P level to 50.
- You need options for 'other' and comments in all your questions

Commentary

Subterranean clover was by far the most common pasture legume under management. Interestingly, 17 respondents reported using serradella (lower P requirement) and 18 respondents reported using Lucerne (higher P requirement than sub clover) – further analysis should give us the opportunity to examine whether or not soil phosphorus management is varied according to species sown. Indeed 59% of respondents did not take into account legume species when applying fertiliser to pastures – hence it is likely that better targeting of phosphorus-based fertiliser could take place on farms. When asked to nominate an ideal legume composition in pastures, 65% of respondents nominated in the range 20-40% with only 6.5% nominating less than 20%. In contrast when reporting typical levels for their pastures only 42% nominated in the 20-40% range while 25% reported less than 20%. Finally, comments on legume production and

ANALYSIS

Given the limited number of respondents it is difficult to carry out a complete analysis of the data according to grower practices, knowledge, attitudes etc. However, it is possible to ask some key questions especially where the number of respondents in subsets is large enough to help come to a reliable set of conclusions. The aim of the survey is to gauge grower attitudes, knowledge and practices with respect to the use of phosphorus fertiliser. The aim of the analyses below is to help focus attention on concepts that need to be better explained in extension material to be developed in future.

Where were the serradella growers from?

Serradella is a feature of all the participatory sites. It was reported to be used by 17 respondents. It is clear that Serradella is currently confined to Western Australia and parts of northern and central NSW – with one exception, a grower on the southern tablelands of NSW.

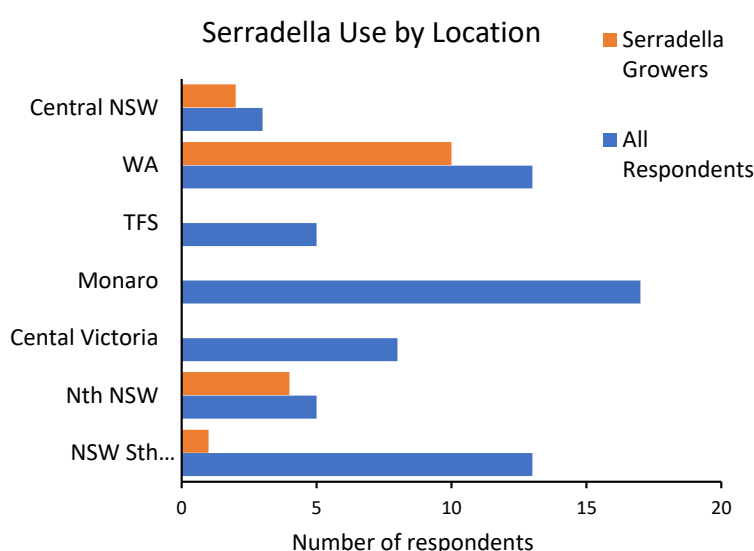
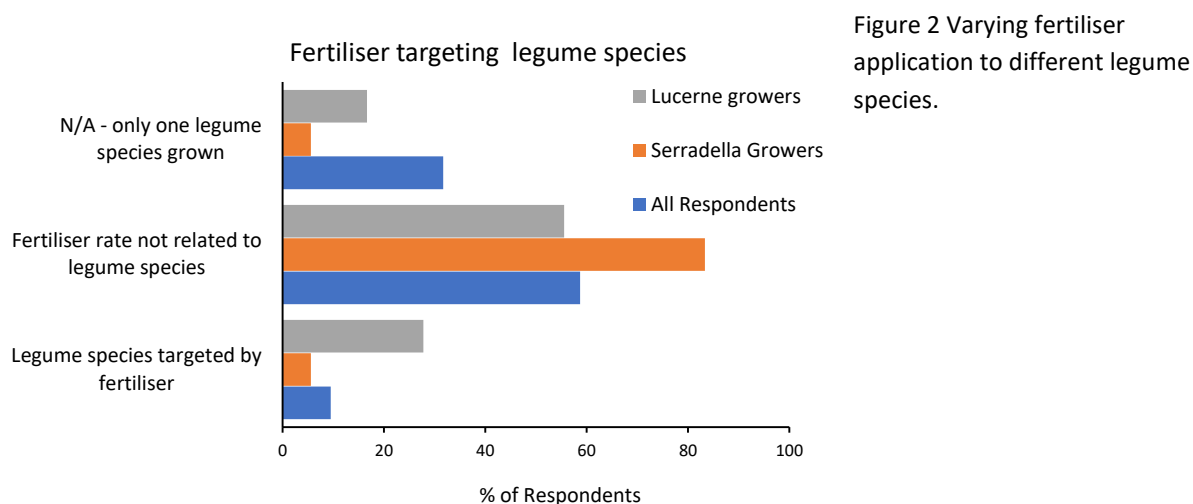


Figure 1 – Serradella use by location

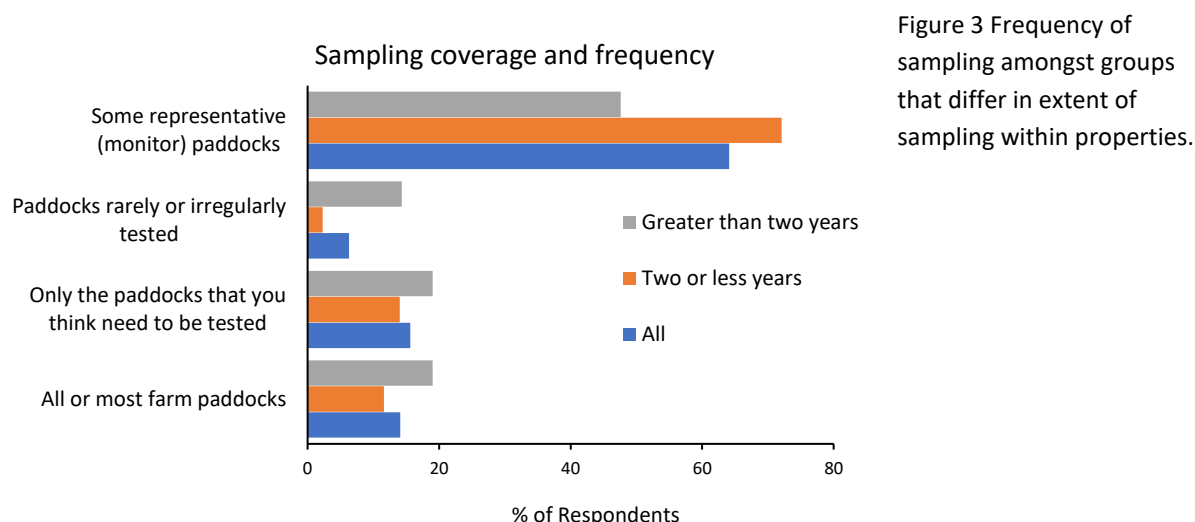
Of the Growers that reported that soil P management was not tailored to legume type, how many gre Lucerne and/or serradella?

There is evidence that serradella has a lower P requirement than sub clover and that lucerne has a higher P requirement than sub clover. The higher P requirement of lucerne is not widely appreciated. The data can be analysed to see whether or not serradella and/or Lucerne growers tailor their P fertiliser management. From the graph below it is clear that Serradella growers do not consider the requirements of different legume species when applying fertiliser. Twenty five percent of Lucerne growers targeted P rates to legume species – this is much higher than for serradella growers and all respondents. In summary, growers generally do not target fertiliser to the requirements of particular legume species and this should be a theme addressed in ongoing communication activities.



Is the frequency with which paddocks are tested, related to the proportion of paddocks on a farm that are tested?

There are some recently published results that show a wide variation in soil test results for phosphorus within properties. Respondents were asked to indicate in broad terms the proportion of paddocks on the property that are soil tested. They were also asked to nominate how often soil were tested. Only a small number nominated “all or most paddocks” and the frequency with which these paddocks were tested did not noticeably differ from that of any of the other categories. Those respondents that reported the use of monitor paddocks also tended to test more frequently. These results should be used when formulating extension material dealing with soil testing. It is possible that the use of a low number monitor paddocks allows growers to more frequently sample. However, while variation in soil test values through time may be minimised, there is still the problem of variation between paddocks. Dealing with one source of variation (frequency) cannot compensate for other sources (paddock).



How much has previous training helped respondents in their understanding of key issues relating to soil phosphorus?

Growers were asked to nominate courses/workshop which they had attended. The most common response was “none”, the second most common was “5 Easy Steps – P Management tool”. Respondents were divided into two cohorts and their responses with respect to the following issues were compared: Understanding of critical phosphorus (Fig 4), knowledge of PBI on their properties (Fig. 5) and frequency of sampling (Fig. 6). It is clear that those who have attended the workshop have a better working knowledge of key soil P management concepts such as Critical P and PBI. They are also more likely to sample their soils more often – compared to those who declared that they had attended no workshop or course related to this topic. These results show that the 5 Easy Steps workshop has most probably been influential in building skills related to soil P management. None of these results prove that the workshop is a causative factor (eg. other activities and events may well have been more frequently attended by respondents who happened to also attend the workshop). Nonetheless, on the face of it, those who have done the workshop have much better understanding of key factors involved in managing soil P.

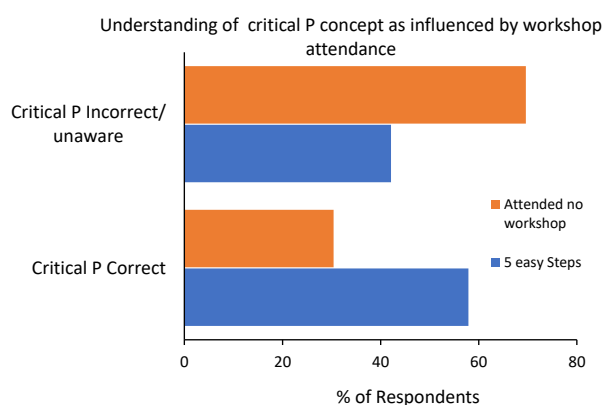


Figure 4 Understanding of the Critical P concept amongst respondents who have attended the 5 Easy Steps workshop versus those who have not attended any workshop/course that deals with management of soil phosphorus

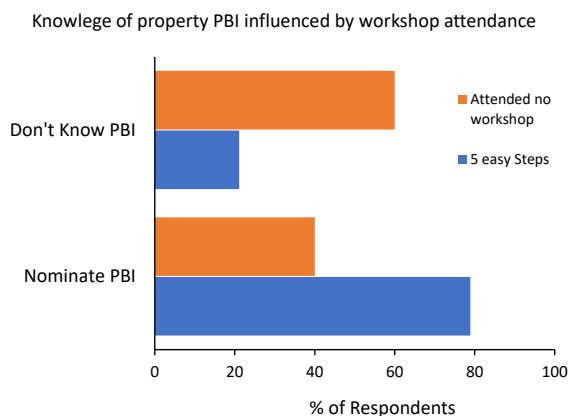


Figure 5 Knowledge of property PBI amongst respondents who have attended the 5 Easy Steps workshop versus those who have not attended any workshop/course that deals with management of soil phosphorus

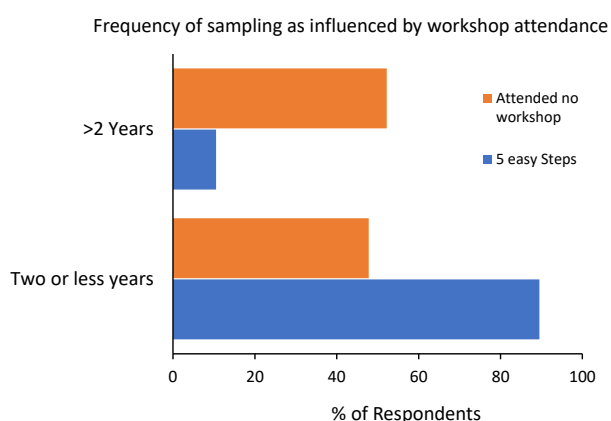


Figure 6 Frequency of sampling amongst respondents who have attended the 5 Easy Steps workshop versus those who have not attended any workshop/course that deals with management of soil phosphorus

How accurately could respondents nominate a level of critical phosphorus for soils on their properties?

Respondents were asked to nominate typical PBIs and Critical phosphorus levels for their properties. As the critical level is calculated from the PBI level, it is possible to measure how accurate respondents are in nominating the critical phosphorus level (see Fig. 7). Overall 49% of respondents could specify the PBI of their soils and 45% could specify both the PBI and the critical Colwell P target for their soils. Considering both Olsen and Colwell P users, 53% had set critical P targets that were within 5 Colwell P-equivalent units of the target suggested by their PBI; 47% were well off target and mostly working with critical P levels that were too low.

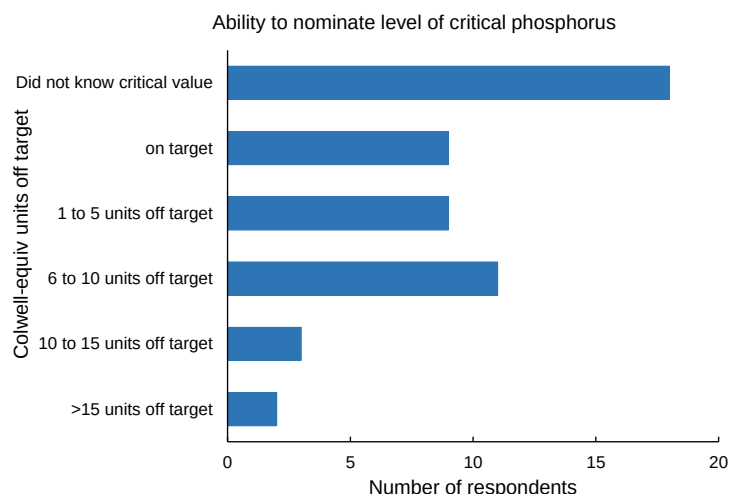


Figure 7 Ability of respondents to nominate an accurate critical phosphorus level.

1) SUMMARY

The survey of 64 producers has provided some important indicators of the current level of knowledge and attitude to, the use of phosphorus on pastures. More than half of the respondents were from southern NSW with the balance from northern NSW, Victoria and Western Australia. Almost all respondents had at least 60% of their properties devoted to livestock production. Most respondents (76%) regularly fertilised pastures and 70% used results of soil tests to guide decision on fertiliser application. This indicated that there is still some way to go to convince the other 30% to use soil tests results.

Sampling strategy varied amongst respondents – most used results from a subset of paddocks on their properties to guide fertiliser decisions. This is a concern given the paddock-to-paddock variation in Colwell P found on farms (Simpson et al. 2018). Sampling frequency also varies – 22% sampling at a frequency of four years or more. Future messages should target both sampling frequency and coverage with the aim of influencing producers to impose a more reliable soil testing regime.

The results show that many producers do not understand the concept of critical soil levels or, more particularly, the phosphorus buffering index (PBI) (Fig. 7). Only 70 % of respondents could nominate typical soil test values on their properties and only around half could accurately identify a level of critical P. There is a lot for producers to remember – when considering the array of information that they have to process and the inability to recall typical values may suggest that it is peripheral information, rather than total lack of understanding. Either way, levels of soil phosphorus will have a large impact on how pastures perform and the key role played by soil P management appears to require further explanation and education.

The vast majority of respondents agreed that knowing more about soil phosphorus would help their business. Currently about a third had not attended any workshop or event that would help them to know more about this topic. It is also likely that those who have attended some of the nominated workshops did not gain a lot of knowledge as details on soil P management may not have been presented (eg. Holistic management workshops). Respondents who have attended the five easy steps workshops had a better grasp of soil phosphorus management concepts and more reliable soil sampling strategies (Figs 5-7). A further role out of this or a similar workshop/on-line learning tool/course would in all likelihood have positive benefits.

Data from the P4Pastures project (and its predecessors) has shown that legume species vary in their P requirements – this is the reason that serradella (a low-P requiring species) is the focus of work on the participatory sites. Results from the survey show that most respondents (59) did not take into account the legume species composition when applying P-based fertiliser. Indeed serradella growers were more likely to

ignore legume species composition than all respondents or Lucerne growers as a subset (Fig. 2). Perhaps there is an opportunity to combine current knowledge on the response of legume species to soil P with existing extension material (eg. workshop contents) to further highlight the need for a more targeted approach to management.

In summary, this survey has revealed much about producers' knowledge, attitude and practices with respect to soil P management. Despite efforts to encourage a high number of participants, the level of response was less than expected (64). Key messages to emerge from the results are:

- Currently a majority of producers use soils tests to guide decision about soil P management. This is a positive results but there are problems in interpretation and sampling strategies
- Producers need further education on factors that govern soil P management. Those who have attended the Five-Easy Steps course tend to have the advantage in this area – but there is considerable scope across the board to improve soil management skills.
- Sampling strategies are a problem in terms of coverage of properties and frequency. This needs to be addressed in messages coming out of the P4Pastures project.
- Tailoring soil P management to legume species is not widely practiced. As this will be one of the key messages to emerge from the P4Pastures project, a target approach will be required.

11.4 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:

- ☐ I am not familiar with this term
- ☐ The minimum amount required for adequate pasture production
- ☐ The value that soil must not exceed to avoid toxicity
- ☐ The value at which pasture production is near maximum
- ☐ The value that will give the best animal health outcome

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

- ☐ Yes – the value is _____
- ☐ No
- ☐ Not Sure

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

- ☐ Yes, the value is _____
- ☐ No
- ☐ Not Sure

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

	Yes	No	Not Sure
a) All pasture legumes have the same phosphorus requirement	☐	☐	☐
b) Serradella has a lower phosphorus requirement than sub clover	☐	☐	☐
c) Serradella buries its seed just like sub clover	☐	☐	☐
d) Serradella persists adequately in my region	☐	☐	☐
e) Every so often serradella needs a late spring grazing break to help it set enough seed.	☐	☐	☐

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

	Yes	No
a) Deeper than 10 cm	☐	☐
b) More frequently	☐	☐
c) Over more paddocks	☐	☐
d) To map paddock fertility	☐	☐

11.5 Communications relevant to participatory sites

Year	Date	Communication type	Description	Scope	Reported by:
Field days and farm walks					
2016	2-Jun-16	field day/farm walk	Dr. Richard Simpson visited the Baynton research site and spoke at a MLA/GSSA Pasture Update field day held at Sutton Grange on the topic of Phosphorus Efficient Legumes.		Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2016	19-Oct-16	field day/farm walk	A small group field day was held at Purlewaugh where the highlights and updates on the trial were discussed and the field site was inspected.	10 attendees	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2017	1-Feb-17	field day/farm walk	Phil Graham (NSW DPI) provided talks to members of both the Bookham Agricultural Bureau (BAB) and Tablelands Farming Systems (TFS) farmer groups about the project aims and scope, and their participatory research role	farmers groups --> Bookham Agricultural Bureau (BAB) and Tablelands Farming Systems (TFS); ~ 60 participants in total	Jim Virgona and Graminus consulting P/L
2017	20-Mar-17	field day/farm walk	A farmer seminar was held at Singleton, in which the progress and highlights of the project were discussed.	40 attendees	R. Freebairn, Boggabri grazing group
2017	18-Jul-17	field day/farm walk	A farmer seminar was held at Leadville, in which the progress and highlights of the project were discussed.	25 attendees	R. Freebairn, Boggabri grazing group
2017	27-Aug-17	field day/farm walk	A field walk for local farmers examined early spring growth at Southern Dirt experimental sites.		Melissa Jardine, Southern dirt
2017	12-Sep-17	field day/farm walk	This project was discussed in detail at a field day conducted in the Purlewaugh area with highlights relating to progress in 2017.	85 attendees (producers and advisors)	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2017	12-Sep-17	field day/farm walk	The purpose and progress of the project was presented at Southern Dirt's TECHSPO event.		Melissa Jardine, Southern dirt
2017	21-Oct-17	field day/farm walk	A field day to be held at Boggabri involved a discussion of the project, including progress made up to that point.	80 attendees	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2017	7-Nov-17	field day/farm walk	A field day held at Coolah informed local farmers on the purpose and progression of the research.	40 attendees	R. Freebairn, Boggabri grazing group
2017	Dec-17	field day/farm walk	A presentation of the trials progress occurred at a MFS summer field day.	30 attendees	Doug Alcock and Graz Prophet consulting
2017	4-Dec-17	field day/farm walk	The Tablelands Farming Systems (TFS) group held a twilight "farm walk" at the Bigga site. Local farmers and members of TFS were introduced to the sites as well as the co-located legume evaluation site	15 attendees with Richard Hayes, Richard Simpson and Jim Virgona from the project team	Jim Virgona Graminus Consulting Pty Ltd.

2017	7-Dec-17	field day/farm walk	Monaro Farming Systems, Soils Club day – Richard Simpson discussed: <i>2017 soil test highlights, S-management experiments, soil P fertility experiments, soil testing strategies</i> , P-efficient pastures project. (Nimmitabel, 7 Dec 17)	~60 farmers attending	Richard Simpson and Rebecca Haling, CSIRO
2017	20-Dec-17	field day/farm walk	A twilight farm walk was held at the Red cliff site where Phosphorus efficient pastures were discussed. The research sites were inspected, speakers were Dr Richard Simpson (CSIRO), Richard Hayes (NSW DPI) and Doug Alcock (Graz Prophet).	15 attendees	
2017	20-Dec-17	field day/farm walk	An initial field day was held on site at Redcliff to inspect both the producer trials and the pure sward trials managed by Richard Hayes. Attendees observed the ongoing growth of the serradellas and also received preliminary results from the first year's measurements as well as a background to the reason for the work on P efficient legumes.	approx. 12 attendees	Doug Alcock and Graz Prophet consulting
2017		field day/farm walk	Updates on trial progress and highlights were given at ASHEEP field days and AGM meetings	ASHEEP members and field day participants	ASHEEP
2018	30-Jan-18	field day/farm walk	A number of local landholders and members of the Bookham Agricultural Bureau visited the Blackburn sites to inspect the plots and become familiar with the progress of the project.	10 attendees, with Drs Richard Simpson and Jim Virgona from the project team and Fiona Leech from Local Land Services, Yass.	Jim Virgona Graminus Consulting Pty Ltd.
2018	23-Feb-18	field day/farm walk	A field day was conducted at the Purlewaugh site, with emphasis on covering issues like soil fertility and species like serradella.	20 attendees	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2018	12-Mar-18	field day/farm walk	A field day at Boggabri included a presentation that covered issues like species choice (serradella) and soil fertility, including P4P progress results	100 attendees	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2018	14-Apr-18	field day/farm walk	Jim Virgona presented at the Tablelands Farming Systems Soils Club day. An update of results from the project was presented as well as advice on soil phosphorus testing and management.	~40 farm businesses	Jim Virgona and Graminus consulting P/L
2018	Sep-18	field day/farm walk	At the Southern Dirt annual Spring field day, Brad Nutt presented at the Katanning P4Pasutres site, presenting the aims and results of the trial and project. The group had special interest in the amount of phosphorus that was available deep in the profile of these poor sands.	50 farmers and industry professionals	Melissa Jardine, Southern dirt Brad Nutt
2018	6-Nov-18	field day/farm walk	A seminar was held at Coolah Seminar to survey the knowledge of farmers of the project.	~45 attendees	R. Freebairn, S. P. Boschma, Boggabri grazing group, NSW DPI
2018	27-Nov-18	field day/farm walk	Suzanne Boschma and Robert Freebairn spoke of the project at a workshop held at Purlewaugh		Suzanne Boschma, NSW DPI
2018	Dec-18	field day/farm walk	A presentation was given at an MFS Soils Club field day which gave an update of results to date. Included trial plot sowings, photos, seedling counts 2018 sowing and biomass measurements at the 2 Redcliff sites.	~45 farm businesses represented	Doug Alcock and Graz Prophet consulting

2018	Dec-18	field day/farm walk	Interim results of the research were presented to the MFS meeting to MFS members and others.	approx. 50 producers (MFS members and others)	Doug Alcock and Graz Prophet consulting
2018	5-Dec-18	field day/farm walk	Richard Simpson participated in a joint Bookham Agricultural Bureau and Tablelands Farming Systems group field day at the Merrill (via Gunning, NSW) research site. Richard Hayes (NSW DPI), Richard Simpson & Richard Culvenor (CSIRO) and Jim Virgona (Graminus Consulting) made presentations on various aspects of P efficient pastures project to attendees and the research plots inspected. Results from the RnD for Profit Phosphorus Efficient Pastures project were presented and plots inspected. In addition results from the participatory sites at Bigga and Blackburn were also presented and discussed	25 attendees	Richard Simpson and Rebecca Haling, CSIRO Jim Virgona and Graminus consulting P/L
2018	7-Dec-18	field day/farm walk	Richard Simpson discussed project results and management of sulphur at the Monaro Farming Systems soil club meeting. Doug Alcock (Grazprofit Consulting) and Jim Virgona (Graminus Consulting) also made presentations at this meeting.	approx. 50 attendees (FARMERS)	Richard Simpson and Rebecca Haling, CSIRO
2018		field day/farm walk	Discussion of the trial progress and developments occurred at events including the 2018 & 2019 AGMs and field days	ASHEEP members and field day participants	ASHEEP
2019	Feb-19	field day/farm walk	Results from the trials and an overall rundown of the project was highlighted in talks given by the Jim Virgona at a Tarcutta Landcare Group meeting	20 Attendees	Jim Virgona Graminus Consulting Pty Ltd.
2019	Mar-19	field day/farm walk	A snapshot report of progress in the project was communicated to the Southern Dirt farm group by Emma Russell		Bronwyn Copestake, Southern Dirt
2019	Mar-19	field day/farm walk	Results from the trials and an overall rundown of the project was highlighted in talks given by the Jim Virgona at a Kyeamba Landcare Group meeting	15 Attendees	Jim Virgona Graminus Consulting Pty Ltd.
2019	3-Apr-19	field day/farm walk	Richard Hayes presented "Sowing new pastures" at a Local Land Services Drought recovery workshop in Tarcutta	20 attendees	Richard Hayes, Suzanne Boschma, NSW DPI
2019	16-Apr-19	field day/farm walk	Updates on progress of the project were provided at meetings of the TFS Soils Club	~40 farm businesses	Jim Virgona Graminus Consulting Pty Ltd.
2019	26-Jun-19	field day/farm walk	The Central Ranges GSSA branch held a farm walk/dinner meeting where a local P4P project update was given.	25 attendees	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2019	Sep-19	field day/farm walk	The northern NSW project team participated in a field day conducted at the Purlewaugh site. Highlights of the trial were presented and a visit to the research station occurred.		Richard Hayes, Suzanne Boschma, NSW DPI
2019	Oct-19	field day/farm walk	A field day was held which included a plot inspection at the SIDN STH site and a presentation by Dr Brad Nutt, Murdoch University. An evaluation sheet was completed by those attending, which included the key question for the project.	approx. 40 attendees	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2019	12-Nov-19	field day/farm walk	Bookham Ag Bureau and Tablelands Farming Systems (TFS) participated in Field Days held at the Merrill research site (managed by Richard Hayes) in which they were provided with updates and highlights on the trial.	~25 attendees	Jim Virgona Graminus Consulting Pty Ltd.

2019	Dec-19	field day/farm walk	Completed research results were delivered to the MFS meeting highlighting the results from 2019.	approx. 60 producers	Doug Alcock and Graz Prophet consulting
2019	Dec-19	field day/farm walk	Completed research results were delivered at the 2019 MFS summer field day	55 attendees	Doug Alcock and Graz Prophet consulting
Farm group newsletter articles					
2016	2-Jun-16	farmgroup newsletter	Following the visit and presentation by Richard Simpson (CSIRO) at the MLA/GSSA Pasture update field day, articles from the field day were featured in the GSSA newsletter.	circulation ~500	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2017	Mar-17	farmgroup newsletter	Project updates and progress was included in the Southern Dirt Autumn 2017 Quarterly Newsletter Project Report	circulation ~900	Emma Russell, Southern Dirt
2017	Apr-17	farmgroup newsletter	An article appeared in the GSSA newsletter relating to the presentation Lisa Warn gave at the MLA Pasture Updates run by the Albury-Wodonga branch of the Grasslands Society. The presentation included information on improving phosphorus use efficiency and the potential role of more P-efficient species like Serradellas.	circulation 500 people	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2017	Jun-17	farmgroup newsletter	New P fertiliser management experiments on the Monaro, Monaro Farmng Systems Newsletter June 2017, by Simpson R, Stefanski A, Haling, R.	~73 farm businesses	Richard Simpson and Rebecca Haling, CSIRO
2017	Jun-17	farmgroup newsletter	Project updates and progress was included in the Southern Dirt Winter 2017 Quarterly Newsletter Project Report	circulation ~900	Emma Russell, Southern Dirt
2017	1-Jul-17	farmgroup newsletter	A newsletter article was distributed to all MFS members relating to new P Fertiliser management experiments on the Monaro.	71 MFS member farm businesses	Doug Alcock and Graz Prophet consulting
2017	Oct-17	farmgroup newsletter	A newsletter article was distributed to all MFS members containing a P Efficient pasture Trials update.	71 MFS member farm businesses	Doug Alcock - Graz Prophet consulting
2017	Dec-17	farmgroup newsletter	An introduction to the project was included in the Southern Dirt Spring 2017 Quarterly newsletter	circulation ~900	Melissa Jardine, Southern dirt Emma Russell
2018	Apr-18	farmgroup newsletter	A report was included in the Southern Dirt Annual trial booklet, an annual newsletter to members highlighting activities and projects they are involved in.	circulation ~900	Emma Russell, Southern Dirt
2018	May-18	farmgroup newsletter	ASHEEP Newsletter Article published May 2018 "Phosphorus-efficient pastures Project" newsletter #48	~160 recipients (92 farm businesses)	ASHEEP
2018	Jun-18	farmgroup newsletter	A newsletter article was published with the most up to date observations in the MFS June 2018 newsletter which was distributed to the entire membership base.	71 farm businesses	Doug Alcock and Graz Prophet consulting
2018	Jun-18	farmgroup newsletter	An article (written by Lisa Warn with assistance from Richard Simpson) creating awareness about the <i>Phosphorus efficient Pastures</i> project appeared in the GSSA newsletter. The article included information on strategies to improve phosphorus use efficiency, the potential role of more P-efficient	Circulation 500	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland

			species like Serradellas, findings from the root morphology work and an update on the local Central Ranges sites. "THE QUEST FOR MORE PHOSPHORUS EFFICIENT PASTURES"		
2018	Jul-18	farmgroup newsletter	Monaro Farming Systems, July 2018 Newsletter article http://www.monarofarmingsystems.com.au/wp-content/uploads/2018/07/MFS-newsletter-June-18.pdf	73 farm businesses	Richard Simpson and Rebecca Haling, CSIRO
2018	Aug-18	farmgroup newsletter	ASHEEP newsletter article published August 2018. "ASHEEP projects update Phosphorus efficient pastures project" newsletter #50	~160 recipients (92 farm businesses)	ASHEEP
2018		farmgroup newsletter	ASHEEP published updates in its quarterly newsletter that is distributed to members, highlighting trial progress.	~160 recipients (92 farm businesses)	ASHEEP
2018		farmgroup newsletter	Richard Hayes contributed a section to the MFS Newsletter which described the relative performance of varieties in the evaluation network, and highlighted the promising regeneration characteristics of cultivars such as Yellotas.	~73 farm businesses	Richard Hayes, Suzanne Boschma, NSW DPI
2018		farmgroup newsletter	an article appeared in the GSSA newsletter relating to the presentation Lisa Warn gave at the MLA Pasture Updates run by the Central Ranges branch of the Grasslands Society. The presentation included information on improving phosphorus use efficiency and the potential role of more P-efficient species like Serradellas.	circulation 500 people	Lisa Warn, Ag consulting P/L and central ranges branch of Grassland
2019	May-19	farmgroup newsletter	An MFS newsletter article was distributed to members containing "P -efficient pasture trials" updates.	distributed to the MFS membership (73 farm businesses)	ASHEEP
2019	Nov-19	farmgroup newsletter	ASHEEP newsletter article published November 2019 "ASHEEP P efficient pastures project update" by Inaya Stone	~160 recipients (92 farm businesses)	ASHEEP Inaya Stone
2019		farmgroup newsletter	A trial update was included in the Southern Dirt spring field day booklet	circulation ~900	Melissa Jardine, Southern dirt
2020	Jan-20	farmgroup newsletter	Lisa Warn wrote an article about the field day and presentations at SIDN STH site for the GSSA's February 2020 newsletter. "GETTING PRODUCTIVE PASTURE IN CENTRAL VICTORIA"	circulation ~500	Lisa Warn, Ag consulting P/L and Central Ranges branch of Grassland Soc.
2020	Feb-20	farmgroup newsletter	ASHEEP newsletter article published February 202 "serradellas and the development on more P-efficient pasture systems" by Richard Simpson	~160 recipients (92 farm businesses)	ASHEEP Sarah Brown